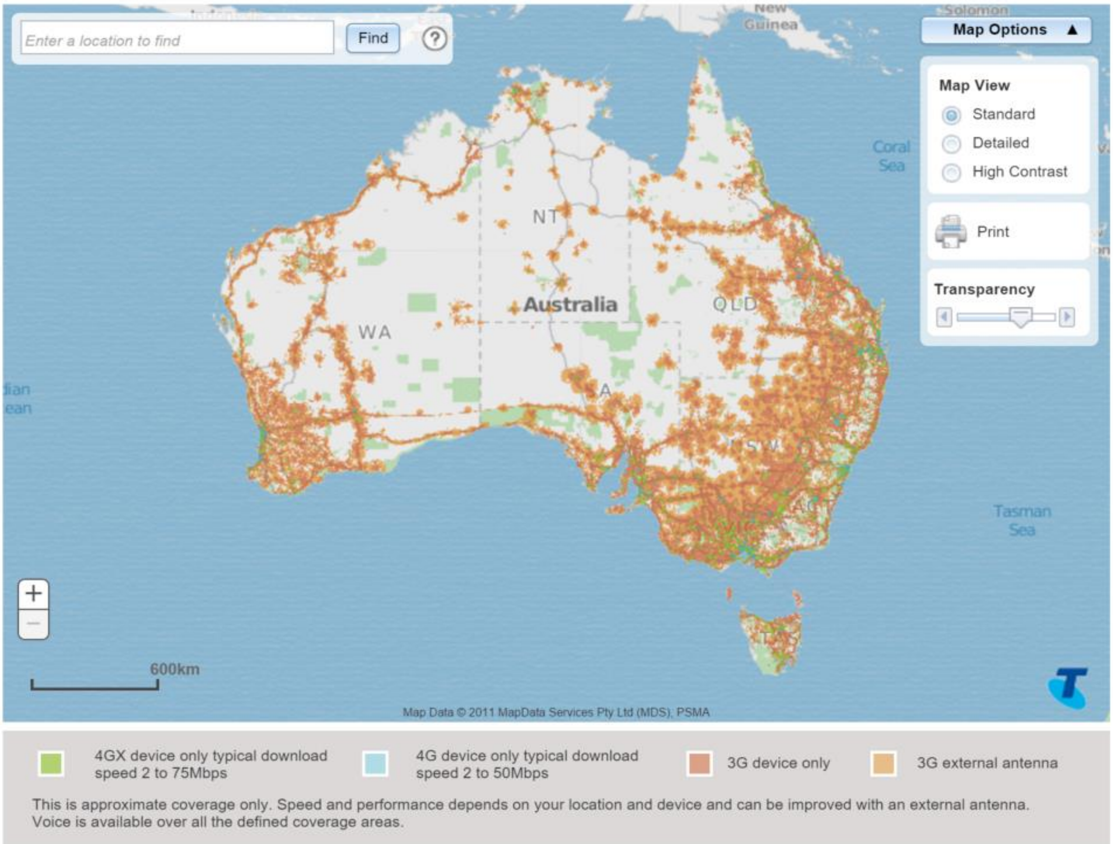
Aerostats All Australia AAA Mobile Coverage



Ben Livson, February 2016 Final Public Release

Disclaimer

All AAA cost estimates are indicative (±50%) to be refined by the mobile carrier, base station equipment vendor and aerostat manufacturer refined over a year-long development of business case, system requirements, architecture and design in conjunction with a full-scale aerostat 4G LTE trial with backhaul in remote Australia as part of establishing AAA Centre of Excellence. Similarly, any claims about AAA coverage for mobile handsets have to be validated in field trials.

Copyright

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Foreword

I think it's time to be "courageous" for all Remote and Regional Australians! Successive Regional Reviews of Telecommunications in Australia over the last 10 years have called for policy recognition of the mobile service for regional Australians to be made available wherever they live, work and play. Hundreds of millions of dollars are paid out by Government and the industry each year to subsidise the provision of an increasingly irrelevant fixed telephone service under a number of programs, the major one being the Universal Service Obligation. While the current Government has taken steps under its Mobile Black Spot Program to improve coverage "at the margins" almost 70% of the land area will remain without mobile coverage. Now Aerostats All Australia (AAA) provides us an opportunity for a "courageous decision" to take the next steps and realise a truly breakthrough solution that addresses this roadblock. This feasibility study by AAA identifies the way forward.

Professor Reg Coutts Chairman TelSoc

Acronyms

Acronym	Definition
AAA	Aerostats All Australia project name
ABSOLUTE	Aerial Base Stations with Opportunistic Links for Unexpected & Temporary Events – a European Union {England, France, Germany, Italy and Hungary with Australian research contribution} funded aerostat project FP7 for providing 4G LTE in emergencies
ACMA	Australian Media and Communications Authority
Aerostat In the context of this paper always tethered	An aerostat (From Greek ἀήρ aer (air) + στατός statos (standing) through French) is a lighter than air craft (the average density of the craft is lower than the density of atmospheric air) that gains its lift through the use of a buoyant gas. Aerostats include unpowered balloons and powered airships. A balloon may be free-flying or tethered.
AIR	Antennae Integrate Radio
ARPU	Average Revenue Per User
BoM	Australian Government Bureau of Meteorology
CAPEX	Capital Expenditure
CASA	Civil Aviation Safety Authority, the statutory authority responsible for the regulation of civil aviation in Australia.
CFR	Code of Federal Regulations part 101 pertains to regulations including aerostats
CHAMP	Cased Helikite Aerostat Maintainable Platform
CoW	Cell on Wheels (CoW) used by carriers in emergencies such as bush fires.
CRSO	Chief Regulatory and Safety Officer
CSG	Customer Service Guarantee
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Dyneema	Aerostat tether material with a one tenth weight of a comparable high-strength steel wire made of Ultra-high-molecular-weight polyethylene (UHMWPE, UHMW) manufactured as lightweight high-strength oriented-strand gel spun through a spinneret.
FAA	Federal Aviation Authority
FCC	Federal Communications Commission
FP7	European Union Integrated Project Funding $11m for ABSOLUTE
GEO	Geostationary Earth Orbit for communications satellites with long latency
Helikite	The Helikite is a type of kite-balloon or kytoon designed by Sandy Allsopp in the UK in 1993. Allsopps UK Patent No 2280381 and US Patent No.6016998A. The Helikite comprises a combination of a helium balloon and a kite to form a single, aerodynamically sound tethered aircraft, that exploits both wind and helium for its lift.
Helium	Non-flammable gas helium is used to provide lift for aerostats as the second lightest gas after hydrogen not used for safety reasons.
LEO	Low Earth Orbit for communications satellites with shorter latency than GEO and MEO satellites but longer than mobile 4G LTE communications latency
LoS	Line of Sight
LTE	Long Term Evolution 4G technology with LTE-A Advanced supporting carrier aggregation and LTU-U extending LTE-A into unlicensed spectrum e.g. WiFi
MEO	Medium Earth Orbit for communications satellites with shorter latency than GEO satellites but longer than LEO satellites and mobile 4G LTE communications latency
MBSP	Mobile Black Spot Programme by Department of Communications and the Arts
NBN	National Broadband Network
OPEX	Operating Expenditure
RFNSA	Radio Frequency National Site Archive used to search for Australian base stations to find Electromagnetic Energy (EME) Reports, site locations, carrier contact details for existing sites and community consultation information for new sites.
STP	Standard Temperature and Pressure
STS	Standard Telephone Service
UAV	Unmanned Aerial Vehicle “drone”
USO	Universal Service Obligation for Standard Telephone Service STS
Wi-Fi WLAN	Wi-Fi is a wireless local area network (WLAN) technology based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards.

Contents

Summary

Vision

Aerostats **All** **A**ustralia (AAA) endeavours to extend Mobile Coverage of Australia's land mass and surrounding sea with aerostats as a disruptive innovative breakthrough technology reducing cost by at least an order of magnitude in comparison to all other alternatives.

The AAA vision is to provide mobile coverage, with low latency, to anyone with a mobile handset opening up interactive real-time Internet applications for remote Australia.

AAA proposes to open up most of the 70% of Australia not currently covered to assist the realisation of the huge potential of the country and nation. This will be achieved in stages over a multi-year plan. The immediate objective is to double mobile coverage from less than a third of the land mass to two thirds by co-location of AAA with existing mobile infrastructure.

This paper is a feasibility study into AAA and how these aims can be achieved.

Our audience is the Australian Government, mobile carriers, NBN and all of us who care about Remote Australia.

Recognising Prior Work

Providing telecommunications to remote Australia has been the subject of many studies. In particular, we wish to recognise:

[1] The Australia Government Regional Telecommunications Review 2015

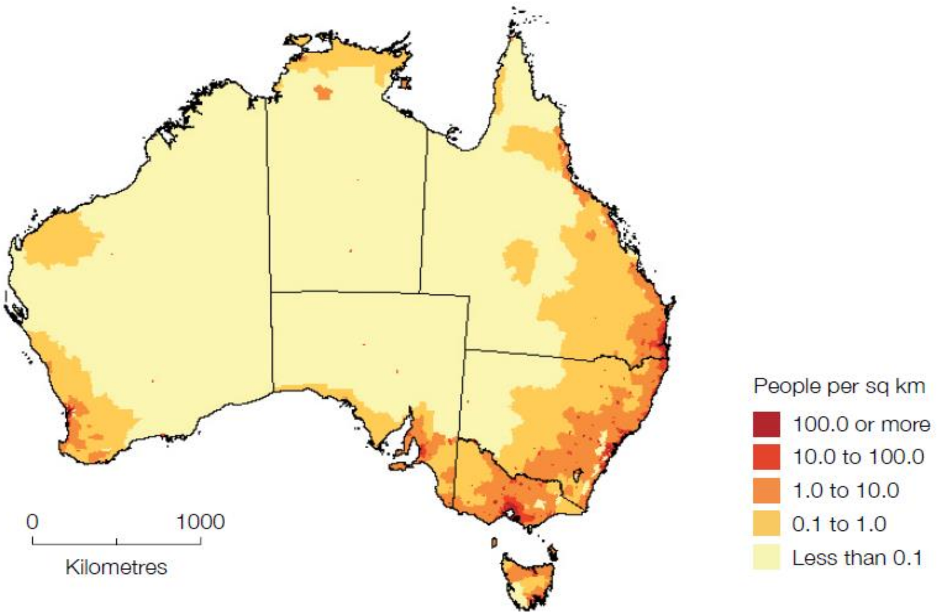
[2] Desert Knowledge Australia's "Fixing the hole in Australia's Heartland: How Government needs to work in remote Australia" 2012

[3] Broadband for the Bush Alliance Papers

The challenge in providing mobile coverage to remote Australia is readily seen from the below map:

Map of Remote Australia Population

Figure 1: Population density – June 2014



As at June 2014 [1], 2.3 per cent of Australians lived in remote or very remote areas of Australia: 323,720 people in remote Australia with population density less than one person per km^2 and 208,344 people in very remote Australia with population density less than 0.1 person per km^2 in a diverse range of settlements.

These settlements include agricultural communities (for example, farming homesteads and workers' barracks), mining communities, tourist facilities, Aboriginal and Torres Strait Islander communities and general pastoral properties. Indigenous Australians represent 16 and 45 per cent of all people living in remote and very remote areas respectively, based on 2011 Census information.

Mobile Coverage Stalemate with Diminishing Returns

The three national mobile operators have invested [1] heavily in their networks to meet the growing demand for data, and to achieve competitive coverage claims. Over the past five years they have collectively invested more than $11 billion in their wireless networks (excluding spectrum spend) to increase capacity in high density (smaller cells & infill etc.) rather than expanding coverage in areas without service.

Despite these significant increases in investment, the proportion of Australia's landmass that has mobile coverage is just over 30 per cent, with the prospect of coverage for the remaining 70 per cent being difficult and uneconomic (unless a new disruptive order of magnitude less expensive technology such as our AAA proposal is implemented).

This is a significant issue for people living in remote communities in need of mobile coverage and in particular impacts people on main transport corridors, on larger properties, or for emergency services [1].

The latest $385m expenditure by the Australian Government's Mobile Black Spot Programme MBSP with 499 towers will provide new handheld coverage to 68,600 km^2 and external antenna coverage to more than 150,000 km^2. The increase is less than 2% of Australia's land area of 7,692,024 km^2.

The average[1] MBSP [cell site tower]() adds merely 300 km^2 to coverage. Using the MBSP approach would cost at least $10b to provide coverage to the remaining 70% of Australia. The Line of Sight (LoS) radius for 300 km^2 coverage is 10 km calculated from Pi x $Radius^2$ with approximately Pi=3.14. The tower height to obtain 10 km radius is approximately 10 m.

A brief explanation of mobile tower types and heights may be found under Mobile Phone Tower Types and Information - Steel in the Air. Also, see List of tallest structures in the United States - Wikipedia and List of tallest structures in the United States by height.

The cost of a 150 m guyed mast is approximately $150K and is easily accommodated within a typical $1m remote cell site budget. The cost of a 300 m mast in remote Australia is at least $2m and for a 600 m mast at least $10 m.

We use the Radio Line of Sight Calculator [10]. This calculator assumes nothing is in the way of the radio signal between the antenna and the horizon at a chosen height above ground. It does not take into consideration the height of the "other" station" antenna which it communicates with nor any attenuation caused by weather, band conditions, antenna gain, path loss, or other factors such as dB loss.

Telstra has mobile equipment on about 9,600 sites covering 2.3m km^2 adding on average[2] per tower 240 km^2 to coverage. Optus and Vodafone cell site coverage is even less; Telstra, as the historic provider of telecommunications in Remote Australia occupies the most desirable locations from a radio perspective.

The obvious question relates to the use of higher towers. The following table details calculations by Radio Line of Sight Calculator [10]:

[1] Many cell sites are built for capacity and by design not for coverage. Hence the average coverage of sites built for coverage is much higher.

[2] Ericsson has built for Telstra on the few accessible mountain tops sites with 200 km radius, giving 400 x the coverage of a site with 10 km radius.

Height meters	Radius km	Coverage km^2	Comment
10	10	300	Typical mobile site
50	25	2,000	Lattice or tall monopole
150	44	6,000	Guyed Tower/Mast
300	62	12,000	Mast
628	90	25,000	KVLY-TV mast tallest cell tower in the world 1978-2004. Mountain tops
900	107	36,000	Mountain tops or airborne maximum handset range
1200	124	48,000	Mountain tops and airborne
1800	152	72,000	Maximum tethered solution and for external antennae
3200	200	126,000	Maximum theoretic 4G LTE

The cell site cost of coverage for the 70% remaining land area would be at least $1 billion with one thousand 150 m guyed masts but more likely in the order of several billion dollars when factoring in such things as access roads, electricity and backhaul.

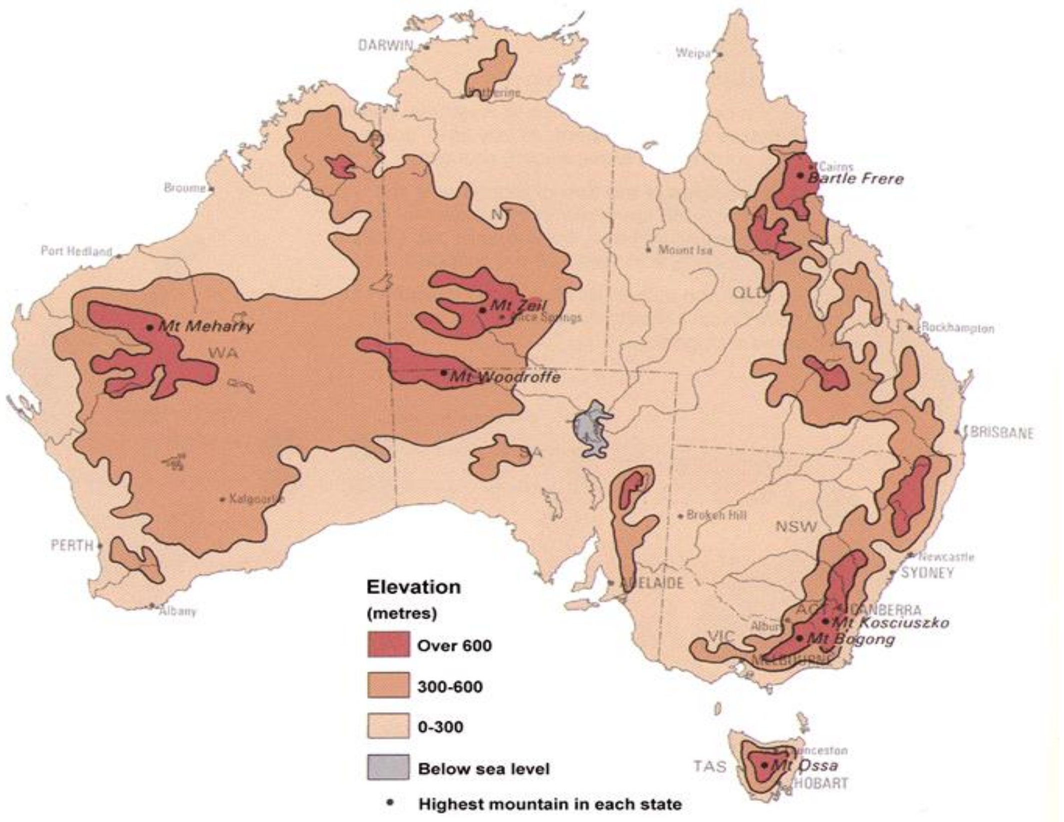
The number of cell sites required with 300 m masts would be halved to 500 with similar cost.

Construction of 600 m masts in remote Australia would not be feasible. In the United States, the FAA and the FCC must approve all towers exceeding 200 feet (61 m) in height. Furthermore, it is very difficult to get permission for structures over 2,000 feet (610 m) high.

We note the many disasters with the very tall cell site structures collapsing during storms: List of catastrophic collapses of broadcast masts and towers. Also, doing any maintenance of such very tall structures would be an unacceptable risk especially in remote Australia.

Using Natural Elevation

Mobile carriers use ground elevation where feasible. Unfortunately, Australia is the flattest continent with 90% of our land area at less than 300 m elevation:



Geoscience Australia Elevation Map [12]

Telstra already has used many of the accessible mountains to extend mobile coverage. The cost of access roads, site civil works, electricity and backhaul would in most cases be prohibitive.

However, worth noting that the calculations in this be paper are highly conservative and do not factor in use of natural elevation.

Stratospheric 60,000' to 90,000' free balloons such as Google Loon [40 and 42] are an inferior solution due to their inability to maintain fixed position and control interference. The higher altitude of these solutions in fact reduces coverage - 80 km for Google Loons - in comparison to AAA aerostats. In addition, Loon's untethered approach means that it is impossible to develop a frequency reuse plan compatible with a telco's mobile network.

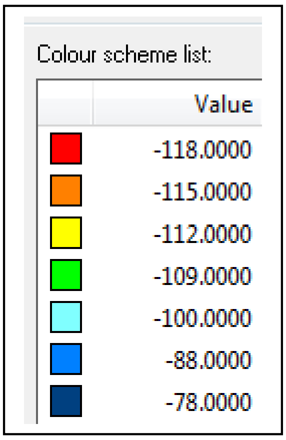
Network Objectives and the Impact on 4G LTE Range

The choice of network objectives has a significant impact on defining 4G LTE coverage range. The assets, e.g. available spectrum, antennas, subscriber type (handset / external receivers), etc. also affects coverage. For AAA, uplink is the primary constraining factor for coverage range. This is because the handset, with its limited output power, must successfully transmit over a long distance to the aerostat. The following network performance objectives were defined before generating coverage plots:

- Minimum cell edge uplink throughput of 128 kbps
- 95% coverage probability of uplink throughput >= 1 Mbps
- Cell edge downlink throughput of 12 Mbps
- Peak downlink throughput of 150 Mbps (LTE-A and LTE Category 6 UE)
- Guaranteed downlink throughput of 1 Mbps supporting 150 simultaneous users. This assumes 200 Mbps backhaul capacity and a paired 20 MHz FDD channel using 2 x 2 MIMO and supporting 64QAM [equivalent to 200 Mbps peak capacity]. NB: Typically, 25% of the air interface capacity is reserved to control signalling such as PDCCH (Physical Downlink Control Channel), PBCH (Physical Broadcast Control Channel), reference and synchronisation signals.

Adjusting these objectives can significantly change the coverage radius. For example, relaxing uplink throughput requirements can significantly increase the coverage radius.

Radio Frequency Plots as Heat Maps



Heat Map Legend

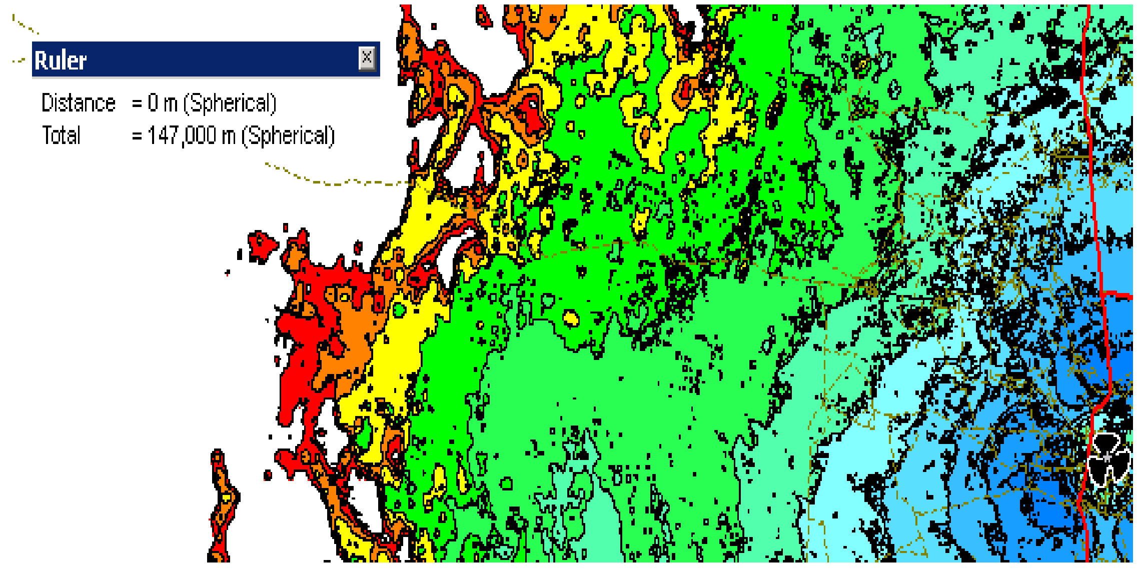
The legend above defines Reference Signal Received Power (RSRP) levels in dBm. The cut-off threshold to achieve the aforementioned network objectives is -118 dBm. Higher values indicate a stronger received signal by the subscriber. The red zone provides between 128 kbps to 1 Mbps uplink throughput and is characterised by a high likelihood of call session failure. Any colour other than red is supportive of > 1 Mbps uplink throughput. All colours support peak downlink throughput of 12 Mbps (only in areas where coverage from multiple AAAs overlap would downlink throughput become constrained). The green area supports > 5 Mbps uplink throughput whilst the light blue zone supports > 10 Mbps uplink throughput. The blue areas support maximum device category throughputs and would only be limited by concurrent user load. For example, 15 users in the blue footprint could simultaneously receive 10 Mbps DL from the AAA.

We have chosen NT Tenant Creek for our analysis as a remote Australia township that does have mobile coverage over a small area. It is on the Adelaide to Darwin fibre optic backhaul. These long backhauls such as Adelaide-to-Darwin, Melbourne-Adelaide-Perth-Broome and long backhaul across Cape York to the Weipa mine are examples of low hanging fruit for AAA co-location where possible with existing cell sites on terrestrial backhaul allowing rapid and low cost doubling of mobile coverage from one to two thirds of the Australian land mass.

In summary, the optimal altitude for AAA has been confirmed to 1,200m with L700 spectrum performing strongly for handsets up to 120 km. Such range is possible for L1800 only with external antennae.

L1800_WNTD

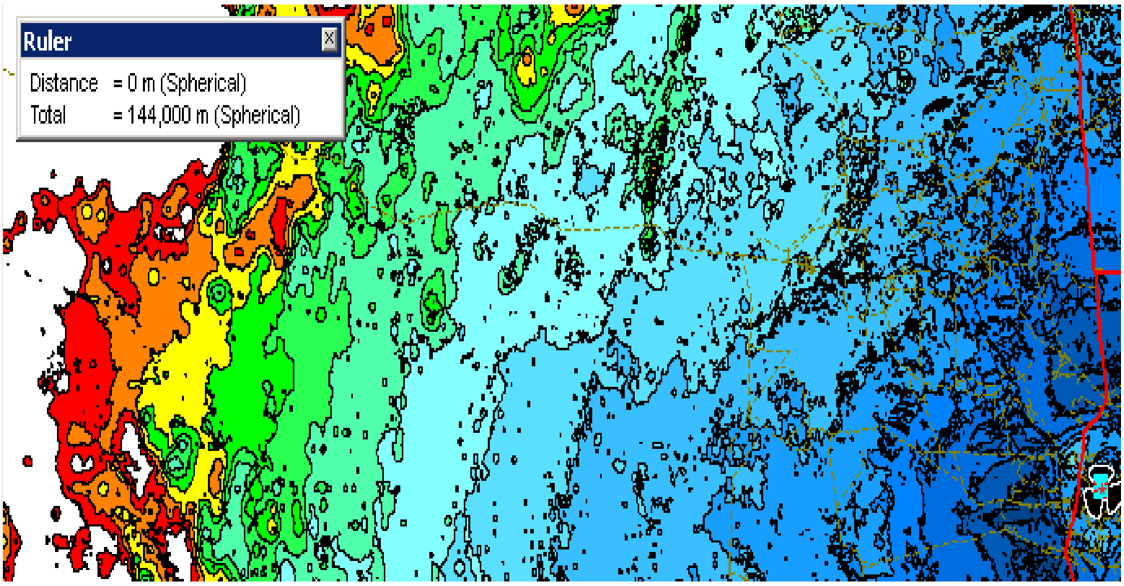
Wireless **N**etwork **T**ermination **D**evice (WNTD) as in external antennae coverage is Green to 121km. Yellow to 129km. Orange to 135km. Red to 140km.



Heat Map for External Antennae at 1,800 MHz Spectrum

L700_WNTD

Pretty much same maximum coverage distance but major difference is that the signal is much stronger along the way. Notice how much more blue there is.

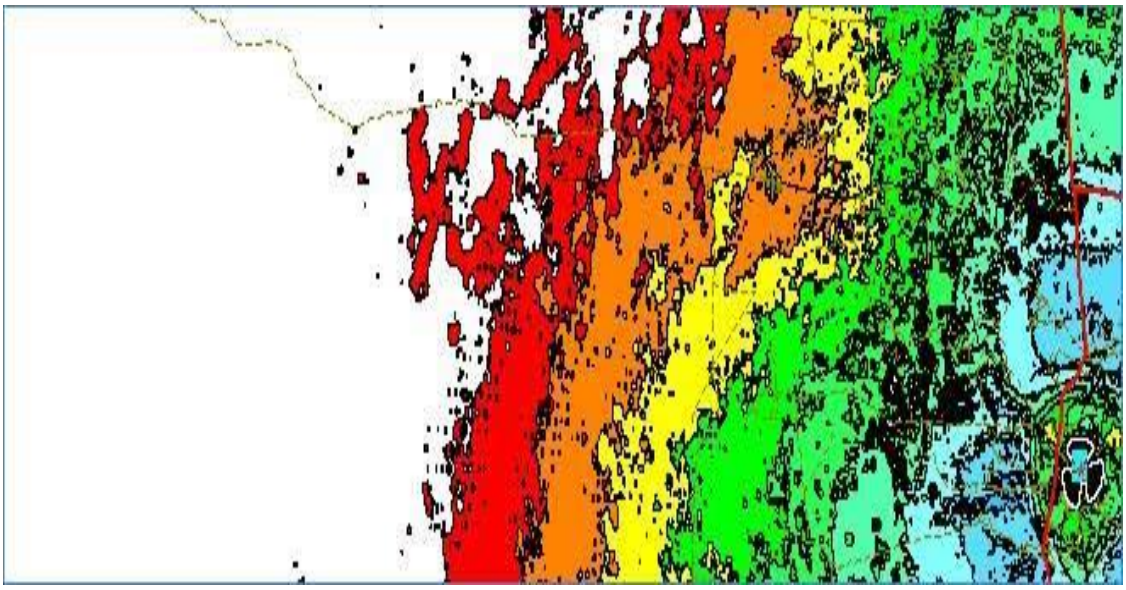


Heat Map for External Antennae at 700 MHz Spectrum

L1800_UE

User Equipment (UE) as in mobile handset coverage is Green to 53km. Yellow to 64km. Orange to 75km. Red to 85km

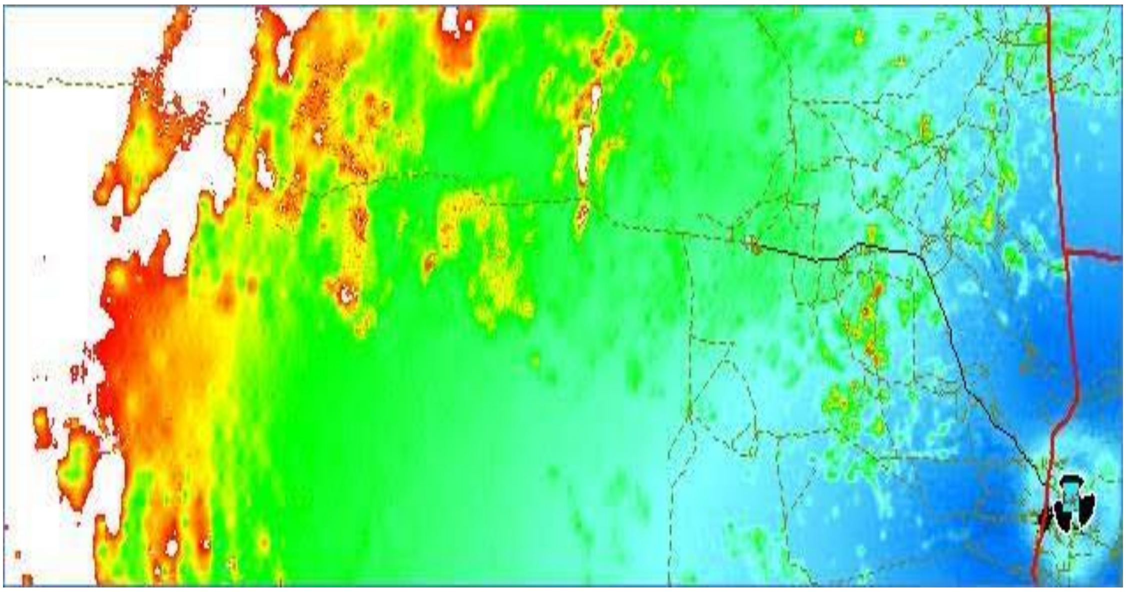
The short L1800+UE range is disappointing as L1800_WNTD reaches almost +60km with +15 dB gain.



Heat Map for Mobile Handset at 1,800 MHz Spectrum

L700_UE

L700_UE is significantly better. Cell edge about 120km. When comparing to L700_WNTD, the signal strength values are expectedly lower (more green vs blue).



Heat Map for Mobile Handset at 700 MHz Spectrum

Radio Frequency Plots Methodology

Radio Frequency (RF) plots have been generated using InfoVista Mentum Planet to simulate coverage and throughput over a variety of spectrum assets. Radio Access Network (RAN) configurations follow.

Frequency Band and Duplex Scheme

LTE standards support both the Time Division Duplex (TDD) spectrum and

Frequency Division Duplex (FDD) technology. We have used:

· LTE FDD Band 28 – paired 20 MHz channel with uplink centre frequency of 713 MHz and downlink centre frequency of 768 MHz.

· LTE FDD Band 3 – paired 20 MHz channel with uplink centre frequency of 1,775 MHz and downlink centre frequency of 1,870 MHz.

· LTE TDD Band 40 – 20 MHz channel with centre frequency of 2,390 MHz.

· LTE TDD Band 42 – 20 MHz channel with centre frequency of 3,410 MHz.

Frame Configuration 1 (symmetrical downlink to uplink ratio) and Special Sub-Frame 7 (half-frame periodicity with 2 guard symbols) has been chosen as the frame structure for LTE TDD. MIMO is setup as 2x2 DL and 1x2 UL. On the downlink, QPSK, 16QAM, and 64QAM modulation is enabled for both duplex schemes. On the uplink, QPSK and 16QAM is supported.

Aerostat Antenna

Each AAA has three 88° quad-port antennas deployed with 15.8 dBi gain. This gain is typical for a standard "wide-beamwidth" antenna. The antennas have a 6.8° vertical beamwidth and 3.5° of electrical tilt applied to minimise radiated power above the horizon. The azimuth of each antenna is 0°, 120°, and 240°. The AAA has been modelled at 1,200m elevation.

Subscriber Type

Two outdoor subscriber types have been created: a standard mobile handset and a high-gain, roof-mounted directional antenna.

The mobile handset is defined as omnidirectional with 0 dBi gain using Extended Pedestrian A (EPA) 5 channel model. The number '5' indicates the Doppler shift, which corresponds to various velocities depending on the frequency band used. For LTE FDD Band 28, this corresponds to an approximate velocity of 7 km/h with the higher frequency bands approximately 2 km/h (+/- 0.5 km/h). The mobile handset is set to +1.8m height and has a maximum transmit power of 23 dBm.

The roof-mounted, directional antenna is similar to the one deployed in the NBN Fixed Wireless network. This antenna would be mounted on rooftops, oriented towards the closest AAA, and calibrated for maximum performance. It is set to +5m height, with +15.5 dBi gain, and a maximum transmit power of 26 dBm. It has a 25 dB front-to-back ratio that allows it to attenuate signals from undesired directions. The horizontal beamwidth is 25° - making it highly directional.

Propagation Model

A heights file and clutter file have been used with geodata sampled in 2006. The resolution of this file is 50m x 50m. Separate propagation models have been used for L700 and L1800 predictions with unique Clutter Absorption Losses (CALs). This accounts for the improved propagation distance and penetration ability of lower band spectra. A 4/3rds Earth curvature model has been used to account for the large propagation distances.

Options for all Australia Mobile Coverage

In summary, terrestrial solution based on cell towers is prohibitively expensive to provide coverage for remote Australia as the remaining 70% of our land area.

We proceed to discuss the options for extending mobile coverage to all Australia and the surrounding sea.

Default Option – Do Nothing – Rely on NBN Satellites

The default option of doing nothing is always the most likely, least expensive, and lowest risk. The Australian Government has invested more than $5b to support communications in remote Australia including $4.7b for NBN satellites and separately $385m for the regional Mobile Black Spot Program. We exclude NBN's $2b investment in fixed wireless, Wi-Fi and other fixed technologies from this discussion as not serving mobile coverage and providing only marginal coverage to remote Australia.

The government has thus invested more than 10% of the total $50b NBN program to support the 3% population in remote Australia to have fixed broadband services but does not address mobile coverage.

However, there are some issues with the NBN satellites are:

- Contrary to statements by some, most[3] voice and interactive Internet applications can work with the long latency introduced by geostationary satellites. However, this performance relies on 'state of the art' customer equipment and Layer 3 management outside the current remit of NBN Co.

- The demand for bandwidth will likely continue to explode. NBN satellites will increase capacity by up to 30-fold in comparison to the interim service, even with increased fixed wireless, satellite capacity limits are very likely in the within five-to-ten years if not sooner. The Regional Telecommunications Review 2015 [1] has recommendations for a more equitable use of satellite bandwidth;

- While satellite services are available those that have a portable satellite radio or a satellite dish, this commands a price premium. True mobile coverage would open up remote Australia to all Australians with the same low cost mobile handset to city users;

- Satellites systems other than the customer equipment cannot be upgraded once launched unlike solutions that have terrestrial access.

This paper is about disruptive breakthrough technology at one tenth of the NBN satellite cost. Aerostats All Australia AAA Mobile Coverage

[3]. Low latency high speed trading, gaming and real-time applications are not suitable over GEO satellites.

The proposed AAA solution will save NBN the cost of sending additional satellites; each $1b NBN Sky Muster satellite costs more than twice AAA implementation. Furthermore, implementing AAA will be faster with lower risk than the multi-year procurement of an additional satellite.

Aerial Platforms

The options to be considered include:

1. Platforms with propulsion
2. Free floating balloons
3. Tethered aerostats

Comparison of Aerial Platforms

European Union Project FP7 ABSOLUTE conducted extensive research into aerial platforms to support 4G LTE for emergency services documented under **Aerial platforms study - CORDIS** [4]

In summary:

Table 1.1 Aerial platform comparison chart

AERIAL eNB PLATFORM CAPABILITIES	TETHERED HELIKITE AEROSTAT	MAST	SATELLITE	MANNED AIRCRAFT	UAV	TETHERED NORMAL AEROSTAT	AIRSHIP
High Payload	**Depends on size**	✓		✓	✓	✓	✓
Wide Area Coverage	✓		✓	✓	✓	✓	✓
Moving Coverage				✓	✓		✓
Heavy/Bulky Payload	**Depends on size**		✓	✓	**Depends on size**	**Depends on size**	✓
Optimum Altitude	✓			✓	✓	✓	✓
Extreme Duration	✓	✓	✓			✓	
Ad-Hoc Network Friendly	✓	✓			✓	✓	✓
Safe for Operators	✓		✓		✓	✓	
Low Attrition Rate	✓	✓	✓				
Instant Deployment	**Depends on size**	✓		✓	✓		
All-Weather Operation	✓	✓	✓	✓			
All-Weather Deployment	✓	✓		✓			
High Technology Security	✓	✓	✓			✓	
Small & Easily Handled	✓				✓		
Single Person Deployment	**For small platforms**	✓					
Airborne Deployment			✓	✓	✓		✓
Inexpensive Coverage	✓						
Air Traffic Friendly	✓	✓	✓			✓	
Tough	✓	✓					
Expendable	✓						
Minimal Training	✓						
No Fuel Required	✓	✓				✓	
Good Antenna Placement	✓	✓	✓	**Depends on configuration**		✓	✓
Widely Available	✓	✓		✓		✓	
Established Technology	✓	✓	✓	✓		✓	
Worldwide Operations	✓	✓	✓	✓		✓	

The main drawback of airborne platforms with propulsion and free floating balloons in comparison to tethered aerostats is the high cost, low capacity and potentially long latency backhaul which would have to be provided by microwave or satellite being inferior to fiber optic terrestrial backhaul.

Telstra has trialed coverage by aircraft and has shared the following information on 20 January 2014:

"*Technology Design: the software in our technology usually has a timing limit which restricts the range signals can be used, we have again modified the network for Australia and can get up to 200km of cell range. In practice we use in the 100km range on land and the balance is light aircraft and out to sea.*"

Key considerations for manned aircraft are:

- Large payload capability
- Significant power available to the payload
- Constantly moving meaning that footprint stabilisation is required, and possibly handoff.
- Expensive.
- High wear.
- Poor wind tolerance
- Used over long periods of time they place valuable pilots at high risk.
- Vulnerable to mechanical failure.
- Fuel hungry.
- Air traffic control problems

Key considerations for Unmanned Aerial Vehicles UAVs ‘drones’ are:

- Ability to fly without the need for people on the ground at remote site.
- Constantly moving meaning that footprint stabilisation is required, and possibly handoff.
- Expensive.
- High attrition.
- Vulnerable to mechanical failure.
- Poor wind tolerance
- Airtrafic control problems
- Limited capability (capacity) – unless large UAV.

Key considerations for airships are:

- Wide area coverage
- Potentially large payload capability
- Significant payload power
- Excessive attrition.
- Fair weather only landing and taking off.
- Large manpower requirement.
- Very expensive per hour and per unit.
- Require significant helium.
- Mechanically unreliable.
- Requires scarce pilots, and used over long periods of time they place valuable pilots at high risk.

Aircraft are able fly to point of use, rather than slower travel by road, thus able to rapidly service emergencies. In particular, low cost and long endurance drones are rapidly evolving and should be considered at least as a backup and emergency solution.

Drones should also be considered in areas where there is no fibre optic backhaul.

Free Floating Balloons

The advantage of free floating balloons such as Google Project Loon is relatively low operating cost per balloon. per balloon. However, the whole operating cost per system ends up quite high due to the huge number of balloons required, the large waste of helium, and the considerable management effort in their operation. The main problem is once again backhauling as well as being able to provide continuous coverage and strictly abide by ACMA's spectrum license area. Google Loon commenced with unrestricted Wi-Fi and in 2014 moved to use LTE. Google is working to provide Indonesia's remote island coverage with 300 Loons in the stratosphere at 60,000-to-90,000 feet [42].

Space Data's military FM repeater technology is based on the simple concept of lifting wireless transceivers into the stratosphere (between 65,000 and 100,000 ft.) using weather balloons technology, the company says: "With transmit power of up to three watts and using frequencies of 225-375MHz, the technology can provide voice and data service to an area with a diameter of 400 miles" [40]. AAA obviously is into 4G LTE serving at much higher 700 MHz and above frequencies covering a much smaller radius of approx 105 km for mobile handsets and 155 km for external antennae with a theoretic maximum of 200 km. Higher spectrum coverage can be seriously degraded with rain, fog and smoke [7].

Free floating balloons cannot be controlled except by forced deflation in emergencies for example after flying into restricted airspace. However, the loons operate in the stratosphere well above commercial flights but take-off ascent and landing with the loons that can end up anywhere is a risk.

We believe free floating balloons would offer a service inferior to what is expected of mobiles.

Tethered Aerostats

Tethered aerostats are balloons permanently anchored by a tether that carries fibre optic backhaul from the base station on the ground to Radio Integrated Antennae AIRs forming the payload.

This study focuses on aerostats as the true mobile tower in the sky.

The overall aerostat systems market was valued at US$ 3,604.7 m in 2014 anticipated to expand at a compound aggregate growth of 13.8% during the forecast period from 2015 to 2022.

Source Jul 28, 2015 -Global Aerostat Systems Market Analysis 2015 - Size, Share ...[8].

The market is highly competitive with a dozen major vendors primarily in the USA and UK.

As so much of the capability will revolve around the aerostat, it is important to consider the advantages and disadvantages of all types of aerostats and outline the reasons for the decision to utilise the Helikite aerostat compared to other available aerostat designs.

There are three basic tethered aerostat types:
<u>Traditional Cigar Shaped Balloons(Blimps)</u>
<u>Jellyfish Shaped Balloons</u>
<u>Helikite Hybrid Kite-Balloons</u>

<u>Traditional Cigar Shaped Balloons (Balloon-Limp = Blimps)</u>
These probably originally derived from 19th century pioneers of flight tethering their dirigible airship balloons for mooring and discovering they were more stable in the sky than tethered spherical balloons. These cigar-shaped aerostat designs were never originally designed to be tethered, but they can be quite stable in high winds if well-made and over 800m3 in size. However, these attributes do not scale down when they are made smaller, easier to handle, and inexpensive enough to be economic. Small blimps exhibit numerous aerodynamic <u>problems</u> when they are tethered.

1) Their long and thin in shape has low net helium lift compared to rounder balloon shapes.
2) Numerous, long seams are very prone to leakage
3) Long thin shape is highly affected by temperature and pressure changes.
4) High winds bend the long, thin shape causing instability.
5) High winds cause the stern fins to rise and the nose to lower causing unstable 'porpoising'.
6) Long, thin shape is hard to ground handle, requiring numerous personnel at short notice.
7) An electric-powered ballonet is required to keep the pressure constant.

8) The ballonet requires constant power via a heavy copper wire in the cable. This reduces available altitude, is prone to breakage, increases ground-handling problems, and is a lightning risk.
8) This cigar shape does not scale down in size from large aerostats to small ones, due to lack of nose lift. Small cigar-shaped aerostats are very unstable compared to the huge versions.
9) Very expensive due to long seams and complex shapes.
10) Fair weather only.
11) The composite skin is difficult to maintain and repair in the field.
12) Uses more helium for the same net lift than other designs.

13) Need to be very large to have the required lift and foul weather capability.

14) Excessively expensive in capital cost and running costs.

For these reasons the traditional cigar shaped aerostat is not suitable for the AAA application.

Jellyfish Shaped Balloons (or Net-Curtain Balloons (NCB's))

These appear to derive from the discovery that netting hanging from one side of a spherical balloon stopped it spinning and therefore facilitated aerial photography. The aerodynamic properties of these balloons are minimal and they therefore rely upon their pure helium lift to combat the wind and the net curtain to keep them from spinning. They have the advantages of being cheap to make and being of simple spherical, or oblate spheroid, balloon construction they have a lot of pure helium lift for their helium volume, so they may be useful in light winds compared to traditional cigar shaped aerostats. However, they exhibit numerous problems for long term, all-weather usage carrying payload:

1) They are often highly unstable in high winds, and also in any turbulent winds.

2) They require extensive, very exact adjustment of their long bridle lines to function at all. This is often extremely difficult to achieve in practice and it is seldom possible for one setting to suit all wind conditions. A bridle line that stretches even slightly will cause instability.

3) The netting skirt moves around in turbulent winds, upsetting the aerostat flight.

4) The balloon wobbles in flight, hence their name 'jellyfish balloons'. This wobble causes instability.

5) They have minimal self-righting ability, so once they turn upside-down and are heading for the ground they seldom recover automatically, even if the wind gust eases.

6) The mesh skirt can rip off in high winds causing destruction of the balloon.

7) The mesh skirt catches sand and dust in it causing a build-up of weight, creating instability.

8) The mesh skirt catches rainwater and snow in it causing a build-up of weight, creating instability.

9) There is no proper payload bay. Therefore, payload is normally tied to the bridle lines below the balloon. These bridle lines are not rigid so the payload moves around a lot.

10) The movement of payload positioned on the bridle lines is not damped at all, so the payload 'pendulums' causing great instability of the balloon. The only way around this is to have a massive balloon in relation to a tiny payload mass, which is then very costly in manufacture, helium, ground-handling, etc.

11) Even when flying properly, varying winds cause a huge difference in flying line angle from 90 degrees in nil wind to 30 degrees in a medium wind. This means their altitude changes dramatically.

12) The difference in flying line angle also affects the flight 'angle of attitude' of the balloon. Meaning that antennas positioned on the balloon are also always greatly changing in their 'angle of attitude'. This means the antenna propagation and range is very variable and causes a serious problem for high gain antenna operation.
13) Large antennas positioned on the balloon cause instability of the balloons flight.

Desert Star Helikites

The Helikite is a type of kite-balloon hybrid designed by Sandy Allsopp in the UK in 1993. Allsopps' UK Patent No.2280381 and US Patent No.6016998A. The Helikite comprises a combination of a helium balloon and a kite to form a single, aerodynamically sound tethered aircraft, that exploits both wind and helium for its lift. Helikites are very well proven aerostats, extensively used by the military, the scientific community and commercial users worldwide. In every practical comparative aerostat flight trial ever undertaken, or comparative aerostat study commissioned, Helikites comprehensively outperformed all other types of aerostat in foul-weather capability, maximum altitude, ease of handling, payload carrying, maritime capability, overall cost, and robustness.

Helikites are the world's only successful, all-weather, lighter-than-air, kite. They were designed from the start to have stable flight in high winds when tethered. They use an oblate-spheroid balloon to maximise pure helium lift in no wind, but also have a large kite section, plus stiff keel to create considerable aerodynamic lift in wind, whilst successfully maintaining stability in high winds. Payloads are easily accommodated in specially designed payload bays on the Helikite. Payload momentum is well damped by the large keel and kite. Desert Star Helikites have numerous advantages for the AAA requirement:

1) All sizes of Helikite are stable in high winds and turbulent winds, with minimal vibration, no yaw or pitching. They make excellent payload platforms.
2) Helikites are true kites and create considerable aerodynamic lift in wind. This lift overcomes the wind drag on the Helikite balloon and the flying line. So wind pushes Helikites up rather than down as with all other aerostats. This is the fundamental difference that enables Helikites to outperform other aerostats and enable them to provide payload lift very economically.

3) Their rounded balloon gives them purer helium lift than comparable cigar-shaped aerostats.

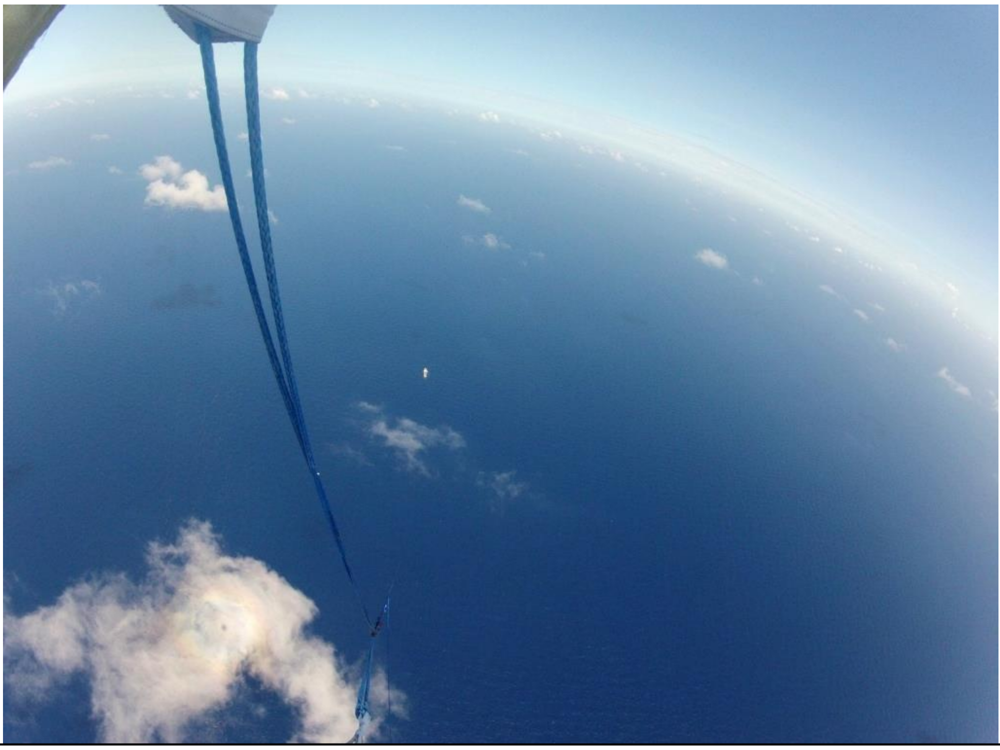
4) Being small and very stable, Helikites are very easy to ground-handle in all weather conditions, night or day, by only one person, or even automatically with nobody present at all

with the correct equipment.
5) Unlike traditional aerostats, Helikites do not need heavy and power-hungry ballonets to keep themselves in shape when different temperatures and altitudes cause pressure differences to occur within the balloon. Helikites have a specialised variable-length-bridle to cope with this problem.

6) Helikites are semi-rigid in construction, with stiff carbon-fibre spars providing considerable structure whatever the situation with the balloon. This provides stability in adverse conditions.
7) Helikites create aerodynamic lift at the front of the Helikite, not at the stern like traditional aerostats. So as the wind rises, Helikites do not become unstable.
8) Helikites have excellent payload attachment systems. Electronic payload and batteries can be firmly and securely attached without movement in high winds. Antennas can be attached in numerous places for best propagation and reception.
9) Helikites are unique in being able to keep the same 'angle of attitude' from nil wind to high winds. This greatly facilitates the operation of high-gain antennas.
10) In any wind, the flying line angle of Helikite is above 45 degrees from the horizontal. This provides a consistently high altitude compared to other aerostat designs.
11) Desert Star Helikites are very strong, with double-line construction capable of withstanding winds that literally tear other aerostats apart. Helikites can even fly unscathed through dust devils.
12) Helikites fly through dust, snow and rain with no problem. Rainwater will add to the weight of the Helikite, but this is easily taken into account when deciding the size of the Helikite to be used.
13) The relatively small size and double-lined nature of the Desert Star Helikite balloon construction, makes Helikites very easy to maintain and repair compared to traditional aerostats.
14) Helikites have an excellent operational and safety record. Since their design in 1993 not a single person has ever been injured in their operation. No Desert Star Helikites have ever been lost or seriously damaged during operations, despite hundreds being used worldwide, in both war and peace.
15) Desert Star Helikites are in service with the Australian Special Forces for radio-relay, after extensive trials showed the Helikites to be ideally suited operating in Australian conditions.

100m3 Desert Star Helikite on US Naval Ship

Helibase Launch

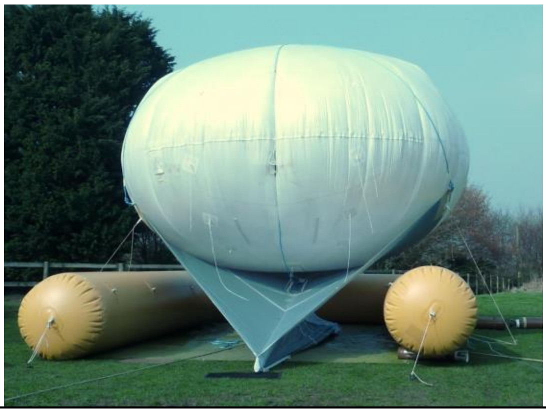


View from 1,500metres altitude. This is 300 metres higher than required

Australian Defence Force Helikite

US Army Helikite in Afghanistan

US Army Helikite at the Pentagon



Stern View of 100m3 Helikite on a

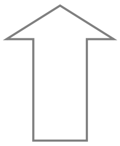
100m3 Desert Star Helikite in Flight

100m3 Desert Star Helikite on Helibase

HIGH

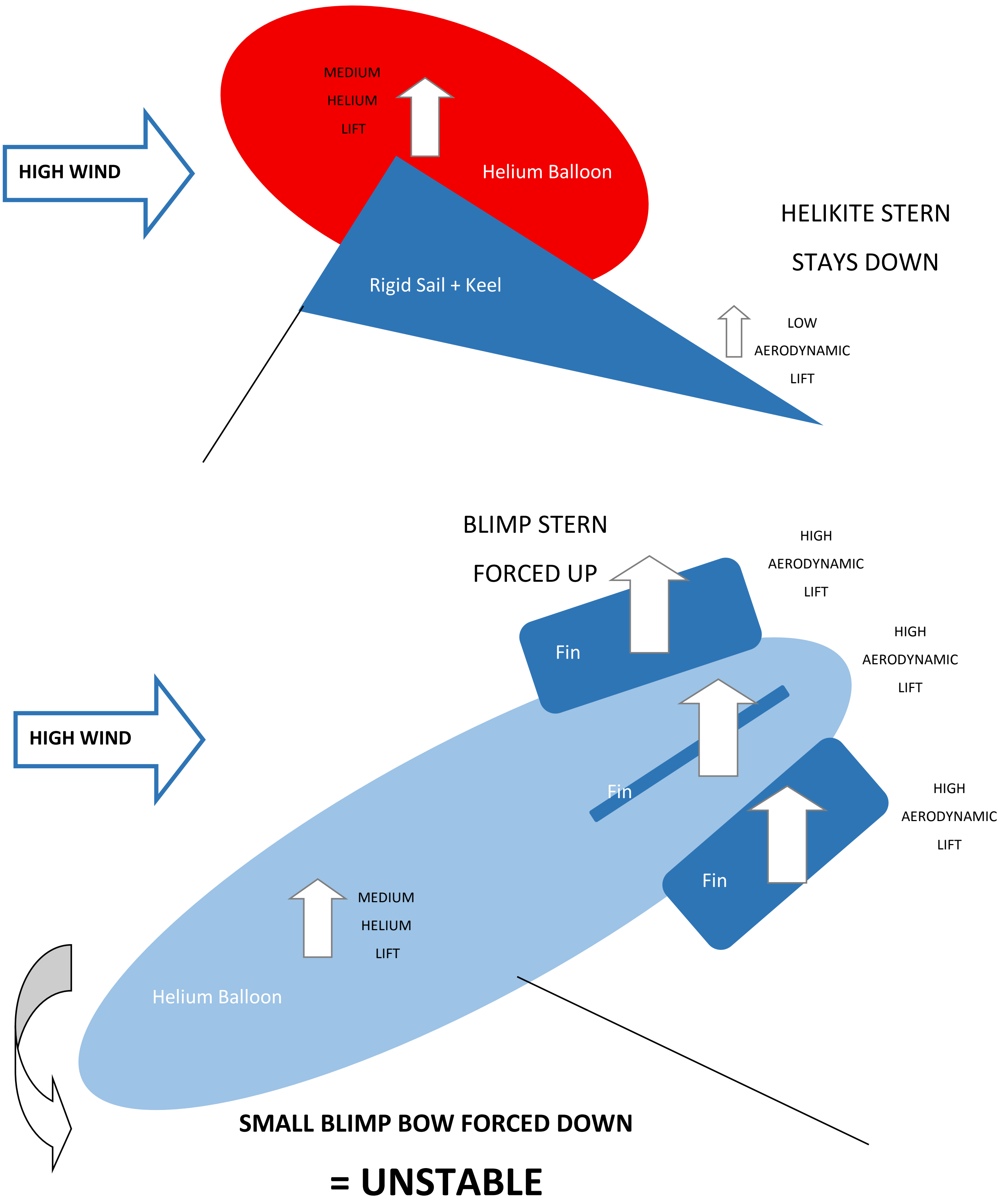
AERODYNAMIC

LIFT



SMALL HELIKITE BOW HELD UP

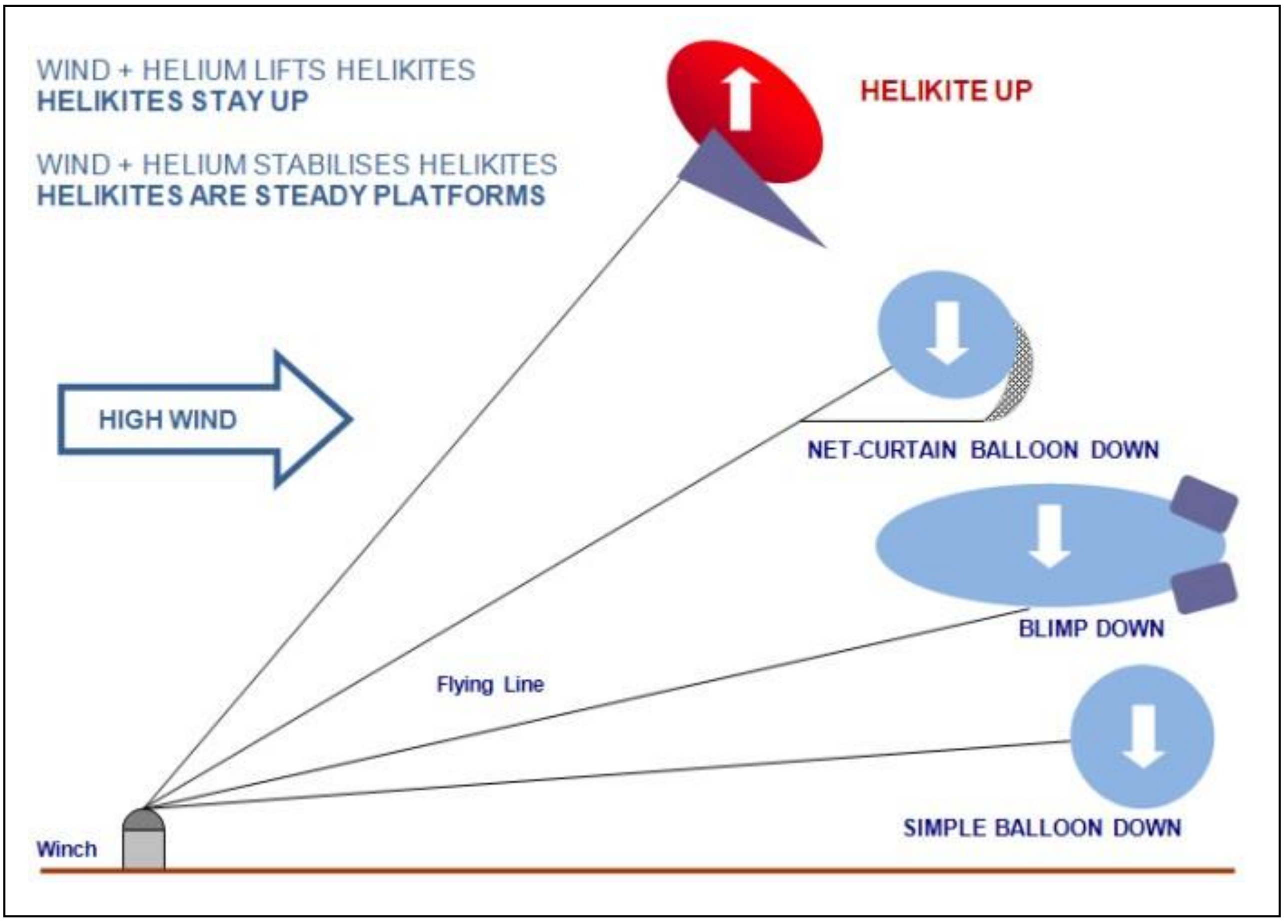
= STABLE



HIGH WIND
MEDIUM
HELIUM
LIFT
Helium Balloon
HELIKITE STERN
STAYS DOWN
Rigid Sail + Keel
LOW
AERODYNAMIC
LIFT
BLIMP STERN
FORCED UP
HIGH
AERODYNAMIC
LIFT
Fin
HIGH
AERODYNAMIC
LIFT
HIGH WIND
Fin
HIGH
AERODYNAMIC
LIFT
Fin
MEDIUM
HELIUM
LIFT
Helium Balloon
SMALL BLIMP BOW FORCED DOWN
= UNSTABLE

Very large 'blimp' aerostats can sometimes remain stable in high winds due to their massive helium lift at the bow that combats the wind. However, these very large blimps are hugely expensive and uneconomical for almost any activity. For small, less expensive blimps, the helium lift at the bow is far smaller, thus reducing blimps wind-keeping capability. This is a major reason why small blimps cannot cope with high winds. Thus large blimps that have some wind-keeping ability are too expensive, and small blimps that are more economical to use cannot cope with high winds. This is why blimps are not suitable for AAA purposes.

Helikites do not have these problems, because the wind lift they gain is at the front and they do not have large fins at the stern creating lift in high winds. So all sizes of Helikite remain stable in both high and low winds with no changes of adjustment. Also, the Helikites' stiff keel and spars create stability and the fin keel provides aerodynamic damping allowing payloads to be attached without causing instability.



Helikite aerostats are a disruptive breakthrough technology that reduce the $1,000+ aircraft operating cost /hr to less than $10 /hr for the Helikite having at least an order of magnitude lower operating cost.

A critical aspect for obtain all Australia mobile coverage is to consider a phased deployment model.

Key considerations with Helikite tethered aerostats:

- Easy to use with minimal manpower (depending on the size of the platform).
- Low or high altitude use (similar to blimp platforms).
- More stable than all other airborne platforms in high winds.
- Persistent
- Reliable.
- Versatile.
- Antenna directivity could be a limiting factor on small payload deployments.
- Inexpensive per hour and per Mbit/s subject to backhaul capacity constraints.
- Need to travel to point of use by road
- Need to manage flight exclusion zone, depending on altitude.
- Tethered aerostats are conceptually closest to carrier comfort zone with mobile towers

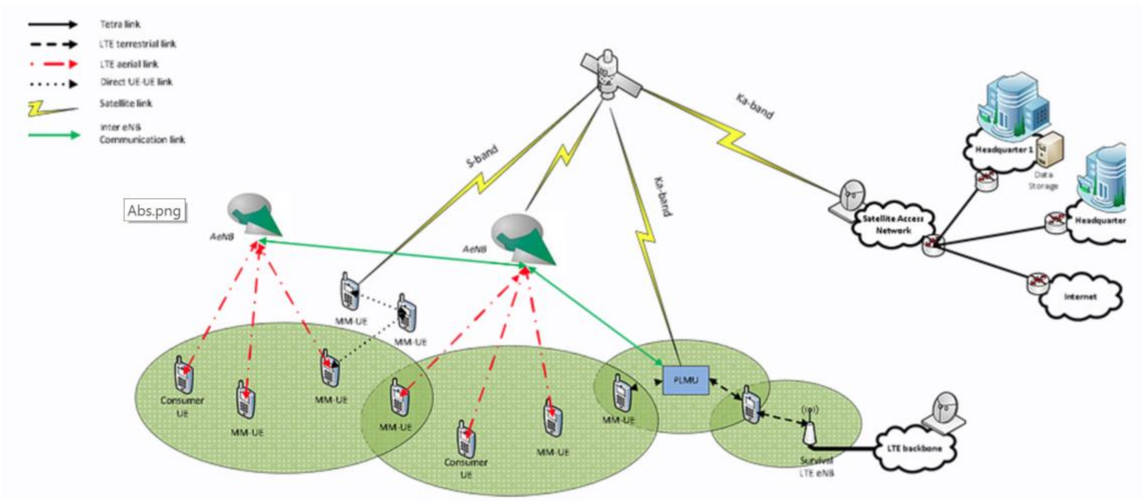
Overview of a Helikite Aerostat Solution

Aerial platforms study - CORDIS [4] provides an overview of airborne solutions including aerostats. The US Homeland Security System Assessment and Validation for Emergency Responders (SAVER) report on Tethered Aerostat Systems [5] is an overview of the aerostat industry, the key characteristics of aerostats and has photos of major makes and sizes. A shorter overview may be found under Wikipedia on Tethered Aerostats [6].

The complete system of the tethered Helikite aerostat consists of the aerostat, the mooring station, and the winch and tether cable. The latter is normally made from Dyneema [15], which is 10 times lighter than steel cable of the same strength and carries to the aerostat fibre optic backhaul and optionally electric power. If carrying electric power, the cable has a copper outer sheath to protect the aerostat from lightning strikes. This adds significant weight.

In locations with no electrical power supply the aerostat may carry its own solar cells and battery. The increased aerostat weight is offset by lighter tether that does not have to carry electricity. This allows higher altitude and therefore greater 4G range. The trade-off depends on the length of the tether to be carried. Whilst our aim is to maximise equipment on the ground to keep the aerostat as light and simple as possible aerostat carrying its own solar panels and battery is preferred in most of remote Australia suffering from unreliable or non-existent mains power.

The European Union FP7 ABSOLUTE project created a tethered Helikite aerostat solution for 4G LTE emergency services [7]. It had contributions from England, France, Germany, Italy, Hungary and Australia. This architectural overview shows the satellite based backhaul for the aerostat to operate over a disaster area:



AAA Aerostat Performance

We require the AAA aerostats to be between 100m3 and 200m^3 to fly at a minimum 1,200m altitude:

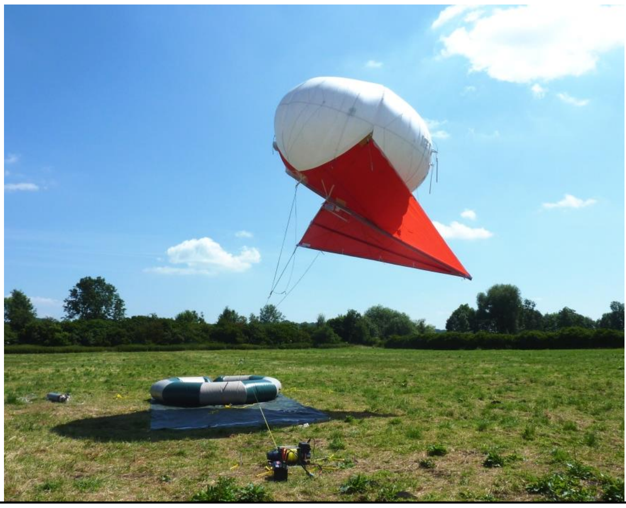
HELIUM CAPACITY m^3	BALLOON MATERIAL THICKNESS Inch/1000	LIFT IN NO WIND Kg	MAX WIND SPEED km/h	MAX UNLOADED ALTITUDE m	LENGTH m	WIDTH m
100	**4**	**50**	**100**	**3,300m**	**10.0m**	**6.7**
200	**6**	**100**	**100**	**3,500m**	**12.2m**	**8.7m**

Performance depends on net helium lift and tether weight. Performance figures are based on base-station dry conditions at sea-level "Standard Temperature and Pressure (STP) [9]" and so will be predictably different in situations where STP does not apply in hot, high elevation, humid, or wet conditions, rain, snow, etc.

Rain, snow, dew and mist all add the weight of significantly dense water over the entire surface of an aerostat. Helikite aerostats of 100m3 or 200m3 predictably lose about 20% of their net lift due to precipitation.

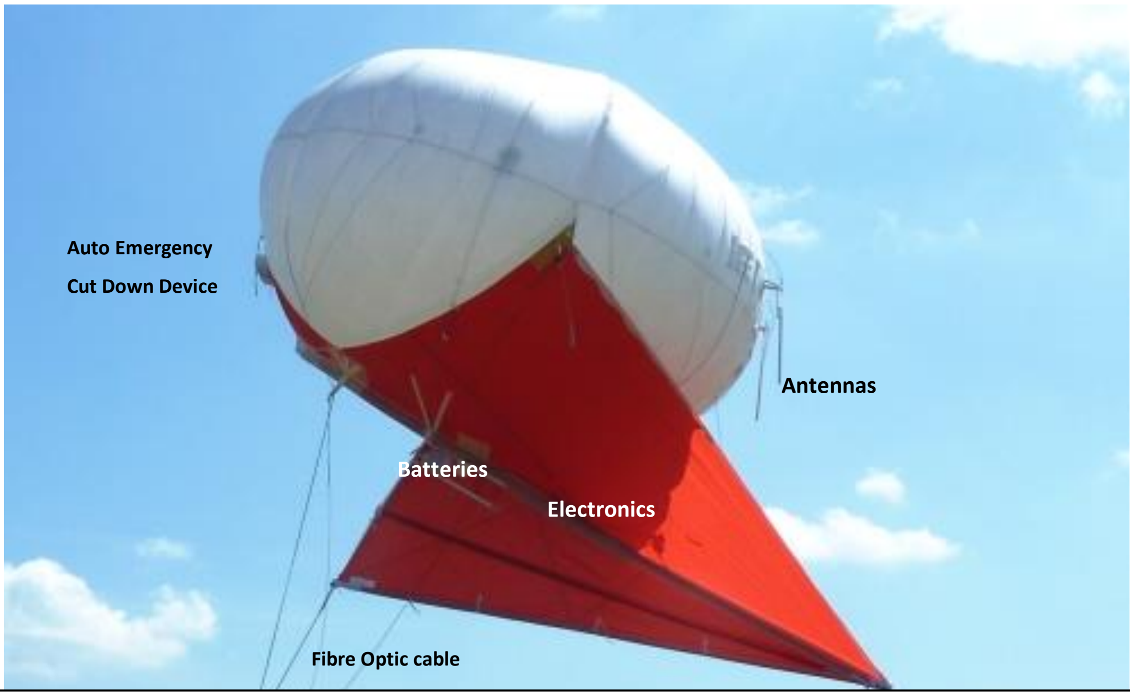
Desert Star Helikites are heavy duty made for dusty, stony, desert conditions. They have a tough, lightweight outer cover made of "Ultra" material protecting the inner removable balloon. The maximum unloaded altitude of 3,300m is theoretic as we see no extra coverage attainable above 1,200m.

The European Union project ABSOLUTE FP7 [7] for emergency 4G LTE used Helikites as their aerostats.



ABSOLUTE 4G 34m3 Desert Star Helikite

ABSOLUTE Helikite in Flight



Position of 4G equipment on the ABSOLUTE Desert Star Helikite

ABSOLUTE radio equipment on the Helikite Electronics

Stern View of ABSOLUTE Helikite showing 4G Radio Equipment'

Helikite operators include: US Navy, US Air Force, US Marines, US Navy Seals, British Army, Royal Marines, Australian Defence Force, Lockheed Martin, DSTL, QinetiQ, CENETIX, Thales, British Antarctic Survey, Norway Oil-spill Response, Sandia National Laboratories, Frauenhofer Institute, CSIR, and NIWA.

Deployment Strategy for Aerostats

An important aid for planning deployment is the Radio Frequency National Site Archive RFNSA used to search for Australian base stations to find Electromagnetic Energy (EME) Reports, site locations, carrier contact details for existing sites and community consultation information for new sites.

We propose aerostat deployment in three stages over four years for all Australia mobile coverage:

Stage 1: Aerostat Centre for Excellence

The aerostat centre for excellence is responsible for:

- Engineering design and trials of the selected aerostat and ground support equipment;
- Field trials in remote Australia;
- Radio Access Network Design;
- Payload Integration and Optimisation;
- Planning of Site Acquisition across Remote Australia;
- Liaison with Remote Australia Stakeholders;
- Obtaining regulatory approvals including ACMA, CASA and Defence;
- Operator Training;
- Level 3 Support and with vendors Level 4 Support

We propose two centres with one in Eastern Australia and the other in Central-Western Australia.

The first year budget is estimated at $10m.

Stage 2: Aerostat Co-Location with existing remote Australia Mobile Towers

The rational for co-locating aerostats at existing mobile tower is availability of access roads, electricity and fibre optic backhaul. This reduces the cost of an aerostat site many-fold from$2m to $500K. These figures are indicative at this stage.

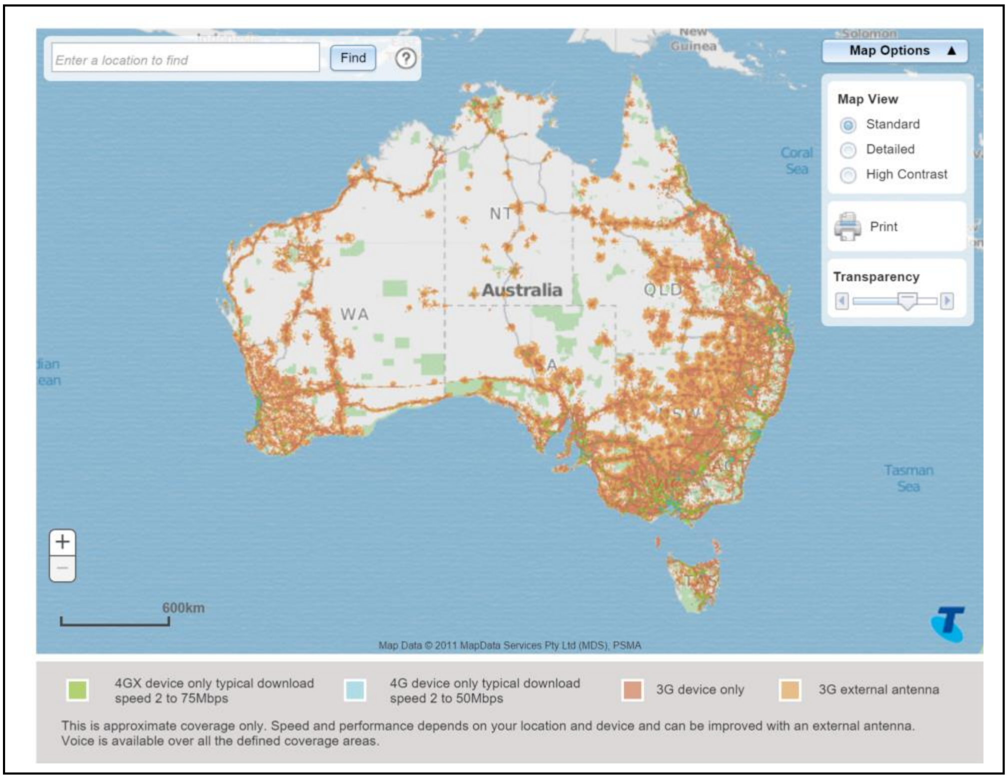
The aerostat must have its own radio spectrum to avoid interference with existing cell sites.

An aerostat at 1,200 m altitude extends a typical cell site coverage 160-fold from 300 km^2 to 48,000 km$^{2.}$

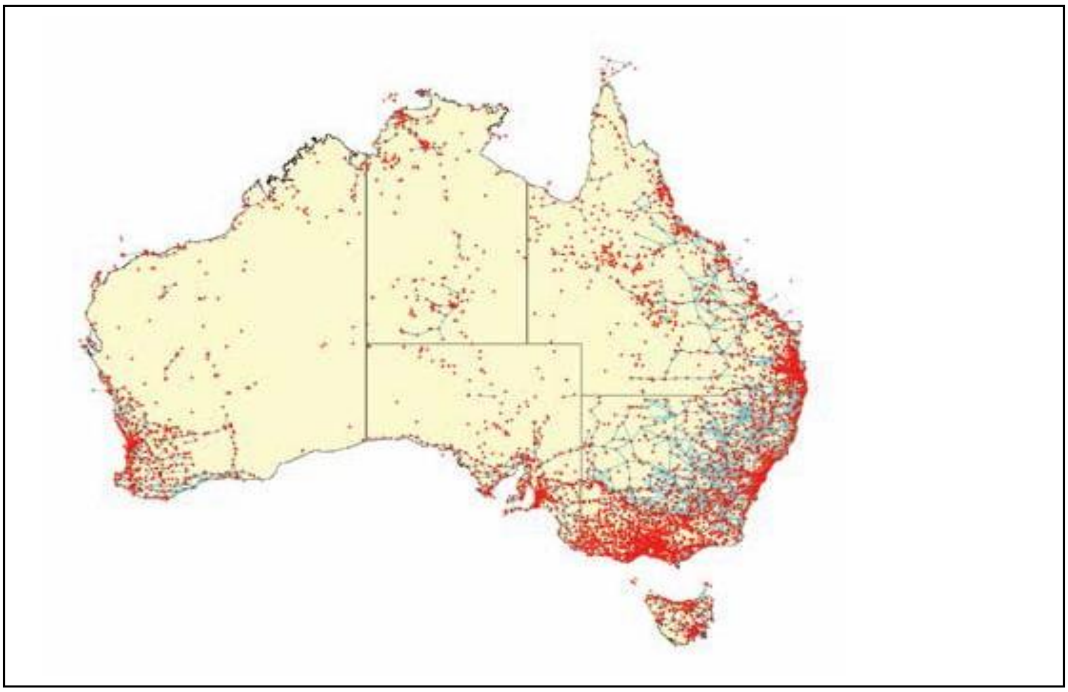
We will proceed to discuss the Radio Access Network design including capacity.

The enclosed Telstra coverage map clears shows that mobile coverage may be extended to a large part of remote Australia.

Telstra Coverage Map [16] – currently 2.3m km² covers 30% of Australia Australia's land area of 7,692,024 km²:



Stage 3: Public Safety Agency Points of Presence and Point-to-Point Links



Points of presence

Point to point links

Source: [1, Figure 6] Diagram produced for the Committee by Anthony Goonan (Yless4U) using Australian Communications and Media Authority data as at 15 June 2015

[1] Recommendation 4 – The Australian Government should consider co-investing with state governments and carriers to support upgrades to regional state-based public safety wireless networks that could also deliver mobile coverage improvements

The use of Public Safety Agency Point of Presence and Point-to-Point links needs to be investigated to reduce cost. If a completely new aerostat site is required, then it should be added where possible as a new Public Safety Agency Point of Presence to maximise economic benefit.

We expect, as can be seen from the maps, that a limited number of new sites in the eastern half of WA and in the western part of NT and SA will be required.

Similarly, aerostat sites will be required in all major Australian islands [17] and in particular for Australia's External Territories [18]. The islands to the north have a high strategic value to the Department of Defence and border protection. These sites should be constructed jointly with Defence funding. Heavier aerostat models can accommodate larger payload with surveillance equipment in addition to the telecommunications payload. We recommend these islands to be covered in the stage 3 deployment.

Aerostat Support Model

The proposed model for supporting a fleet of 250 aerostats at 1,200 m altitude to provide Australia wide mobile coverage comprising:

L1 support on-site weekly[4] inspections and to recover the aerostat for cyclones;

L2 support for monthly service and for setting up new aerostat sites;

L3 support for annual major service, technology upgrades and major repair;

L4 support jointly with the vendors requiring expertise.

Level 1 Support to inspect and protect Aerostat

Each of the 250 aerostat sites will require up to two person days for a weekly inspection and for protecting the aerostat from cyclone force winds.

The weekly inspection requires the aerostat to be winched down, visually checked with minor adjustments if required and winched up. We expect an outage window of no more than two hours scheduled for low activity, say Sunday 2-4 am. Weekly inspections will maximise an aerostat's operation life to up to ten (10) years by preventing small issues from escalating into major problems.

Wind exceeding 100-to-120 km/hr will automatically trigger a winch down if not already invoked by L1-support who will inspect the aerostat for any damage and decide when the aerostat can be safely winched up. Some of the remote areas such as Cape York are prone to cyclone force winds. All airborne solutions are affected by adverse weather. The aerostats proposed have superior adverse weather performance to aircraft, UAVs or other airborne solutions.

The L1 crew of two will be regular mobile carrier staff, contractors and trusted locals such as land owners, rangers and emergency staff that will be provided with satellite radios for communication when the aerostat is not available.

We budget up to ten (10) hours of scheduled downtime a month providing almost 99% availability less downtime during storms. The length of unscheduled downtime will depend on the area of remote Australia and needs to be studied with the Australian Government Bureau of Meteorology [19].

We estimate $25m pa L1 support for a fleet of 250 aerostats.

[4] Weekly inspection may be extended to monthly in low wind inland areas.

Level 2 Support: Monthly Service and Set up of new Aerostats

A dozen two-person carrier L2 support crews across Australia will service the aerostats including any repairs and supply of helium. An annual supply of helium is usually kept on aerostat site. L2 crews set up new aerostat sites, rotate aerostats for L3 refurbishment and technology upgrade as well as train the local L1 support resources. Servicing more than one site per day by a L2-crew is not feasible.

The setup of aerostats in the Aerial platforms study - CORDIS [4] was less than an hour per aerostat. However, in practice we would expect this and the associated training to take a full day for each new site after any site preparation including electricity, backhaul, base station, civil works such as access roads, equipment shed, winch and other aerostat ground equipment have been completed. We also note the long distance the crews have to travel on four wheel drives or trucks or possibly by helicopter in the most remote sites. The outage per service is less than two hours unless repairs are required. L2-crews will always carry a spare aerostat with helium, materials and tools for repair. We are proposing heavy duty 100-to-200 m^3 aerostats.

L2-crews will be supported by a dozen depots around Australia. Where feasible these are existing mobile carrier depots.

We estimate L2-support to cost $15m pa.

L-3 Support for Aerostat Annual Overhaul and Technology Upgrade

The L3-support carries out aerostat overhaul and technology upgrade as well as repairs and other support requiring L3 skills and facilities on demand. Aerostats will be rotated by L2-crews between AAA sites and L3-Depots for overhaul and technology upgrade. We expect two L3-depots set up as part of the stage-1 Australian Centre for Aerostat Excellence. We expect L3 support to cost $10m pa.

L-4 Expert Support

The Australian Centre for Aerostat Excellence jointly with the vendors will provide L4 expert support.

We estimate L-3 and L-4 support to jointly cost $10m pa. Thus, the total annual support cost for all support levels L1-to-L4 to be $50m pa.

Total Aerostat OPEX Estimate

A further $10m pa in administration and R&D will be required for the Australian Centre for Aerostat Excellence. The aerostat amortisation is up to 20% pa to refresh the fleet in five-to-ten years. The ramp-up of OPEX will take four years to commission the 250 aerostat sites:

OPEX Category	Annual Cost [$m]
L1 Support	25
L2 Support	15
L3-L4 Support	10
Sub-Total L1-to-L4 Support	**50**
Australian Centre for Aerostat Excellence with two national sites	10
Amortisation	10
Contingency at 20%	15
Total OPEX	**85**

Assuming a four-year deployment of the aerostats translates into an OPEX estimate:

OPEX Year	Annual Cost [$m]	Comment
1	10	Setup Centre of Excellence
2	25	Stage 2 Cell-Site Co-Location
3	50	Stages 2 and 3
4	75	Deployment completed
5 onwards	**85**	**Full Fleet Operations**

Observe: All cost figures are ± 50% estimates to be refined by the Australian Centre for Aerostat Excellence.

Combined Year 1 – 4 CAPEX and OPEX

Year	OPEX [$m]	CAPEX [$m]	Total [$m]	Comment
1	10	10	20	Setup Centre of Excellence
2	25	40	65	80 Stage 2 Cell-Sites Co-Located at $500K/Aerostat
3	50	135	185	70 Stages 2 x $500K and 50 Stage 3 Aerostats x $2m
4	75	100	175	50 Stage 3 Aerostats x $2m
1-4	**160**	**285**	**445**	**Combined CAPEX and OPEX**

Observation: In our revenue model we include 1/3 revenue attribution to recover the cost of backhaul, call termination, Internet data cost, marketing etc. carrier expenses. The amount of attribution depends on the carrier implementing AAA.

Revenue Model

As at June 2014, 2.3 per cent of Australians lived in remote or very remote areas of Australia: 323,720 people in remote Australia with population density less than one person per km^2 and 208,344 people in very remote Australia with population density less than 0.1 person per km^2 in a diverse range of settlements [1].

Our model assumes 100,000 new post-paid mobile subscribers in remote Australia that never had mobile coverage. Most of the rest would already have a Telstra mobile service covering 99.3% of the population as opposed to only 30% of our land area.

Also, we assume 100,000 post-paid mobile subscribers that select the aerostat carrier as their second post-paid plan. Handset technology is rapidly evolving into SIM-less, thus facilitating the same handset dynamically configured to multiple plans. Also, many have more than one handset and some handsets support more than one SIM card.

We believe the assumption for 200,000 additional post-paid plans is extremely conservative.

The new subscribers would be charged at standard mobile plan rates. Assume 90% people want a large plan at 60^{/mth}$ for 10 GB of data and 10% of heavy business users require a premium plan at 195^{/mth}$ for 25 GB of data thus yielding $144m pa revenue. The plans quoted are Telstra's. This closely aligns with the Average Revenue Per User ARPU, excluding the impact of mobile repayment options (MRO), increased in 2014 0.7 per cent to $65.80 as customers used more data. Source: Telstra Annual Report 2014 [20]. There is further significant revenue from many having more than one mobile service for example for Wi-Fi-hubs and Machine-to-Machine M2M services.

The 60^{/mth}$ would be a significant impost on many of remote indigenous communities and would have to be subsidised by the Government possibly via the Universal Service Obligation USO.

Remote Australia domestic visitors number around 5.5 million per year; international visitors number around 1.3 million per year according to the NINTI One CRC for Remote Australia Economic Participation [21] based on data published by Tourism Research Australia (TRA).

Assuming a take up of 10% prepaid $30 plans by the approximately 2.7m non-Telstra remote Australia visitors and the international visitors we can expect approximately 400,000 $30 prepaid plans sold per annum for remote Australia coverage yielding an extra $12m pa revenue.

Many of the prepaid plans will convert to postpaid plans for further revenue; it is not unreasonable to expect from year 5 onwards approximately $156m revenue pa.

Out of the $156m revenue approximately one third at $55m would have to be deducted to recover the cost of backhaul, call termination, Internet data cost, marketing etc. carrier expenses. This would be in addition to the $85m pa cost of operating and supporting the aerostats.

The combined cost of $140m pa would still be less than the $156m pa revenue. Thus AAA all Australia mobile coverage would recover its operating cost.

Factoring in the $285m four-year CAPEX cost would require funding by both the carrier(s) and the government possibly under the USO umbrella.

The government and/or NBN funding of AAA CAPEX would save NBN having to order a third $1b Sky muster satellite costing more than twice AAA implementation. The initial aggregate AAA bandwidth of 250 Gbps is twice the aggregate 135 Gbps bandwidth of NBN satellites [43].

Funding by Universal Service Obligation USO

Department of Communications managed special account [1, Figure 7] for USO totals $337m pa:

- $253m standard telephone service
- $44m payphones
- $21.5m emergency call services
- $18.8m national relay services for the hearing and/or speech disabled

Government funds $100m pa out of the USO and carriers the rest as their USO obligation.

The Customer Service Guarantee (CSG) is antiquated [1] - it covers only standard telephone service. CSG does not cover mobile phone services and internet services.

Aerostats All Australia AAA mobile coverage would offer a superior service replacing the need for standard telephone service, payphones and emergency call services as well as providing high speed low latency mobile and Internet as stipulated by international consumer safeguards that Australia still needs to implement.

Telstra is bound under contract with the Australian Government until 2032 to deliver the USO on the assumption there will always be some uneconomic telecommunications services where competition alone will not deliver the required outcome. Meeting the CSG Standard timeframes and benchmarks is a condition of this contract. Telstra's obligation is technology neutral, meaning it can choose the technology over which they provide this service.

[1, Recommendation 8] – Current consumer safeguards as they relate to the STS are increasingly irrelevant. The Australian Government, in consultation with industry and consumer groups, should develop a new Consumer Communication Standard for voice and data which sets technology neutral standards in terms of availability, accessibility, affordability, performance and reliability.

Competing carriers have protested USO as antiquated proposing instead maximum use of mobile coverage.

USO is primarily to (a) fund a standard telephone service, and (b) there is a strong move to retire it in favour of something more appropriate. Possible successor schemes include the Consumer Communications Fund proposed in the RTIRC report [1]. Also, there are proposals to transfer USO from Telstra to NBN for example [44] "Better telecommunications services for all Australians - Rethinking the Universal Service Obligation by Professor Reg Coutts with the support of Vodafone for [1] and TelSoc journal".

An additional perspective [47] by Robin Eckermann calls for an economically efficient approach to service mobile coverage in remote Australia by way of example:

- *one operator could deploy infrastructure and offer roaming options to customers of the other two networks; or*
- *a neutral operator (such as nbn) could build and operate infrastructure on a wholesale-only basis, enabling access to customers of all three networks.*

We recommend the government to reallocate its $100m pa USO contribution to build AAA over four years with temporary partial relief to Telstra until built and fully operational. This would de-risk building the AAA and acceptable to the extent Telstra is not financially disadvantaged.

We see AAA requiring an ongoing operational subsidy for the disadvantaged remote Australia communities that would struggle to pay for having a mobile phone plan.

We recommend the government selecting one operator to build and operate infrastructure and to mandate enabling access to customers of all three networks with roaming and/or wholesale arrangements for the two other networks similar to [47].

Finally, we have not been able to cost satellite backhaul required in the most remote parts of Australia. The cost will depend on the percentage of aerostats that cannot get backhaul by other means than satellite. We would recommend government subsidy for satellite backhaul. The inadequacy of remote Australia fibre optic backhaul is demonstrated by backhaul maps [45].

Regulatory and Safety Issues and Approvals

AAA will require Civil Aviation Safety Authority CASA, Defence, ACMA, Public Safety Agencies, Site acquisition, community consultation, indigenous representation, crown land and national park approvals.

Spectrum Approvals

Any use of spectrum has to be approved by the Australian Communications and Media Authority ACMA.

We strongly recommend the government to mandate the carrier chosen to build and operate to offer the other national mobile carriers wholesale and/or roaming to open up access to remote Australia.

We also expect ACMA to maximize spectrum available to the chosen AAA operator.

Any unallocated spectrum in the 700/1800/2600 MHz bands should be gifted to AAA and carriers with spectrum not used mandated to surrender their unused spectrum in remote Australia to the AAA operator on the principle that 'unless you use it you will lose it'.

Spectrum needs to be aggregated from all spectrum bands available to maximize capacity up to 100 MHz x 2 supported by LTE-A enabling 1 Gbps capacity per macro cell provided there is sufficient backhaul.

Currently only Telstra has the full 100 MHz x 2 spectrum holding in non-metro areas [1, Figure 2 Spectrum Holdings].

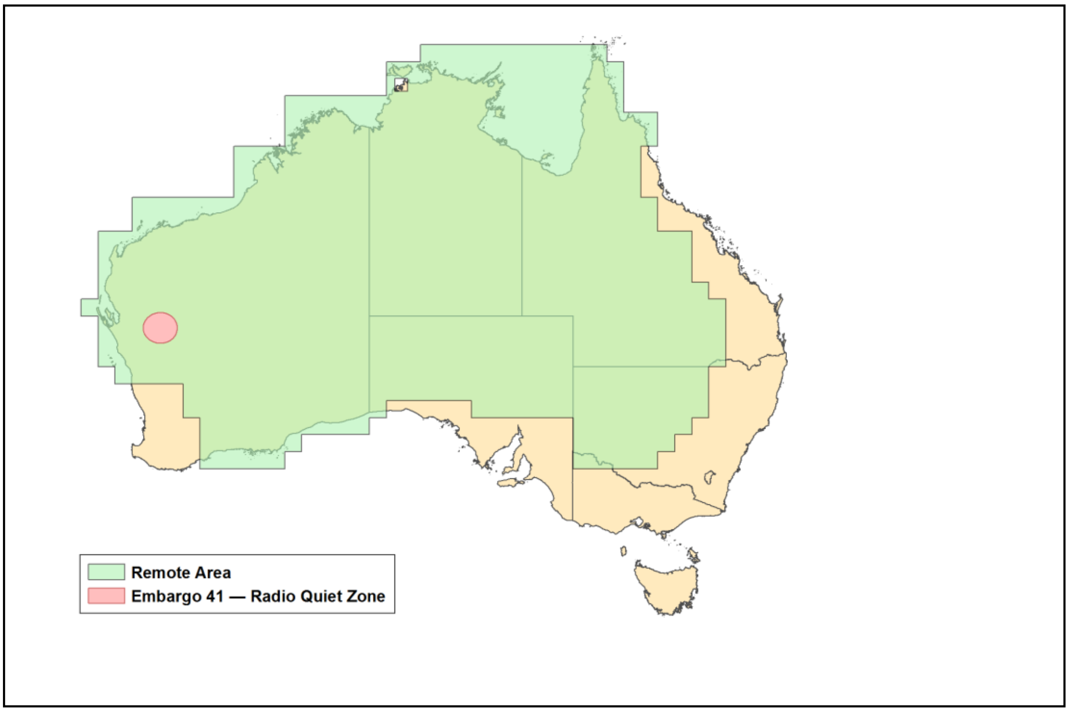
ACMA's regional 1800 MHz auction will alleviate spectrum shortage.

Element of draft recommendation	The ACMA's proposed recommendation
Licence type	Spectrum licences
Parts of the spectrum	1725–1785 MHz and 1820–1880 MHz in regional Australia, where ‘regional Australia’ is defined by the HCIS identifiers described in the ACMA’s written notice
Reallocation period	Two years in all parts of the spectrum
Reallocation deadline	12 months before the end of the reallocation period.

ACMA regional 1800 MHz auction [22]

ACMA is able to allocate up to 120 MHz under 1725–1785 MHz and 1820–1880 MHz in regional Australia. Ideally AAA could use this unallocated spectrum.

ACMA [48] has restricted the spectrum assignment to Telstra, Optus and VHA to no more than 2 x 15 MHz of spectrum. Telstra, VHA and Optus are able to apply for licenses immediately. We recommend ACMA to allow pooling of remote 1800 MHz spectrum as well as any other unused spectrum such as 700 MHz for AAA to maximize aggregated capacity to 100 MHz”



ACMA [48, Figure 1] Remote areas for the administrative allocation

This is particularly important where AAA aerostats are co-located with existing mobile towers. It is imperative for the aerostats to be allocated their own spectrum to prevent interference with existing mobile service.

A mobile handset seeing more than one spectrum available would set AAA's spectrum to lowest priority thus maximizing AAA spectrum for those that only can receive on AAA's spectrum e.g. a handset would always use existing coverage where available and AAA only where there is no other coverage.

This still leaves the problem of managing overlapping AAA coverage. The geometric overlap could exceed a third of the area covered. However, there is a wealth of knowledge and experience managing overlap and [mobile handover](#) [23] between cells, say when driving across cell boundaries.

Civil Aviation Safety Authority CASA Approval

Aerostats have to meet civil aviation safety regulations. This will include lights and radar reflectors for aerostats and illumination of the tether at night possibly by illuminating paint at regular intervals. Also, automatic and/or remote deflation of the aerostat is required to safely handle tether breakage.

AAA Helikites have an excellent operational and safety record. Since their design in 1993 not a single person has ever been injured in their operation. No Desert Star Helikites have ever been lost or seriously damaged during operations, despite hundreds being used worldwide, in both war and peace.

The United States Part 101 - eCFR — Code of Federal Regulations [24] covers aerostats as moored balloons and kites. Search of CASA web-site shows minimal or no restrictions on tethered aerostats proposed by AAA. In managing the risk of the balloons going in and out of Australian airspace, CASA asked Google to provide evidence of its compliance with the US Civil Aviation Safety Regulation Part 101.

Compliance included having an Automatic Dependent Surveillance – Broadcast (ADS-B) transponder, radar reflectors, a parachute, collision lights and independent redundant mechanisms to remotely terminate flight, as well as the capability to provide regular position updates for air traffic management.

The first group of balloons entered Australian airspace over the Indian Ocean on 19 March 2014. Google has maintained continuous position tracking, with reports available every one minute and accessible by Airservices Australia when required. More information can be found on the project website at www.google.com/loon/

AAA will require CASA's approval to operate tethered aerostats 24x7 at an altitude of up to 1.8 km. CASA's List of schedules of airworthiness directives for Australian registered airships and balloons [62] has no reference to tethered aerostats except for European Aviation Safety Agency EASA approved Aérophile S.A. Model 5500 manned tethered balloon with a spherical envelope of approx. 5,500 m^3 total volume used as a tourist attraction with CASA accepting the EASA certificate.

For security and safety reasons, air space around US Air Force tethered aerostat radar-system sites [25] is restricted for a radius of at least two to three statute miles and an altitude up to 15,000 feet (4,600 m).

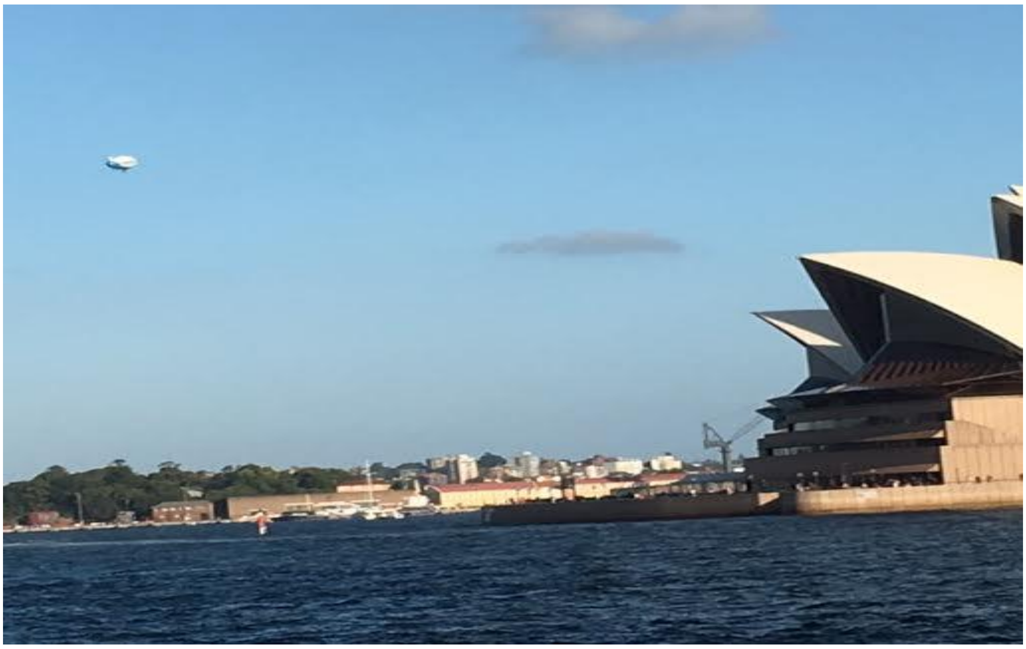
Such licenses have been granted in the USA. For example, for the twelve aerostats along the southwest border of the United States and Mexico, the Straits of Florida and the Caribbean in support of federal agencies involved in the drug interdiction program.

These aerostats are massive 12,000 m^3 carrying downward-radar payload of up to 1 ton as opposed to AAA's 100-to-200 m^3 aerostats with payloads less than 50 kg at 1,200m average altitude. The AAA objective is to minimise the payload under 10 kg possibly even under the US FCR 101.1 exemption.

Hence AAA aerostats should be able to obtain a permanent CASA license to operate for AAA as long as the aerostats are well outside aircraft flight paths and especially take-off and landing areas.

Helikites have been flown extensively by the Australian Defence Force up to altitudes of 2,000ft for training. They were granted air-traffic permission without any issues.

An example of what CASA permits is the large blimp on 8 January 2016 passing over Sydney Harbour Bridge, Opera House and the strategic Garden Island Naval Base:



The AAA operator will be even stricter on safety than the regulator as the operator cannot afford accidents. The operator will require a Chief Regulation and Safety Officer CRSO.

Leading aerostat manufacturers [31] provide FAA Certification and Compliance Services including:

- Type Certificate (TC)
- Amended Type Certificate (ATC)
- Supplemental Type Certificate (STC)
- Technical Standard Order (TSO)
- Parts Manufacturing Approval (PMO)

Restrictions

AAA will, unlike mobile towers, easily be located to overcome any planning restrictions. The 100 km+ radius of coverage implies that the planners can readily adapt the aerostat site location to comply with local restrictions. The aerostat can readily be flown higher if required. AAA will, of course, consult in order to comply with restrictions and obtain approvals by:

- Department of Defence restriction;
- Community consultation;
- Land title owners and other indigenous groups;
- Crown land and national park authorities;
- The WA Radio Quiet Zone [26] will require avoidance except in emergencies

We expect minimal community opposition to aerostats as opposed to mobile towers in populated metro areas. An aerostat several tens of kilometres away is to all intents and purposes invisible compared to mobile telephony towers. Aerostats will avoid any concerns about radiation from nearby residents.

Most objections to aerostats relate to surveillance. AAA aerostats will not carry surveillance equipment except for any joint aerostats with defence in strategic locations such as Australia's External Territories.

Aerostat Support Equipment

In costing an aerostat solution, we have included comprehensive support equipment [14]:

Winch

The winch chosen is a large and very powerful wheeled gasoline winch, specially designed by Allsopp Helikites Ltd, suitable for large Helikite operations originally designed to operate from US Navy ships.

SPECIFICATIONS:

Power: 22 HP OHV Honda gasoline motor

Weight = 1225Kg

Overall dimensions with wheels and tow-hitch stowed:

Length: 232cm Width: 1500cm Height: 146cm

Line speed 100 metres per minute forward and reverse.

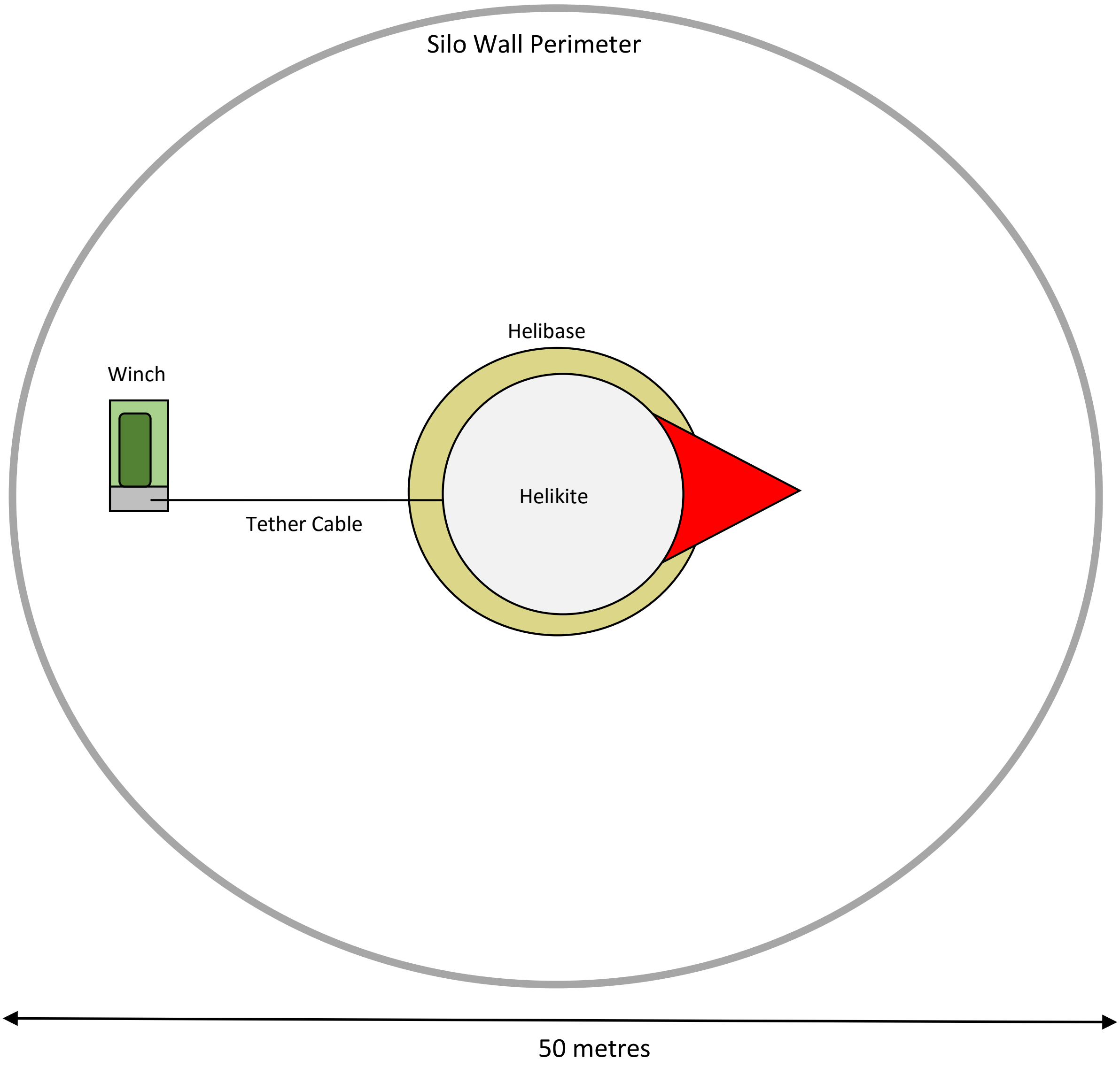
Max. Recommended Working Line tension is 750Kg. Max line pull is 1000Kg.

Helibase

Helibase eliminate the problems associated with ground handling large Helikites. They allow the largest Helikites to be safely and easily handled by only one or two people whatever the weather conditions. This considerably reduces manpower costs and is far safer for the Helikite and the operators than struggling with a large half-filled helium object on a dirty tarpaulin, in a high wind. The Helibase makes Helikite deployment fast, easy, stress-free and safe.

A secure launch base is critical in the cyclone prone coastal areas of northern Australia.

Launch Base



Silo Wall Perimeter
Helibase
Winch
Helikite
Tether Cable
50 metres

The Helibase, winch and Helikite will be operated out of a protected and secure Launch Base. This will be based on silo building technology. Essentially, an open topped silo, 50 metres in diameter and 9 metres tall. Helikites have flown from such open silo Launch Bases before with no problems. The Launch Base will protect the Helikite, winch and Helibase from unauthorised visitors and also provide excellent protection from storm force winds when the Helikite is landed.

Helikite Flying out of a silo Launch Base in London

Balloon Remote Deflation Devices

AAA aerostats will be fitted with a system whereby they will automatically deflate if they get loose from their tether. This ensures that they cause as little damage as possible to buildings or overhead wires and also that they do not disrupt air traffic. This can be achieved by any of the below three types of aerostat deflation devices [14]:

1) Automatic Barometric Balloon Cut-Down.

Air pressure reduces with altitude. A sensor on the aerostat detects the difference between the atmospheric barometric pressure of its launch height and its present barometric pressure. If it detects that the Helikite is at too great an altitude, it initiates a hot wire cutting device that creates a suitable hole in the balloon material which quickly release the helium gas to initiate a controlled descent. This system requires no human interaction besides the initial setting of the height parameters and so should satisfy any legal requirements.

2) Radio-Controlled Balloon Cut-Down.

An encrypted radio signal is sent from a ground station transmitter to a radio receiver on the Helikite, which initiates a hot wire to cut a large hole in the balloon material to cause the gas to escape and the Helikite to descend. The signal can be sent within 10 Km of the Helikite. This can be a very rapid method of downing a Helikite. So it is quite possible that the operator would be able to retrieve the Helikite quickly and with minimal damage.

Both these systems are extremely simple to use plug-and-play designs for very fast deployment, and yet they are very sophisticated and computer controlled with an ability to test the circuits and wires for faults before deployment. They also check the battery power is sufficient. They use Lithium Ion batteries which operate at very low temperatures and have years of shelf-life.

The electronics of both the ground station and the airborne components are water-resistant. The total weight of the airborne components is 1.3Kg.

3) *New* GPS Controlled Balloon Cutdown system

The HCS-03M is a safety device for tethered plastic skinned helium balloons, blimps or Helikites. It is designed to deflate the balloon in the event of a tether break in order to help recover the payload and protect other airspace users. It uses the GPS satellite system to monitor the position of the balloon. If the balloon moves more than a certain distance away from its launch point, the HCS-03M will pass a current through a wire placed in contact with the balloon material. The wire heats up and melts a hole in the balloon, allowing the helium to escape and the balloon to descend.

Cased Helikite Aerostat Maintainable Platform (CHAMP)

Normally the footprint for high altitude aerostats consists of trailers, winches, helium bottles, generators, cables etc. This is because normal blimps need to be huge and complex to achieve serious altitude. However, Helikites are far smaller and simpler for the same performance, allowing the entire footprint to be reduced to just one CHAMP container and a separate winch.

A version of CHAMP will be made available for storage of everything required to create and operate a permanent Helibase with a year's supply of Helium.

CHAMP and the winch trailer are optimised to be transported by mobile L2 support crews.

Aerostat Support Manuals

AAA Centre of Excellence will during its formative year complete support manuals together with the aerostat manufacturer and mobile carrier. An example of the required manuals is found our Lindstrand Technologies web-site [32]:

1. Flight Manual
2. Winch Manual
3. Maintenance Manual
4. Training Manual

Commercial Helium Information

BOC Australia Limited (Industrial Gases) has operated in Darwin NT one of the 14 global Helium plants since 2010 [28] that allows B.O.C. Gasses Australia to recover the helium component of the existing waste nitrogen stream coming from within the Darwin L.N.G. plant. See information about BOC Helium Sales**.**

Price: In fiscal year (FY) 2013, the price for crude helium to Government users was **$2.44 per cubic meter** and to nongovernment users was **$3.03 per cubic meter** according to HELIUM - USGS Mineral Resources Program [29].

Helium cost has been included in our support cost and is not considered major compared to the cost of the containing vessels and transport. For more information about Helium production and resources see HELIUM - USGS Mineral Resources Program **[30].**

Aerostat Payload for 4G LTE

The guiding principle is to minimise aerostat payload to low kilograms by using a miniaturised Antennae Integrate Radio AIR. Payload specifications and architecture for aerostat 4G LTE and radio communications in general has been documented by the:

1) European Union ABSOLUTE FP7 project [7]
2) SkySite® Xiphos with transmitting equipment is an Ericsson RBS 6000 series Radio Unit [38]
3) Syntonics White Paper on “High Antennas for Radio Communications” (HARC) [38] explains how the lightweight FORAX-HARC™ payload enables any aerostat to become, in effect, a tall antenna tower for radio communications over long distances up to 100km and rugged terrain. The equipment is military standard and the aerostats are ginormous.
4) Syntonics’ HTA-Aerostat tactical aerostat antennas [39] are ultra-lightweight, rugged, broadband dipole antennas optimized for airborne use on weight-constrained aerostat platforms.

The AAA Centre of Excellence technical mission is to develop an ultra-lightweight aerostat optimised for 4G LTE integrated with base station and backhaul for remote Australia. A significant Radio Access Network engineering effort will be required as part of the technology integration no less challenging even with off-the-shelf components.

Capacity – Dimensioning Aerostat Fleet

Dimensioning the aerostat fleet is a function of both the coverage required and capacity per service. In particular, the capacity per service should be no worse than with existing mobile towers. The criteria we are using is Telstra having 9,600 towers for 16.5m services. Thus Telstra cell sites serve on average approximately 1,700 services.

A fleet of 250 aerostats is similarly serving on average 1,600 services per aerostat e.g. altogether some 400,000 services. Obviously there will be significant differences in capacity between aerostats as experienced between mobile towers.

The intention is to place the aerostats where feasible next to existing cell sites so as to ensure backhaul and to minimise cost.

Ensuring backhaul will be the most critical success factor.

Electricity

Lack of electricity is not a serious issue since aerostats can be solar powered with battery storage for overnight operation and the winch can be gasoline or diesel powered. Alternative terrestrial solar power with battery storage may be used with electricity transmitted by the tether to the aerostat. The solar powered solution with battery storage on the ground as against the aerostat being solar powered with battery storage is a trade-off between increased weight of the tether and transmission losses versus the aerostat having to carry solar panels and battery storage. Our weight budget of 50 kg for 1 KW solar cells, battery storage and power head is achievable making solar power the preferred aerostat solution.

Backhaul

The main challenge for AAA mobile coverage of remote Australia will be ensuring sufficient backhaul. We are mitigating this risk by deploying aerostats, wherever feasible, next to existing mobile cell sites with backhaul. AAA as a solution can be made independent of terrestrial mains electricity.

- Backhaul can be extended from any terrestrial backhaul point via technologies [33] such as

  Free space optics (FSO)
- Point-to-point microwave radio relay transmission
- Satellite Backhaul and in particular Low/Medium Earth Orbit LEO/MEO satellites e.g. o3b [56] for reduced latency in comparison to geostationary satellites.

The aerostat at 1,200m altitude will have a long distance 100 km+ line-of-sight. The range limiting factors are:

- Fog (10...~100 dB/km attenuation)
- Beam dispersion
- Atmospheric absorption
- Rain
- Snow
- Terrestrial scintillation
- Interference from background light sources (including the Sun)
- Shadowing
- Pointing stability in wind
- Pollution /smog

Obviously, some of these are lesser issues in remote Australia.

There is major research into free space optics for example Li-Fi:

Li-Fi (Light Fidelity) is a bidirectional, high speed and fully networked wireless communication technology similar to Wi-Fi. Li-Fi is a subset of optical wireless communications (OWC) and can be a complement to RF communication (Wi-Fi or Cellular network), or a replacement in contexts of data broadcasting. It is so far measured to be about 100 times faster than Wi-Fi, reaching speeds of 224 gigabits per second.

It is wireless and uses visible light communication or infra-red and near ultraviolet (instead of radio frequency waves) spectrum, part of optical wireless communications technology, which carries much more information, and has been proposed as a solution to the RF-bandwidth limitations.

Again the ability for long range is in question as well as the commercial maturity of these solutions.

SKYFIBER Mobile Backhaul Whitepaper [34] discusses Operators need to deploy a disruptive combination of backhaul technologies.

Australia's CSIRO has developed a backhaul technology called Ngara: Next gen wireless - CSIRO [35] have developed three new wireless technologies (Access, microwave backhaul and E-band backhaul)

CSIRO Develops 10 Gbps Microwave Backhaul [36]

Backhaul can extended by aerostat to aerostat backhaul as well as satellite backhaul – preferably low earth orbiting satellite backhaul to reduce latency - in the most remote areas of Australia farthest away from terrestrial backhaul. Investigating backhaul options should be a key focus of the AAA Centre for Excellence.

OCEUS Networks 4G LTE aerostat [40] proposes to reduce backhaul costs by using regional "small cores" rather than backhauling all network traffic.

The six backhaul links built under the Government's $250 million blackspot scheme [46] is an example of investment that would facilitate AA.

Mobile Technology Evolution

Mobile technology is under a very rapid evolution. AAA aerostats can be easily brought down for service and any technology upgrades applied as and when necessary. The aerostats are much more convenient than mobile towers as aerostats can be brought to a central depot whereas cell sites have to be upgraded in situ.

This is in sharp contrast to satellites that grow progressively more obsolete and out of capacity in a matter of years after their launch thus not achieving a long useful life although technically they may operate for up to 15 years. The inability to upgrade communications satellites while in orbit is a severe problem given the current rate of technology evolution.

AAA capacity will benefit from LTE Advanced being extended to unlicensed spectrum (LTE-U) [57]. LTE-U offers better performance and spectral efficiency over carrier Wi-Fi due to:

- The LTE radio link being more robust and efficient with features such as Hybrid ARQ (HARQ), more efficient and granular Modulation and Coding Schemes (MCS) and better receiver performance.
- LTE-U has a higher MAC layer efficiency with robust protection of control channels, intelligent network based scheduling and rate control based on CSI feedback, and interference coordination with synchronized operation within the same deployment.

These link and MAC level features allows LTE-U to provide better capacity as the network gets denser and interference becomes the dominant factor of performance. LTE-U is likely to stimulate further technology innovation in unlicensed spectrum, including both LTE-U and Wi-Fi evolution, which is expected to ultimately improve unlicensed band efficiency and provide consumers with more choices.

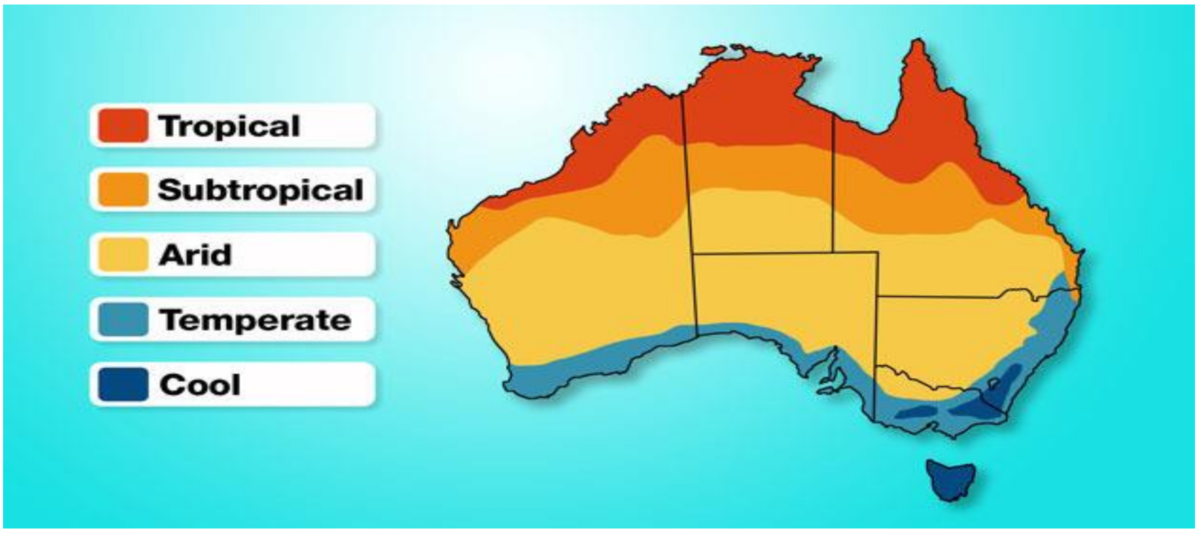
Ericsson has recently completed LTE-U open air trials with Qualcomm [58] using the 5 GHz spectrum [59]. ACMA [59] requires devices operating using the 5 GHz spectrum to employ dynamic frequency selection (DFS) and transmit power control (TPC) capabilities. Use of LTE-U should enable AAA to increase its capacity by 1 Gbps similar to IEEE 802.11ac [60] subject to backhaul availability of course.

AAA will greatly benefit from mobile handset upgrades and in particular SIM-less handsets with ability to subscribe to multiple carriers plans and dynamically select the carrier. Potentially this could worth up millions of additional second mobile plans for the carrier implementing AAA. However, our revenue model is not built on such a speculative uptake.

Technology Risks

AAA has a number of technology risks that must be rated high until the Centre of Excellence has optimised and validated the technology:

Coverage in North Australia Wet Tropics

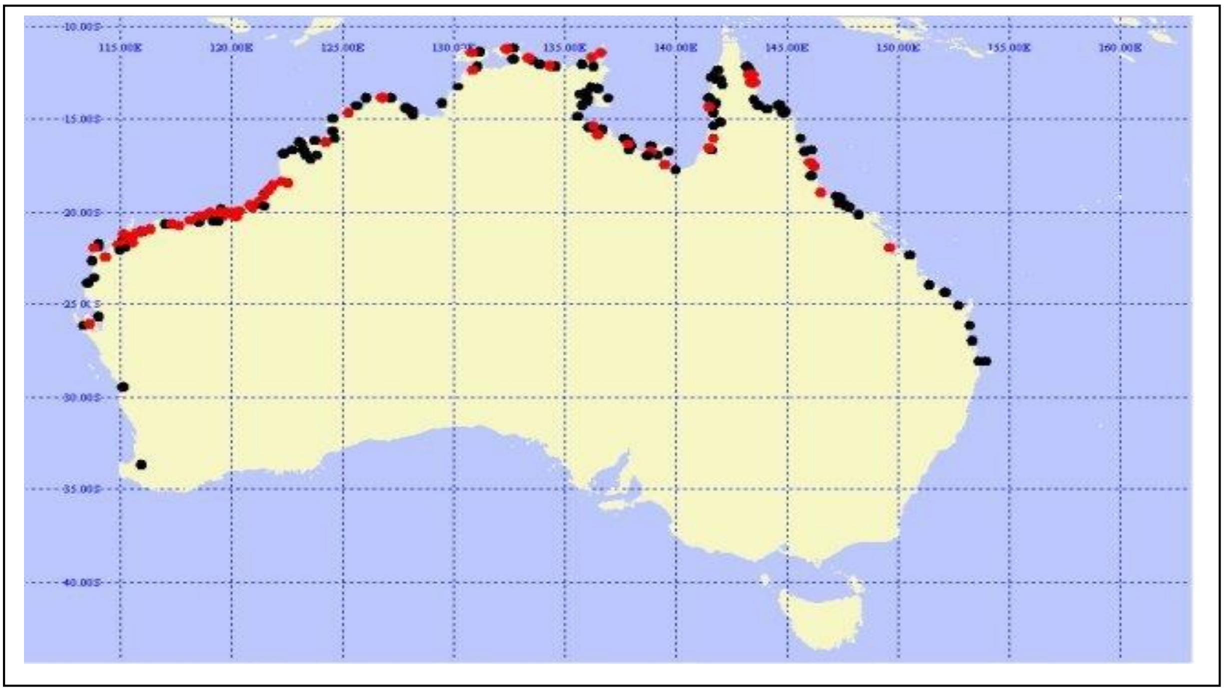


Drones may also be considered for larger emergency areas such as floods or bush fires.

High Wind Risk

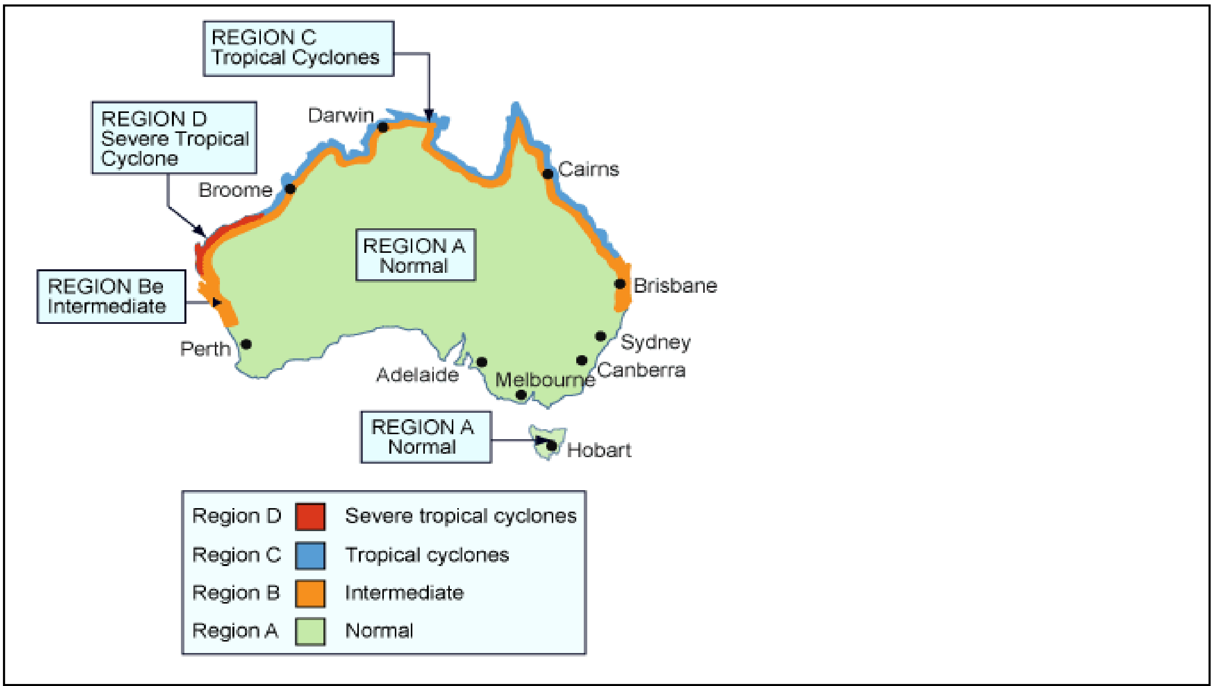
Australia averages 30 tropical cyclones a year [49] distributed [50] to northern coastline:

[50, Figure 1]. Coastal crossing points between 1970-71 tropical cyclone season and 2007-08 season. Red dots represent severe tropical cyclones (category three or higher) and black dots represent non-severe cyclones (sub-category three):



See [51] for BoM cyclone and in general wind category definitions.

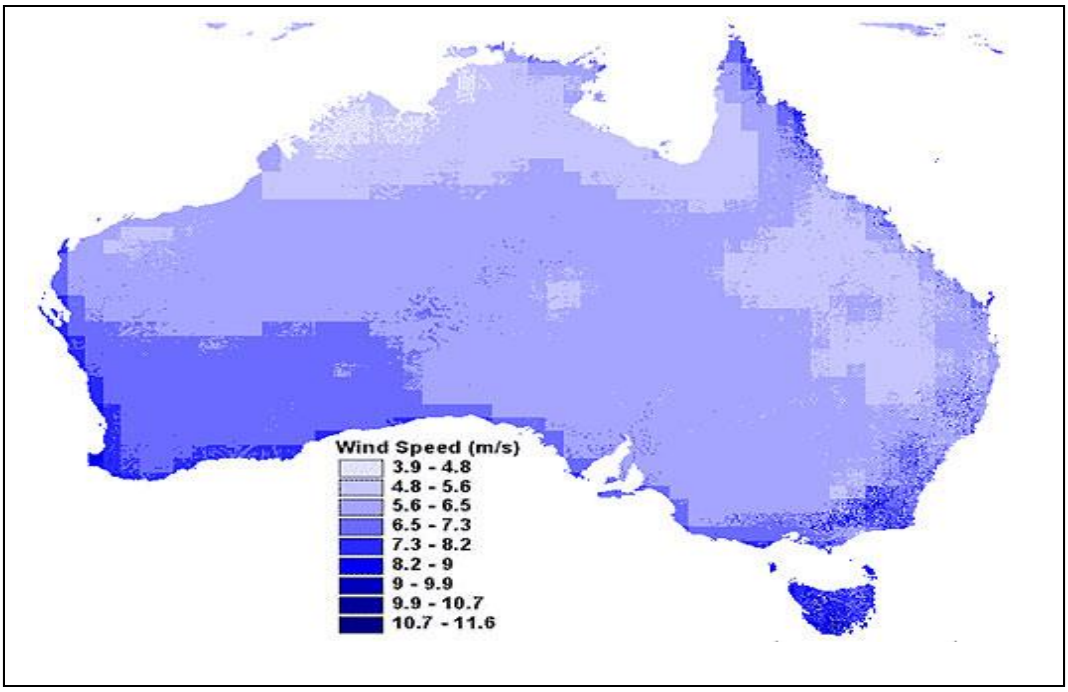
Also, see [52] for [Building Code of Australia Requirements of High Wind Areas]:



The so called ‘normal’ areas especially on the coast may have unexpected storms such as the tornado-like super cell that hit 16 Dec 2015 Sydney’s southern suburbs of Cronulla and Kurnell at more than 200 km/hr [53].

In order to prevent serious damage, AAA aerostats have to be able to be winched down rapidly and deflated in winds approaching cyclone conditions. Aerostats should carry a wind speed sensor that triggers a winch down when required. Alternatively, this can be activated from the ground, preferably remotely.

Average wind speeds [54] in the ‘normal’ and especially inland areas are very benign to aerostat operations:



Wind speed at altitude can be computed by [55].

Management of wind speed in aerostat operations is high priority to ensure the required 99% availability and to minimise damage to aerostats. Helikites [14] would minimise the risk as Helikites are known for their stability in high wind.

Payload Stability

An unstable payload with the antennae wobbling sideways in high wind presents a risk to coverage as well as increases risk of interference [7] to adjacent macro cells. Choice of Helikites [14] would minimise the risk as Helikites are known for their stability in high wind.

Payload Integration and Optimisation

Payload architecture, weight minimisation and integration with carrier's mobile base station and backhaul will require significant effort and expertise for a payload optimised for remote Australia. However, this effort will be aided by the existing experience gained during the EU ABSOLUTE project.

Cost and Latency of Backhaul

Ensuring backhaul at a reasonable cost and with low latency is a high risk. In particular, the cost, latency and performance of satellite bandwidth is a major concern.

Prevention of Spectrum Interference

AAA has to be allocated its own spectrum due to its macro cells having very large coverage. Ability to prevent interference is mandatory for the solution to be acceptable to mobile carriers and ACMA.

Epilogue

As a befitting ending and historic context we quote our reviewer's Maurie Dobbin's 1983 paper [64] entitled *The Future of Communications* published by the Northern Territory University Planning Authority as *'A Selection of papers on Northern Development'*:
"The average citizen of the Northern Territory travels extensively and desires to have reliable communications while he is in transit. The future for this citizen lies in the application of the cellular radio principle of the radio concentrator system to serve the mobile subscriber"
The paper went on to mention that the cost of Telecom's (then) public automatic mobile telephone system was out of the reach of the average citizen and commented in conclusion:
"So while we are still some distance from wristwatch telephones communicating via satellite, advances in communications technology in recent times offer the potential over the next two decades for connecting every citizen of the Northern Territory into the National Telephone Network and thus allowing him to enjoy the same privileges as city-based subscribers. Developments in cellular radio technology in particular promise the means of implementation of true 'wireless' communications, hence improving the flexibility of the network to accommodate changes in society's requirements."
We think you would agree that the same sentiment exists today some 33 years later! and that AAA our disruptive innovative breakthrough solution will open up most of the 70% of Australia not currently covered to assist the realisation of the huge potential of the country and nation.

References

The Australia Government Regional Telecommunications Review 2015

[2] Desert Knowledge Australia's "Fixing the hole in Australia's Heartland: How Government needs to work in remote Australia" 2012

[3] Broadband for the Bush Alliance Papers

[4] Aerial platforms study - CORDIS

[5] The US Homeland Security System Assessment and Validation for Emergency Responders (SAVER) report on Tethered Aerostat Systems

[6] Wikipedia on Tethered Aerostats

[7] European Union funded project FP7 ABSOLUTE tethered aerostat solution documentation for 4G LTE emergency services:

1. Architectural overview
2. Technical Background
3. Newsletters
4. Whitepaper
5. Australian contributions by RMIT and ACMA: Capacity_Evaluation_of_Aerial_LTE_Base-Stations_for_Public_Safety_Communications

[8] Jul 28, 2015 -Global Aerostat Systems Market Analysis 2015 - Size, Share ...

[9] Standard Temperature and Pressure (STP)

[10] Radio Line of Sight Calculator

[11] Mobile Tower Resources

1. Cell Site Tower
2. Typical mobile site
3. Lattice or tall monopole
4. Guyed Tower/Mast
5. Mobile Phone Tower Types and Information - Steel in the Air
6. List of tallest structures in the United States - Wikipedia
7. List of tallest structures in the United States by height
8. List of catastrophic collapses of broadcast masts and towers

[12] Geoscience Australia Elevation Map

[13] Macro Cells

[14] Allsopp Helikite - Attempting to launch Helikite in 45 mph ground level winds ...

[15] Dyneema

[16] Telstra Coverage Map

[17] Australian islands

[18] Australia's External Territories

[19] Australian Government Bureau of Meteorology

[20] Telstra Annual Report 2014

[21] Remote Australia Visitor Numbers NINTI One CRC for Remote Australia Economic Participation

[22] ACMA regional 1800 MHz auction

[23] Mobile Handover

[24] The United States Part 101 - eCFR — Code of Federal Regulations covering aerostats

[25] US Air Force tethered aerostat radar-system sites

[26] Radio Quiet Zone

[27] Radio Frequency National Site Archive RFNSA

[28] BOC Australia Limited (Industrial Gases) Darwin Helium plant. Also BOC Helium Sales.

[29] Price of HELIUM - USGS Mineral Resources Program

[30] Helium production and resources HELIUM - USGS Mineral Resources Program

[31] Aeros FAA Certification and Compliance Services

[32] Lindstrand Technologies Aerostat Support Manuals:

(a) Flight Manual (b) Winch Manual (c) Maintenance Manual (d) Training Manual

[33] Backhaul Technologies: Free space optics (FSO), Li-Fi (Light Fidelity) and point-to-point microwave radio relay

[34] SKYFIBER Mobile Backhaul Whitepaper

[35] Ngara: Next gen wireless - CSIRO

[36] CSIRO Develops 10 Gbps Microwave Backhaul

[37] AIR 32 launched to boost mobile broadband coverage and capacity

[38] Syntonics White Paper on "High Antennas for Radio Communications" (HARC)

[39] Syntonics' HTA-Aerostat tactical aerostat antennas

[40] Google's balloon-based wireless networks may not be a crazy idea

[41] Images for tropical area Australia

[42] Google Loons: Bringing the Internet within reach of 100 million Indonesians

[43] NBN's first satellite, Sky Muster, launches successfully into orbit

[44] Better telecommunications services for all Australians - Rethinking the Universal Service Obligation by Professor Reg Coutts with the support of Vodafone for [1] and TelSoc journal.

[45] Australia Fibre Optic Backhaul Maps

[46] Nextgen wins $250m NBN backhaul project

[47] An additional perspective to the economic problem that prevails in the areas of very low population density by Robin Eckermann

[48] ACMA Allocation of apparatus licences for public telecommunications services in the 1800 MHz band for remote Australia Applicant information paper 30 November 2015

[49] BoM: Australian tropical cyclone season outlook

[50] BoM: Climatology of Tropical Cyclones

[51] BoM: Understanding Wind Categories

[52] Building Code of Australia Requirements of High Wind Areas

[53] Sydney Tornado Supercell storm strikes Sydney's east including tornado 16/12/2015

[54] Wind Power Energy – Average Wind Speed

[55] What is the average wind speed at different altitudes?

[56] O3bCell – Revolution in Mobile Backhaul

[57] Qualcomm LTE Unlicensed (LTE-U) Extending LTE Advanced to unlicensed spectrum

[58] Ericsson and Qualcomm complete LTE-U over-the-air demonstration in China 24.9.2015

[59] List of WLAN Channels

[60] IEEE 802.11ac

[61] Balloons soar in the stratosphere - CASA approval of Google Loon flights over Australia

[62] CASA Airworthiness Directives for Procedures Manual

[63] BA.020 Aérophile 5500 - EASA - Type Certificate Data Sheet

[64] The Future of Communications by Maurie Dobbin 1983 on NT Development