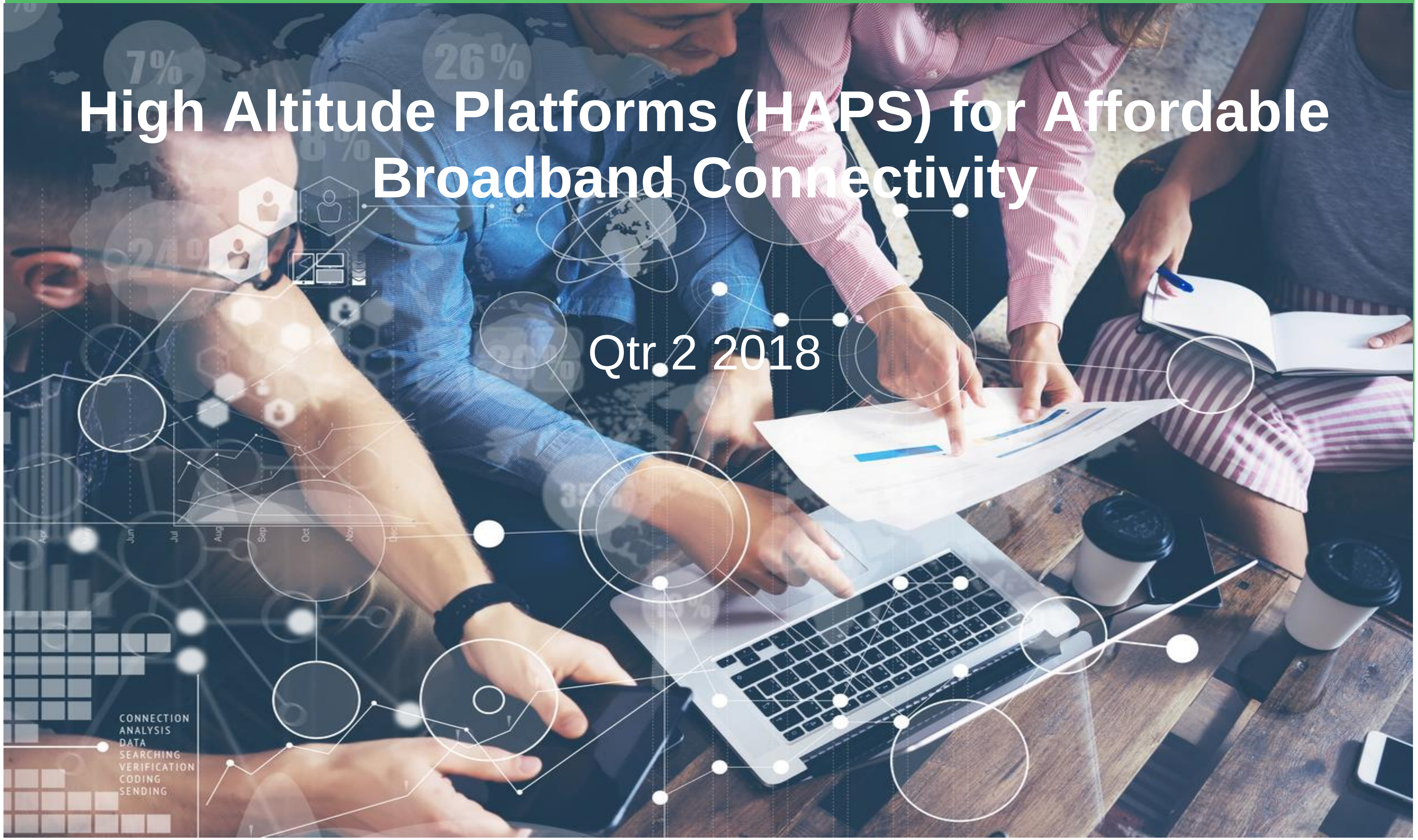
High Altitude Platforms (HAPS) for Affordable Broadband Connectivity

Qtr 2 2018



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1 Summary

About *Cenerva Ltd (UK)*

Cenerva is a specialist communications consultancy. We help our clients address the challenges of the digital society.

- We provide world class support through our regulatory advisory service
- We deliver bespoke project-based consultancy, which combines local focus with global insights.
- We offer capacity building through our regulatory training service.

i. **HAPS backhaul is a clear strategic need, particularly for sparsely populated and remote areas worldwide**: High Altitude Platforms (HAPS) would enable affordable broadband connectivity to unserved and underserved communities via solar aircraft – by providing communications backhaul. It is nimble for disaster relief situations as well as for backup "link failure recovery" to other technologies. It would be key to the mix of communications solutions underpinning the SDGs[1].

ii. **HAPS are happening and becoming reality:** Granted that HAPS has promised much in the past and *arguably* not 'delivered' – but Cenerva is *confident* about the new versions of HAPS. This is because recent innovations in battery technology, material sciences, solar power and avionics, along with an evolving HAPS/Aquila ecosystem (including companies like AeroVironment, Airbus, AltaDevices, Boeing, Chinese HAPS Companies, the European Space Agency (ESA), Facebook, Google, Lockheed Martin, Thales Alenia Space, etc.) would make HAPS a reality. **Indeed, HAPS exist and are flying today**.

iii. **HAPS and low-cost satellites are incredibly key to the other '4 Billion' and to meeting the SDGs, SDGs that are particularly acute to meet in the United Nations-designated Least Developed Countries (LDCs)**: it is self-evident that the promises of HAPS are both (i) realistically achievable in the medium term and (ii) most incredibly relevant to sparsely populated and remote connectivity areas in particular - and contributing to reducing the 4 billion unconnected worldwide in general. New more *Affordable satellite solutions* are similarly very relevant to connecting the billions unconnected.

[1] Wikipedia defines Sustainable Development Goals (SDGs) as a "collection of 17 global goals set by the United Nations … total number of targets is 169. SDGs cover a broad range of social and economic developmental issues. They include poverty, hunger, health, education, climate change, etc.".

iv. **More spectrum is needed for HAPS**: it is clear from all the analyses of existing HAPS spectrum allocations that they are *neither* sufficient nor optimal (geographical restrictions and bandwidth) to backhaul multi-gigabit broadband applications – indeed, this is why WRC 2015 agreed to study additional bands including 21.4-22 GHz, 24.25-27.5 GHz and 38-39.5GHz.

v. **Feasibility of HAPS Coexistence with other services is growing:** Cenerva is also confident of the *revised* sharing studies with other incumbent services – which utilise HAPS–Agnostic[2] **PFD/EIRP limits and masks** for the incumbent services. That is, the revised sharing approach emphasis is purely down to PFD/EIRP limits at the incumbent receiver taking into consideration its characteristics. This revised approach is increasingly 'demonstrating'[3] – with more confidence – the co-existence of HAPS services with Fixed Services (FS), Fixed Satellite Services (FSS) as well as 5G and Scientific Services. ALL these communities are increasingly comfortable with this revised approach to the sharing studies – see Section 10 (Appendix I) for details. Furthermore, HAPS proponents are *cautiously* making further proposals to even further minimise risks of interference into these incumbent services, e.g. only transmitting in one direction rather than both as currently assumed in some HAPS frequency scenarios.

vi. **HAPS Pilots/Test Flights**: There have already been several technical trials and test flights. Cenerva welcomes the further new HAPS *technical* pilot that has been commenced and is ongoing in Australia by Airbus and Facebook[4].

vii. **Recommendations**: Cenerva encourages Administrations (particularly those in Developing Market Countries) to (i) enthusiastically follow and engage this 1.14 HAPS agenda item towards their backhaul and disaster needs, particularly before CPM text freeze in August 2018 and beyond (ii) vocally (and in writing) support it at WP 5C with contributions, perhaps multi-country support (iii) and engage/support the CPM process. This principally include the ITU and spectrum regulators across the world, but also all the national administrations who are struggling to meet their Sustainable Development Goals (SDGs).

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[2] A Power Flux Density (PFD) limit approach is agnostic to the HAPS design, and mainly emphasises interference into (potentially) interfered service's receiver.

[3] Admittedly the studies are still desk-based, but there in increasing consensus on the methodology and results from the key 'to be interfered' stakeholders.

[4] https://code.facebook.com/posts/2265698886989780/facebook-and-airbus-working-together-to-advance-high-altitude-connectivity/ (accessed April 2018)

One nirvana for the connecting the other 4 Billion would be the deployment of thousands of HAPS platforms and other space-based solutions in unserved and underserved areas in Africa, ASEAN, etc.

Cenerva Ltd strongly believes the new HAPS is the most concerted and likely-to-succeed HAPS efforts ever. Spectrum regulators, and administrations are recommended to engage and support, particular those in Developing Markets.

HAPS and other space-based and Upper-Atmosphere solutions in development have the following intrinsic "advantages"[5]: wide area coverage, geography agnostic, instant infrastructure, ease of deployment, reliability, they are environmentally green, and they could be deployed and supported for the long term. It is however true that several of these "advantages" are still being proven via more HAPS trials and test flights. The areas of HAPS potential application cover many of the SDG areas including education, health, banking, agriculture, maritime, environmental, disaster response, oil/gas exploration and Government

Furthermore, Cenerva strongly **recommends and encourages HAPS proponents to work closely with other *Affordable Satellite* Services proponents**. Fixed Satellite Services (FSS) proponents are indeed looking at HAPS to incorporate into their networks. Indeed, as the Forward in Broadband Commission report from the Working Group on Technologies in Space and the Upper-Atmosphere[6] note:

> *"… as countries develop and revisit their broadband plans, they should consider the profound ways in which satellite and high altitude technologies can help them reach their goals".*

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[5] Working Group on Technologies in Space and the Upper-Atmosphere: Identifying the potential of new communications technologies for sustainable development, September 2017, http://www.broadbandcommission.org/Documents/publications/WG-Technologies-in-Space-Report2017.pdf (last assessed 5 May 2018)

[6] *Ibid.*

HAPS is ultimately about facilitating access to broadband applications delivered by high-altitude platform stations to remote and rural areas

2. Introduction: WRC AI 1.14, HAPS context and deployment scenario

2.1 Purpose of white paper and intended audience

The purpose of this white paper is to provide a gentle introduction to High Altitude PlatformS (HAPS) – an emerging way to providing communication services to rural and remote areas of the world which is home to a significant percentage of the 'other 4 Billion' broadband-unconnected. This is why the previous page notes that one possible nirvana for the 4 Billion unconnected would be the deployment of thousands of HAPS platforms and other space-based solutions in unserved and underserved areas of Africa, ASEAN, Middle East, Latin America, China and elsewhere.

The paper is written from a spectrum and technology perspective as it is principally aimed at spectrum regulators, national country administrations and spectrum policy professionals. It is also deliberately written in a way that hopefully demystifies some of the "fog" about the debates happening about the HAPS at the ITU and in various regional ITU study groups around the world. The reader could read the "headlines" on every page of this white paper, and "delve deeper" into the pages as needed to understand the key messages of this paper.

Spectrum regulators and those representing their national administrations at the ITU on spectrum issues – particular those in developing markets - are the key audience of this paper. Similarly, their counterparts in developed markets would hopefully understand better too why innovations like HAPS are quite important for developing markets' spectrum policy.

HAPS have been studied by the ITU since the 1990s. They include manned/unmanned aircrafts in the stratosphere for months or longer

2.2 What are HAPS

The ITU defines HAPS in the Radio Regulations “as a station located on an object at an altitude of 20-50 km and at a specified, nominal, fixed point relative to the Earth, and is subject to No. 4.23”[7]. Article 4.23 of the Radio Regulations states that “transmissions to or from high altitude platform stations shall be limited to bands specifically identified in Article 5. (WRC-12)”. High altitude platform (HAPS) solar aircraft are frankly not new, and they have been pioneered for decades – previous attempts were arguably ahead of their time. Spectrum for HAPS was first identified in the 1990s, but the state-of-the-art of the technologies at the time was dominated by poor aeronautics and even poorer communication technologies that we have today.

The WRC-19 Agenda item 1.14 specifically aims “to consider, on the basis of ITU R studies in accordance with Resolution 160 (WRC-15), appropriate regulatory actions for high altitude platform stations (HAPS), within fixed-service allocations”[8]. Resolution 160 (WRC-15) itself speaks of “Facilitating access to broadband applications delivered by high-altitude platform stations”[9].

Two types of HAPS are emerging:

- Heavier -Than-Air (HTA) HAPS which consists of a solar-electric powered autonomous aircraft
- Lighter-Than-Air (LTA) HAPS which consists in an autonomous Airship using buoyancy to provide lift and solar-electric power to maintain its position against stratospheric winds.

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[7] ibid

[8] https://www.itu.int/en/ITU-R/study-groups/rcpm/Pages/wrc-19-studies.aspx

[9] https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000C0015PDFE.pdf

HAPS are happening and becoming reality this time round due to significant advances in its underlying technologies – HAPS would be indispensable to LDCs and in future disasters like Hurricane Irma

Today, unlike in the 1990s, HAPS are truly happening and becoming reality as advancements primarily in battery technology[10] (lithium batteries), high efficiency solar panels, lightweight materials, autonomous aircraft avionics and microwave payloads have combined to make HAPS solar aircrafts being able to provide a communications backhaul service realisable in the medium term. The concept is one of an unpiloted High-Altitude, Long Endurance (HALE) platform which relays telecommunications from Gateway stations and user terminals on the ground. HAPS solar aircrafts are not quite HALE-yet, but have already demonstrated continuous flights over multiple days, which are being extended to several weeks and months, if not up to a year. This is core to ongoing tests.

HAPS solar-powered aircrafts will provide efficient, affordable and available communications coverage for areas where connecting terrestrial infrastructure is economically not viable or where infrastructure is just hard to deploy (and quickly) like in disaster zones. Hurricanes Irma/Maria in the Caribbean[11] in 2017 are classic scenarios for the quick deployment of a HAPS solar aircrafts. Satellites are not that easily deployable in such disaster zones – there is nothing like a "gradual deployment" of satellite. HAPS deployments would be rapid and flexible (they are not constrained by geography) and their payloads would be reconfigurable to suit.

UN-designated Least Developed Countries (LDCs) with challenging geographies and low population densities are key HAPS markets.

[10] HAPS aircrafts possess rechargeable power systems using solar power to fly during the day and high capacity Lithium LI-ion batteries for use at night

[11] https://www.gsma.com/mobilefordevelopment/programme/mobile-for-humanitarian-innovation/the-2017-atlantic-hurricane-season-mobile-industry-impact-and-response-in-the-caribbean/

The ITU Connect 2020 Agenda acknowledges that a significant fraction of the 'other 4 Billion' unconnected live in remote and rural areas where the cost structure of current technologies do not extend – innovations like HAPS to redress this must be supported by these very Developing Economies as their broadband costs are prohibitively high

As the Broadband Commission report[12] cited earlier notes:

> *"the majority of countries that are underserved by conventional broadband technologies share certain characteristics. They tend to have challenging geographies, sparse population distribution, large rural populations (who make up 70% of the people without access to broadband), and are less economically developed and therefore less able to afford broadband investment. Space-based technologies and those in upper atmosphere… can provide broadband to the rural user at the same cost as an urban user. This cost structure has allowed technologies in space and the upper atmosphere to extend to hard-to-reach areas, supplementing terrestrial providers of broadband for whom this cost structure is not viable" (p.13)*

The Broadband Commission Report also highlights the case for HAPS and other space-based/upper-atmospheric innovations for countries dominated by mountains, landlocked countries or Small Island Developing States (SIDS). The latter are frequently isolated from global fibre-optic backbones. So the report continues to note whilst broadband connections costs on average 1.5% of monthly income in Europe, the average for developing economies is over 100%. HAPS promise much cheaper costs structures.

The report further reports on an estimated 30% of the population of sub-Saharan Africa beyond the reach of a backbone network, 20% in the Middle East and 40% in Asia Pacific, i.e. these populations are out of reach of physical backhaul links like fibre. **Therefore, the cases of the 100% monthly income costs for broadband in developing economies along with such percentages beyond the reach of backhaul networks should be key incentives for LDCs to support such innovations**.

[12] Working Group on Technologies in Space and the Upper-Atmosphere: Identifying the potential of new communications technologies for sustainable development, September 2017, http://www.broadbandcommission.org/Documents/publications/WG-Technologies-in-Space-Report2017.pdf (last assessed 5 May 2018)

HAPS is both complementary and supplementary to satellites and terrestrial 4G and future 5G networks, and its deployment scenarios are much simpler and nimbler

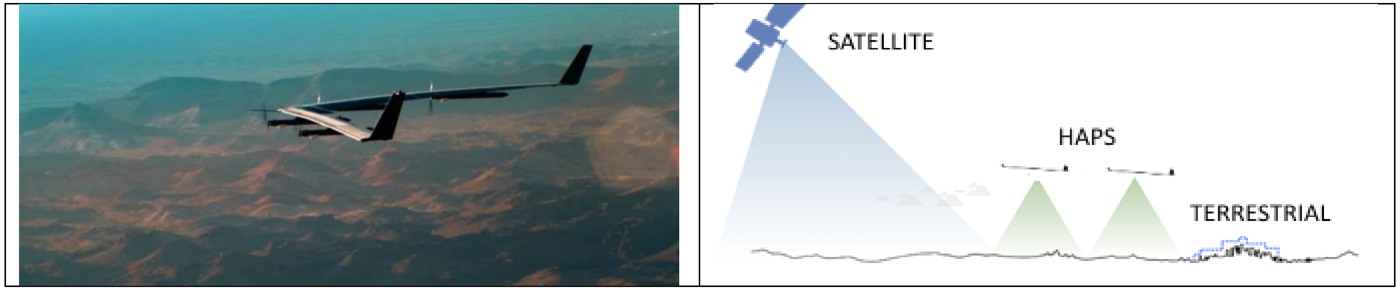

Figure 1- An Aquila HAPS Platform in Flight & the Complementarity of HAPS to both Satellite and Terrestrial

Therefore, the real benefit of HAPS Solar aircrafts is that it adds to the solutions options for backhauling in rural and remote areas, since the ITU Connect 2020 Agenda[13] acknowledges that a significant proportion of the 4 Billion people unconnected are disproportionately in such remote or rural areas. These areas need all the communication services enjoyed by those in the urban areas, along with humanitarian support as with hurricanes, blue-light public safety services (fire-fighting, ambulance, police law enforcement) as well as backhauling affordable 2G, 3G, 4G or Wi-Fi services. HAPS would also cover the seas and would be clearly lower OPEX and CAPEX because there is very limited ground infrastructure beyond the gateways and the user terminals.

HAPS – as Figure 1 depicts – also truly complements both satellite and terrestrial by filling the gap: whilst dense urban areas are best covered by terrestrial networks (as they require high quality connectivity), satellite (LEOs, GEOs, etc.) best cover low density of population areas with little or no connectivity. HAPS Solar aircrafts complements these two by best covering medium density areas as shown on the right picture of Figure 1.

[13] https://www.itu.int/en/connect2020/Pages/default.aspx (last assessed 5 May 2018)

Broadband backhaul connectivity is the Number 1 use case for HAPS, and the many emerging HAPS deployment scenarios reflect this use case

As noted earlier, HAPS not only complements, but can supplement satellite by helping to further integrate with ground-based terrestrial infrastructure, not only for traditional telecommunications. So HAPS can supplement multicasting and/or broadcasting, supplement navigation in the seas and even supplement earth observation works.

2.3 Classic HAPS Deployment Scenario Attributes

The following are the current expected key attributes and deployment scenario for HAPS:

- Key deployment Scenario Use-case: to provide backhaul solutions in order to enable high-speed broadband to underserved and remote areas.
- Altitude: the expected altitude would be 20 km to 25 km, so well above commercial airspace and the weather – and more significantly above the weather. However and clearly, HAPS aircrafts would need to be coordinated with commercial aircrafts – hence why the International Civil Aviation Authority (ICAO) and civil aviation authorities worldwide need to be involved. At this altitude, signal delay to the ground is very tiny compared to those from satellites.
- Station keep and Time: the aircraft would also circle in approximately 3-5 km radius to station keep of the nominal nadir platform point, and can be station-keeping for 3 to 12 months.
- Footprint – at 20 km altitude - a HAPS platform would cover a radius of 50 km or up to 100 km diameter. The HAPS platform would communicate with a set of fixed terminals or Customer Premise Equipment on the ground within the coverage area.

The broadband connectivity use case promises more than 200,000 user terminals feasible within a 50 km radius HAPS platform area, with each user throughput circa 2.5Mbps. HAPS would be fit-for-purpose for most remote and rural contexts

- Service Life – the service life is expected to be approximately 10 years for each platform.
- Overall/End User Throughput & Availability Assumptions – assuming 50 km radius coverage above with 33 users per km^2 suggest 235,500 user terminals within the coverage area. End user throughput is expected to be circa 2.5 Mbps and a data volume per month of circa 30 GB per user. However, geospatial simulations suggest that 90% of demand would be met by HAPS providing a throughput of 30 GBps.
- Non-Conventional HAPS Deployment – conventional HAPS deployments would involve one gateway and user terminals in line-of-sight of the HAPS platform. However, where gateways are difficult to deploy because of no ground infrastructure, interconnected HAPS can be *cascade-fed* by one gateway. This bridging configuration can be used to extend coverage with less terrestrial infrastructure and less up/down links. However, inter-HAPS links would increase the need for higher payloads and may need additional spectrum, more weight and more power than a classic one-HAPS-to-one-Gateway configuration.

2.4 Focus of the Rest of the Paper

With the above description of HAPS and expected deployment scenarios covered, we return to the key goals of this report. This report focuses on spectrum needs/requirements for HAPS. Specifically on

- What spectrums does HAPS aircrafts need to provide fit for purpose communications services?
- The challenges with the current spectrum allocations to HAPS.

HAPS Agenda Item 1.14 needs the attention of spectrum regulators and national administrations. There are many issues they need to understand.

- What is the ideal spectrum needs for HAPS Services?
- What are the new bands being studied for HAPS and what are the current emerging results from the studies?
- What should spectrum regulators and administrations do with this Agenda Item 1.14, particularly those from countries with large remote and rural populations?
- What HAPS sharing and coexistence studies are ongoing and how are the results being used by HAPS proponents?
- What pilots and tests have taken place already and are ongoing?
- What about the security of HAPS?
- Why HAPS Proponents should ‘partner’ with affordable satellite proponents.
- What should developing and emerging countries do towards supporting HAPS?
- Etc.

It is important for spectrum regulators, administrations and other spectrum policy professionals to understand these, and support efforts towards maximising the benefits of communications from HAPS solar aircrafts.

3. HAPS Spectrum Requirements and Challenges

3.1 What Spectrums do HAPS Aircrafts Need

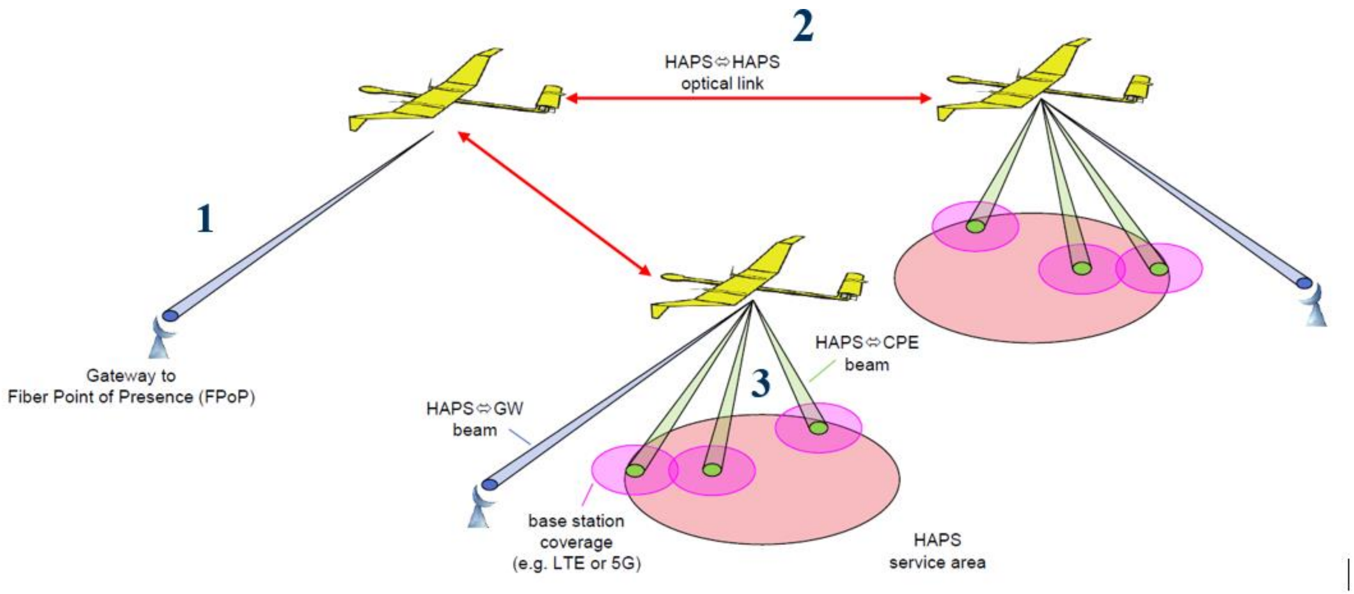

Figure 2 – Proposed System Architecture for HAPS Agenda Item 1.14 - Backhauling (Source: Airbus[14])

[14] https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjOiKHBt9XaAhVkCMAKHTDeBxAQFggpMAA&url=https%3A%2F%2Fcept.org%2FDocuments%2Fcpg-pt-a%2F38618%2Fpta-17-info05_haps-presentation_ai_1-14_airbus_201710&usg=AOvVaw31yrAM9MfYYXuyU4nw6DGz (last accessed 25 April 2018)

HAPS needs bidirectional spectrum for Ground Gateway to HAPs Aircraft, and ditto from the Aircraft to the remote or rural ground Service Areas

Figure 2 depicts the proposed *backhauling* system architecture for HAPS Agenda Item 1.14. Figure 2 notes three core spectrum needs:

1. Spectrum for Gateway Feeder Link (line of Sight) a feeder link, and according to Article 1.15 of the ITU Radio Regulations is defined as "a radio link from an earth station or vice versa conveying information for a space radiocommunication service other than for the fixed satellite service"[15] Simply, it is the line of sight communication link between a satellite and the Gateway Earth Station. All satellite services too require spectrum channels for such feeder links between the satellite and ground stations – similarly a HAPS aircraft (or "mother" aircraft in case of cascading) needs spectrum to connect to the gateway earth station.

2. HAPS to HAPS Optical Links: such Optical Inter-Platform Links (OIPLs) do not use relevant radio spectrum that the ITU oversees, as this works well above the weather and the clouds. Free space optics (FSO) uses light propagating in free space (i.e. outer space, vacuum, etc.) to wirelessly transmit data between HAPS aircrafts, and can be implemented using lasers.

3. Spectrum from HAPS to Service Areas (see "3" in Figure 2): this service area generates the need for backhaul. For example, as Figure 2 depicts, a 2G, 3G, 4G, Wi-Fi deployment or even 5G remote base station would need to be backhauled (back into the Internet via the HAPS platform down to the Gateway Station). Such backhauling in this context would be facilitated by a HAPS Customer Premise Equipment (CPEs) or User Terminal. It was noted earlier that there would be more than 200,000 such terminals feasible to backhaul many "users" broadband needs.

In essence, ignoring Free Space Optical (FSO) links, HAPS principally needs spectrum for the following needs (i) Ground Gateway to HAPS platform bidirectional spectrum and (ii) HAPS Platform to Ground HAPS Service Areas spectrum.

[15] ITU Radio Regulations, Section IV, Radio Stations and Systems – Article 1.115.

Current existing HAPS bands in 6Ghz, 28/31GHz and 47/48GHz suffer from limited capacity, geographical restrictions and rain fade issues (in the only global band)

3.2 What is the current spectrums allocation to HAPS – and challenge

Figure 3 shows the picture of existing HAPS bands across the world.

Frequency band	Use	Direction	Bandwidth	Identification
6440-6520 MHz	GW	↓	80 MHz	5 Admins (R1, R3)
6560-6640 MHz	GW	↑	80 MHz	5 Admins (R1, R3)
27.9-28.2 GHz	GW, CPE	↓	300 MHz	23 Admins (R1, R3)
31-31.3 GHz	GW, CPE	↑	300 MHz	23 Admins (R1, R3)
47.2-47.5 GHz	GW, CPE	↑↓	300 MHz	Worldwide
47.9-48.2 GHz	GW, CPE	↑↓	300 MHz	Worldwide
GW Gateway CPE fixed terminal Customer Premises Equipment				

Figure 3 – Current Existing HAPS Bands (pre-WRC 2012)

Limited bandwidths (all less than 300MHz) are hardly sufficient for multi-Gigabit backhaul needs. The 6 GHz band only has 5 allocations by 5 administrations worldwide (4 in Africa and one in Latin America) whilst 28/31GHz only has the support of 23 administrations. The global allocation in 47/48GHz is not only limited at 300MHz, but suffers badly from significant rain fade and costly deployments (due to the high frequencies). **All in all, this amounts to virtually nothing for multi-Gigabit backhauling.**

Realistic studies endorsed by the ITU suggest that HAPS Broadband would require in the order of 4GHz of spectrum, not the *max* 680MHz existing

3.3 What is the minimum spectrum requirements for Broadband HAPS

Figure 4 shows a table along with some realistic assumptions and the inferred spectrum needs required for 30GHz GW-HAPS.

		Forward		Return		
		GW =>HAPS	HAPS => CPE	CPE=>HAPS	HAPS => GW	
Capacity	Gbps	30	30	3.75	3.75	a
Spectral efficiency	bps/Hz	5.5	4	4	5.5	b
Overall required bandwidth	MHz	5,454	7,500	937.5	681	$c = \frac{a \times 1e3}{b}$
Nb of beams		1	4	4	1	d
LHCP and RHCP polarisation factor		2	2	2	2	e
Reuse factor		1	1	1	1	f
Spectrum needs taking into account the polarisation and reuse factors	MHz	2,727	938	117	341	$g = \frac{c \times f}{d \times e}$

Figure 4 – Minimum Spectrum Requirements for HAPS

Figure 4 has some very clear and realistic assumptions on Bits per hertz, number of HAPS beams, reuse factor and LHCP/RHCP[16] assumptions. The assumptions clearly suggest 2727 + 938 + 117 + 341, which suggests the 4GHz needed. 2727 GHz from GW-HAPS is realistic. Note that 5G proponents are now proposing 1GHz per mobile operator! A 30Gbps HAPS platform would be "typical".

[16] LHCP and RHCP stand for Left/Right-Hand Circular Polarization respectively. RHCP is designed rid an LHCP multipath signal and vice versa. Polarization purity helps maximize throughput.

It is therefore right that WRC 2015 agreed to study additional bands including 21/22 GHz, 24/27 GHz and 38/39GHz – though sharing studies need to be carried out. However, there are still geographical restrictions with the new candidate bands.

3.4 What new candidate bands are being studied – and would it be enough

Figure 5 shows the new bands agreed at WRC 2015 for detailed sharing studies for HAPS (see Section 10 [Appendix I] for details)

Frequency band	Use	Direction	Bandwidth	Identification	Sharing With?
21.4-22 GHz	GW, CPE	↑↓	600 MHz	R2	BSS
24.25-27.5 GHz	GW, CPE	↑↓	3250 MHz	R2	FS, Space, ESSS (passive), Radio Astronomy, IMT2020
38-39.5 GHz	GW, CPE	↑↓	1500 MHz	Worldwide	FSS, FS, BWA
GW Gateway CPE fixed terminal Customer Premises Equipment					

Figure 5 – Candidate Bands for HAPS agreed at WRC 2015

Figure 5 shows that even if the sharing studies are all successful, there still will clearly *not* be enough in some regions (Regions 1 and 3) since 21.4-22 GHz and 24.25-27.5 GHz are only identified in Region 2. Hence, WP 5C has developed a Preliminary New Draft Proposal (PNDR) indicating an approximate 4 GHz spectrum needs for broadband HAPS alone. The sharing studies on the new Candidate Bands are ongoing as can be seen in Figure 5, as also ongoing sharing studies too on the Existing Bands of Figure 3.

4. Emerging Results from Ongoing HAPS Studies

1.1 – WP 5C developed a view that 4 GHz spectrum 'is needed' for broadband HAPS

Figure 6 shows arguably the most important "result" so far from studies ongoing – that WP 5C developed a Preliminary New Draft Proposal (PDNR) indicating an approximate 4 GHz spectrum is needed for broadband HAPS. This is a significant new view on HAPS.

Figure 6 – PDNR indicating approximately 4GHz of Spectrum is needed for Broadband HAPS

Forward		Return	
GW => HAPS	HAPS => CPE	CPE => HAPS	HAPS => GW
2 727 MHz	938 MHz	117 MHz	341 MHz

4.2 – Many peer-reviewed HAPS sharing contributions

At the November 2017 Working Party 5C meeting in Geneva, there was – for the first time – some 900 pages of sharing studies - HAPS is one of the most studies areas of this WRC cycle. Contributions were received from several countries including Australia, Canada, France, Germany, Korea, Mali, Mexico, Senegal, UAE, USA, etc.

4.3 – HAPS characteristics were defined along with Draft CPM Text

In Geneva too in November 2017, consensus on HAPS characteristics also begun emerging. This is important as different HAPS proponents were developing with different HAPS characteristic assumptions: e.g. number of gateways, urban vs. rural, power limits, gains, etc. All such parameters need to be standardised and harmonised as much as possible across HAPS developers.

A WRC Draft Conference Preparatory Meeting (CPM) text was also developed. This text would undergo continuous drafting as the studies are ongoing until there would be a CPM freeze in August 2018. The sharing studies (Section 10 [Appendix I]) will continue even after the CPM Text freeze.

A better PFD/EIRP Limits and Masks study approach which is non-system specific and aimed at protecting the incumbent service has been adopted for HAPS sharing studies

4.4 – Critique of the November 2017 HAPS sharing studies

In Geneva too in November 2017, though there were 900 pages of compiled sharing studies, there was a concern that much of the 900 pages reported on *system-specific* sharing studies. This means that the methodology allowed for every HAPS proponent to have their own systems with their own HAPS characteristics: different number of gateways, different power limits, different gains, different HAPS elevations, different clutter assumptions for urban, sub-urban and rural, etc. Clearly, this is sub-optimal. Therefore, HAPS characteristics needed to be harmonised – and then a more system agnostic approach adopted for sharing studies.

4.5 – Power Flux Density (PFD) & EIRP limits & masks non system-specific approach is well used in ITU Radio Regulations

Since WP 5C in Geneva (November 2017), a more non-system specific approach has been adopted based on Power Flux Density (PFD)/EIRP limits at the receiver of the incumbent service. The new approach has its basis in assuring that the aggregate 'interfering' power at the incumbent receiver does not exceed a given threshold – and they are very specific, e.g. "-100 dBW/m^2/MHz for any 1 MHz for angles of arrival between 20 and 90 degrees (elevation) above horizontal plane". These underpin the PFD mask calculations.

Consider scenarios of HAPS Platform (20 km up) transmitting into (i) an FSS[17] satellite ground downlink receiver or (ii) an EESS[18] passive sensor. With this approach, many simulations of likely configurations, power limits, gain, angles of arrival into receivers, heights of receivers, etc. are repeated until the worst case characteristic limits are obtained. The worst case receiver gain and receiver elevation - ensure the PFD/EIRP receiver limits for either the FSS ground downlink or the EESS passive sensor is not exceeded.

[17] Fixed Satellite Service (FSS)
[18] Earth Exploration Satellite Service (EESS)

PFD/EIRP Limits & mask Limit approach is agnostic to HAPS design and is leading to cautious proposals on HAPS sharing, e.g. some erstwhile bidirectional links would now only be unidirectional in order to "guarantee" protection of incumbent services

4.6 – Benefits of the PFD/EIRP Limits with masks non-system specific study approach

As noted earlier (as in the example of the FSS downlink receiver or the EESS Passive receiver), this PFD/EIRP Limits and masks approach emphasises power received by the incumbent service receiver. It also has the following benefits which should increase the confidence level of regulators and administrations:

- This approach is HAPS system agnostic – so if HAPS systems are configured differently, it is immaterial as one is only concerned as to what energy arrives at the incumbent receiver
- The PFD/EIRP limits approach is quite common practice in Radio Regulations at the ITU – a well peer-reviewed approach.
- The PFD/EIRP limits approach provides flexibility to national administrations in managing access to spectrum
- The PFD/EIRP limits approach with masks is derived directly from the designed protection criteria and parameters of the receiver, taking into consideration their characteristics such as height of receiver, elevation angle and more

4.7 – So what types of PFD/EIRP studies are ongoing which regulators must understand

They include:

1 EIRP power limits for receivers, e.g. for the HAPS into FSS downlink receiver
2 PFD masks, e.g. for HAPS downlink into FS (fixed satellite station like a VSAT), MS (mobile station) and FSS receivers
3 Statistical analyses, e.g. for a HAPS Ground station terminal into FS, MS or FSS downlink transmissions. This is clearly about the minimum separation distances between HAPS and other incumbent ground stations, e.g. the separation distance between a HAPS gateway station and an IMT-2020 (5G) station, or between HAPS Gateway and a Fixed Earth Station.

Mitigations methods to enable coexistence include separation distances between ground services, automatic transmit power control and shielding

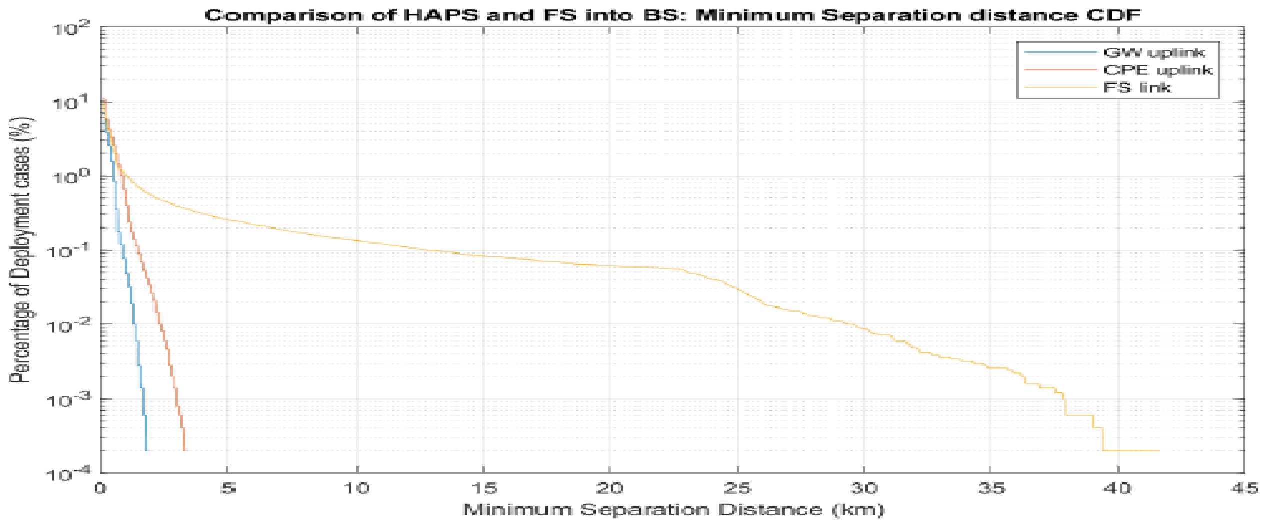

Figure 7 – Minimum separation distance (km): comparison of HAPS and FS into IMT-2020 Base-station (Source: Access Partnership Ltd)

Figure 7's statistical analysis show the sort of results obtained, e.g. in this case showing that the separation distance between FS Gateway terminal and MS terminal (base stations) is much greater compared to the separation between a HAPS ground terminal and an MS terminal (station). **This is an important result because since HAPS is identified in the Fixed Service (FS) allocation, this means the HAPS ground terminal is an FS station. Therefore there may be no need for specific HAPS regulatory provisions in the Radio Regulations because any potential interference from a HAPS FS into MS stations could be managed by administrations and regulators in the same way FS and MS stations are managed today.**

Conservative Changes are being proposed by HAPS proponents to protect incumbents from HAPS. These proposals would underpin modifications of existing footnotes and associated resolutions in ITU Radio Regulations

4.8 – Some proposed HAPS directional changes resulting from PFD/EIRP limits and Masks studies

Frequency band	Use	Direction	Identification	New Proposed Direction
21.4-22 GHz	GW, CPE	↑↓	R2	↓ HAPS => GW HAPS => CPE
24.25-27.5 GHz	GW, CPE	↑↓	R2	↑↓ (CPE<=>HAPS) ↑ (GW =>HAPS)
28/31 GHz	GW, CPE	↑↓	5 admins	↓ (HAPS => CPE) – 27.9-28.2 GHz ↓ (HAPS => GW) – 31.0 – 31.3 GHz ↓ (HAPS => CPE) – 31.0 – 31.3 GHz
38-39.5 GHz	GW, CPE	↑↓	Global	↑ (CPE =>HAPS) ↑ (GW =>HAPS)
47/48 GHz	GW, CPE	↑↓	Global	↑ (GW =>HAPS) – 47.2 – 47.5 GHz ↑ (GW =>HAPS) - 47.9 – 48.2 GHz

Figure 8 – Some evolving proposed changes to protect incumbents from HAPS

Figure 8 shows some proposed changes. 47/48GHz clearly has the highest rain fade attenuation and it makes sense to maximise the use of this band (it is only 300 MHz too) for gateway links from ground to HAPS platform. This is also because Automatic Transmit Power Control (ATPC) can be used at the gateway to adjust for fading conditions by possibly going to maximum power fractionally. HAPS Proponents have also modified System 6 frequency plan which outlines the links chosen within each band to be considered. The key reason for the proposed updated frequency plan as Figure 8 above and directions is to protect the incumbent services.

In light of the HAPS sharing studies on the 38 – 39 GHz band, a worldwide HAPS identification in a new footnote (ground-to-HAPS) appears proportionate

4.9 – Some more details on HAPS Feasibility Sharing Studies on the 38 – 39.5 GHz Band

Given the importance of the candidature of the 38 – 39.5 GHz band (1500 MHz of spectrum and being a proposed global identification), it arguably merits more attention on what the sharing studies to date are concluding. Under the current proposed frequency plan, as Figure 8 depicts, this band would be used for uplink from CPE or Gateways to the HAPS station. The sharing studies covered all possible interference arising from the following deployment scenarios:

- Impact of HAPS ground stations (CPE and GW) into Fixed Service
- Impact of HAPS ground stations (CPE and GW) into Mobile Service
- Impact of HAPS ground stations (CPE and GW) into Fixed Satellite Service

The emerging results are summarized below:

Interference Scenario	Emerging Conclusions from Sharing Studies
HAPS ground stations (GW & CPE) into Fixed Service (FS) – see interference "6" in Fig 9	• Results suggest that HAPS ground stations can be considered as any other FS station • Indeed that the impact of HAPS ground station emissions into FS station receivers is less than that from FS emitting station into an FS receiving station.
HAPS ground stations (GW & CPE) into Mobile Service (MS) – see eqv. of "6" in Fig 9 (but change FS station to MS station)	• Results suggest that sharing between HAPS ground stations and MS stations is feasible as maximum separation distance is less than 500 meters (see Figure 7 earlier) • This "finding" means the interference from HAPS ground stations into an FS station can be managed with no new HAPS-specific provisions in the Radio Regulations.
HAPS ground stations (GW & CPE) into FSS Earth Station Receivers see interference "5"	• Results suggest that sharing between HAPS ground stations and FSS Earth Stations receivers is feasible. Any interference from HAPS ground Stations can be managed by administrations locally or bilaterally.

Therefore, based on the above conclusions, there is arguably no need of additional regulatory provisions in the Radio Regulations for this case for HAPS co-existence with other services in the 38-39.5 GHz band.

The sharing analyses are mathematically and statistically rigorous and may be difficult to grasp by some, but visualisation may help make the studies "intuitive"

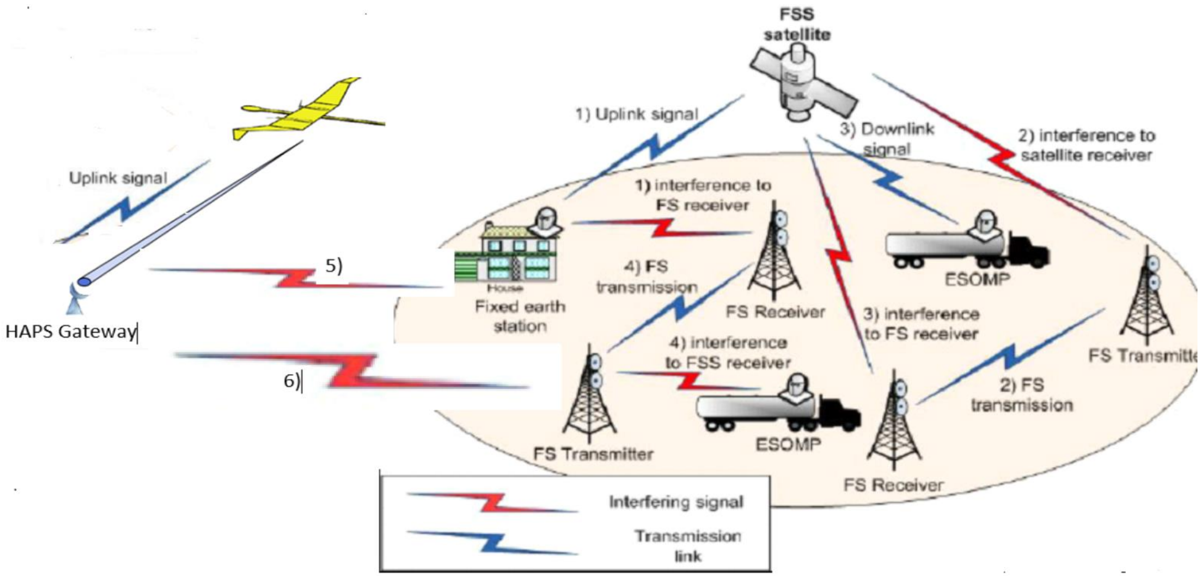

Figure 9 – Some Interference Scenarios to enhance understanding. Adapted from Source[19]

- The HAPS parameters (gateway and CPE links) used in this study are System 6 from Annex 14 of the WP 5C Chairman's Report (Document 5C/410).
- The statistical analyses followed steps to derive the minimum separation distance CDF between (i) a single HAPS ground (interferer) and (ii) HAPS Terminal stations (interferer) into various Victim stations, i.e. an FS station (victim), MS (victim) or a FSS Earth Receiver Station Receiver (victim)

[19] Source: https://www.researchgate.net/figure/Spectrum-sharing-in-Ka-band-FS-service-as-primary-and-FSS-services-as-secondary_fig3_261074284

It is reasonably clear that ideally HAPS should be allocated globally a few set of decent-size contiguous *shared* spectrum given it is a spectrum truly required for broadband HAPS and disaster scenarios for the billions unconnected. ITU-D should arguably be championing.

4.10 – Should ITU-D not be championing activities like HAPS, low-cost satellites which prioritise the unconnected Billions

Drawing from all the previous sections it is clear that the piecemeal, geographically-restricted (i.e. non-global), low bandwidth, high spectrum (e.g. 47/48 GHz with rain fade challenges and high costs) **are not ideal.**

It is just a reality that the poor and the billions unconnected do not run or significantly influence world spectrum policy – the rich countries and biggest vendors do.

Imagine if all of these billions people unconnected were in one country, the Universal Service Policy in this fictitious “country” would help to try and address this digital divide gap. However, because the real digitally unconnected and distributed across poor countries (largely) – and disproportionately in rural and remote areas in these countries – there is no “Government” to champion them. Should ITU-D not step in more proactively?

There is a strong argument for ITU-D to champion spectrum policy for the unconnected billions which would likely include services like HAPS.

HAPS exist and are flying. HAPS Platforms are being ordered from the likes of Airbus. Chinese HAPS companies are driving forward too. HAPS pilots and flight tests are ongoing and progressing, and more others are planned

5. HAPS Orders, Pilots and Flights Tests are ongoing

5.1 China is innovating HAPS to serve its rural areas

It is easy to miss this fact that HAPS platforms are being designed, ordered and delivered. For example, the Chinese Government has acknowledged that due to the recent innovations covered earlier, they believe HAPS would achieve multi-gigabit broadband capacity even when deployed to serve rural areas. So China is working and proposing several HAPS proposals.[20] The Chinese HAPS proposals are pioneered by the China Aerospace Science and Technology Corporation (CASC).

5.2 Airbus Zephyr - HAPS platforms are been designed, ordered and delivered

Airbus (a key player in the HAPS ecosystem) has designed the Airbus Zephyr platform - a solar-powered HAPS platform designed to deliver numerous broadband and commercial connectivity payloads. Indeed in February 2016, Airbus received a production order for two Zephyrs from the UK, the first contract in the world for operational HAPS platforms.

5.3 Facebook's Project Aquila

Project Aquila is the name to the Facebook HAPS project which aims to deploy platforms at altitudes of circa 20km in the stratosphere, covering a 75 to 100km diameter area whilst generating circa 10 GBps capacity.

[20] "Proposals on working document towards a preliminary draft new Report ITU-R", Submitted to ITU-R. Peoples Republic of China.

5.4 HAPS Platform Builders, Pilots and Test Flights

HAPS pilots and tests have been ongoing for some time now. Companies like Airbus – whose business it is and would be to design, build and deploy such HAPS platforms – are already building and flying operational HAPS, and they continue to test their HAPS platforms daily to improve their performance. Other companies including Thales Alenia Space (from France), Lockheed Martin (USA) and CASC (China) are or would be building their own platforms too.

Facebook has already successfully made two test flights showing steady progress of their Aquila HAPS platform.

5.5 The 2018 Airbus Facebook Test Flights in Australia

In November 2017, Airbus and Facebook announced an important further trial of HAPS broadband connectivity platform for 2018 in the Australia desert. Cenerva understands that the choice of Australia was driven by the following very wise reasons:

1. Airbus already has facilities in Australia – so Airbus principally picked Australia
2. The deserts of Australia are ideal for high altitude and long endurance tests of such HAPS platforms – the reader should note that most Australians live on their East coast, and the desert “outbacks” are extremely sparsely populated. Earlier in the paper we noted the concept of an unpiloted High-Altitude, Long Endurance (HALE) platform still needs to be proven; HAPS solar aircrafts are not quite HALE-yet. The Australian pilot is testing amongst many other things for HALE. The Australian desert thus present *minimal* risks both in terms of interference and safety to other incumbent service providers using spectrum, and also commercial aircrafts respectively.
3. Airbus and Facebook announced too that the trial would advance both spectrum and aviation policy to support HAPS;
4. … and to continue demonstrating the viability of HAPS systems for providing broadband connectivity.

The Airbus-Facebook HAPS pilot and flight tests in Australia would inform future tests and eventual deployments across Africa, Asia, Middle East and the rest of the world

So in respect to the aims of the Australian pilot, Cenerva understands the goals are mostly technical but it would also carry payloads:

1. Airbus would continue to test all technical aspects of its Zephyr HAPS platform: HALE endurance in the stratosphere, station keeping, gateway line-of-sight tests to HAPS platform, HAPS platform tests to both gateway and CPEs (not final CPEs but "mock" breadboard ones), etc.
2. Airbus would continue to collect more and more data on how the platform works
3. It is also expected later on in the year (2018), Airbus and Facebook would actually test connectivity payloads to CPEs and HAPS Service areas from the HAPS platform, as well as HAPS platform to the ground-based gateway.

The Australian tests would hopefully continue to portend the full-scale commercial reality of Project Aquila adding to all previous test results to date which have been very promising.

5.6 The Read-Across from the Australian HAPS Pilot and Flight Tests to other Markets

Cenerva believes the reasons for the choice of Australian desert for the continuation of the HAPS pilot and flight tests are sensible, and that the results would naturally be very relevant to the regions of Africa, the Middle East and South East Asia – indeed everywhere else. It shows continuing maturity in the HAPS evolution across its many proponents. The Chinese HAPS companies would almost certainly be announcing similar tests in the not-to-distant future

5.7 Future Pilots elsewhere in the world

Cenerva understands from Airbus-Facebook that future pilots elsewhere in the world (in ITU Regions 1 and 2) may be planned as HAPS evolves on its way to real commercial deployments. Other HAPS proponents would surely announce similar pilots.

HAPS security would be under the control of the national administration or country concerned.

5.8 HAPS Security

A frequent concern with HAPS by national administrations and regulators is that of security. There are a couple of key points to make on this subject.

1. Most of the current HAPS proponents including Airbus, Thales Alena, Lockheed Martin, Facebook, etc. would be **not** locally licensed players in local markets. These players are driving the ecosystem, driving tests and pilots, helping to scale HAPS globally in order to drive broadband backhaul capacity, and finally helping to drive affordable HAPS equipment.
2. **It would be operators under the jurisdiction of the national administrations and regulators who would be running HAPS services – and it would be up to these national operators to own and be responsible for local HAPS security concerns.**
3. Drawing from 2 above, unlike geo and non-geo satellites, HAPS Gateways and its users are likely to be in the country or within a well-defined geographic coverage area or footprint. This means that HAPS and its operations would likely be limited to one country/footprint only – unless the operator straddles several countries and gets the necessary approvals from the countries concerned to operate this way. However, the default likely scenario would be one HAPS-gateway-per-country and users within that country. Therefore, no one outside the country would be able to transmit or receive from the HAPS. This also means the HAPS would not be subject to jamming.

Therefore, administrations would be in control of their HAPS security.

The clear inference is that Developing and Emerging Countries should be Champions for a WRC Agenda Item 1.14 on HAPS as such innovations are most likely to benefit them the most. The fact that a key BRICS emerging economy like China is a key HAPS player should spur other BRICS including Brazil, India and South Africa. And developing economies should similarly be vocal in their support at ITU-R WP 5C

6. Agenda Item 1.14 Implications for Developing & Emerging Economies

6.1 Agenda 1.14 Implications for Developing Countries – Vocal Support at WP 5C at the ITU

With an average of 100% of monthly income in developing countries on broadband connections costs (vs. 1.5% in Europe) - and with estimates of 20%, 30% and 40% of people beyond the reach of the backbone network in the Middle East, Sub-Saharan Africa and South East Asia respectively – it is totally logical for these reasons and more for these countries and regions to champion the HAPS 1.14 at WRC-19.

It would be logical for each of such countries to (likely) benefit from HAPS to individually or jointly (as in multi-country) increase vocal support for HAPS at WP 5C at the ITU.

The countries should engage to understand the sharing and compatibility studies so as to be able to fully contribute to the Conference Preparatory Meeting (CPM) text. In order to understand and/or participate in sharing studies, countries need help define and/or understand the representative HAPS system characteristics along with other technical issues covered in this paper. The technical issues include the determination of preferred band plans in order to support the proposed HAPS systems.

6.2 Understand and Draft Supportive HAPS CPM Text

It is important countries and regions draft supportive CPM texts for HAPS AI 1.14. This could/would involve (as covered in this paper) the following:

- That the country/region supports broadband connectivity by HAPS for its specific reasons (a subset of those covered in this paper)
- That the country or region supports the ITU-R studies in the frequency bands in accordance with Resolution 160
- That HAPS proponents are converging on a shared approach to determine conditions of coexistence between HAPS and other services – based on the use PFD/EIRP limits with masks.
- That studies suggest that sharing with 5G is feasible: that even IMT-2020 deployments as planned for urban densely populated areas would co-exist with HAPS. HAPS co-existence in rural ones is much easier. Geography facilitates coexistence.
- HAPS seek to use spectrum shared with FSS in the opposite propagation direction. This facilitates coexistence easily.
- That provided that the relevant studies continue to demonstrate sharing and compatibility with existing services and candidate services are feasible, countries/regions would supports appropriate regulatory actions to facilitate the deployment of HAPS; including modifications to existing footnotes and associated resolutions, and addressing additional spectrum needs.
- **That in view of the fact (as covered earlier) that a HAPS ground terminal is an FS station, therefore there may be no need for specific HAPS regulatory provisions in the Radio Regulations because any potential interference from a HAPS FS into MS stations could be managed by administrations/regulators in the same way FS and MS stations are managed today.**
- HAPS Methods: CPM texts would also typically propose methods that would be applicable to the current and candidate bands after the studies in order to satisfy the agenda item’s coexistence and sharing criteria. The methods could be (i) No change (ii) identification of the band for HAPS either in a new or existing footnote (iii) make an allocation to Fixed Service (FS), i.e. HAPS as an FS (iv) to suppress an existing HAPS identification on the basis of the results of current studies.

Ultimately, only supportive CPM text from regions would ensure HAPS are likely to deploy in their regions after WRC-19.

The key conclusion of this paper (beyond the clear need for HAPS) is that it is not a matter of *whether* HAPS services can co-exist with other services – they can. It is *how* they would co-exist. Sharing studies clearly suggest co-existence of HAPS and existing services is clearly feasible

7. Emerging Conclusions & Recommendations from HAPS Studies

7.1 Primary Conclusions

Key conclusions include

1. The need for services like HAPS is clear - HAPS-type solutions for unserved and underserved communities are self-evident.

2. It is true that that HAPS had arguably not delivered in the past, but it seems clear it would deliver for the unconnected this time round. HAPS exist and are flying today in different levels of maturity. A key emerging economy like China is a key driver along with many key companies.

3. HAPS would be key to connecting the next 4 Billion unconnected, it would be complementary to 5G, and its promises are both (i) realistic to achieve economically and technically and (ii) and incredibly relevant to sparsely populated and remote billions.

4. HAPS ideally needs large contiguous, globally-allocated, cost effective-to-deploy spectrum. HAPS arguably needs to be prioritised for some shared spectrums to maximise economies of scale and minimise costs in order to connect so many in rural and urban hard-to-reach areas.

The key recommendation of this paper is that developing and emerging countries (particularly LDCs) must fully understand that innovations like HAPS and others must be supported towards connecting their unconnected Billions.

5. HAPS can co-exist with many services as the studies are increasingly showing. Through some combination of separation distances, power control, shielding, transmitting uni-directionally rather than bi-directionally, ensuring abidance by the PFD/ERIP limits for EESS, IMT, FS, FSS, etc. terminals – sharing would happen. By the time one considers that HAPS' "sweet-spots" are in remote, rural or disaster areas, the risks of interference to incumbents would very low indeed. HAPS seek to use spectrum shared with FSS in the opposite propagation direction. This facilitates coexistence. The studies also suggest that sharing with 5G is feasible: IMT-2020 deployments are even planned for urban densely populated areas and would not be interfered into by HAPS after the new proposals from HAPS proponents across 26 GHz and other bands.

6. Administrations – particularly for developing markets - should support CPM text to satisfy AI 1.14 and understand the **methods** applicable to every current or candidate HAPS band (i.e. No change, Identification for HAPS in an existing or new footnote, across each band to ensure, HAPS allocation as a FS, or suppress existing HAPS identification).

7. HAPS proponents are converging on a shared approach to determine conditions of coexistence between HAPS and other services. This is based on the use of PFD/EIRP limits and masks

8. HAPS and Affordable Satellite Services must look for ways to work together. They can share too. In general it makes sense for sharing between HAPS links and satellite links to be operated in opposite directions (for easier co-existence) on how the frequencies propagate. Furthermore, HAPS wherever possible should use the maximum contiguous amount of spectrum within each link or else more with frequency bands, the complexity of the payload increases.

The occasional (and public) disagreements between HAPS and Affordable Satellite Proponents is regrettable as it is not a matter of EITHER of the innovations. The other 4 Billion needs both innovations and more. These are "rich people" arguments.

7.2 HAPS Proponents should be partnering with Affordable Satellite Proponents

Cenerva has interacted with many satellite operators, some of who take the view that HAPS' "piecemeal" existing and candidate identifications is sub-optimal, and that it should be arguing for a dedicated and contiguous assignment. A couple of other satellite operators whose satellite constellations are bandwidth hungry arguably see HAPS as competition – and Cenerva has seen such battles fought within CEPT[21] in Europe. The spectrum policy reality is that HAPS proponents have to deal with what they have today.

It is no surprise this is happening in Europe because they are unlikely to happen in Africa, ASEAN, Latin America, India and/or in the rural and urban parts of the world where the 4 Billion broadband-unconnected disproportionately reside. Both set of proponents should not forget their shared goals – to help connect the other billions affordably!

HAPS would complement other satellite networks; indeed they would complement and extend satellite capabilities to further integrate with ground-based infrastructure covering the domains of telecommunications, earth observations, navigation, etc.

If HAPS turns out to be more cost effective than satellite solutions, then surely the satellite community would do deals with HAPS proponents. Indeed, **Broadband HAPS is most likely to succeed particularly well in scenarios where there would be a mix of terrestrial, solar aircraft and satellite backhaul and access technologies all working in combination in a single network – with each technology being leveraged where it is cost-effective, efficient and reliable.**

[21] https://www.cept.org/ - CEPT is the European Conference of Postal and Telecommunications Administrations (CEPT) is the coordinating body for European state telecommunications and postal organisations. Final CEPT positions underpin European Common Positions (ECPs).

8. Cenerva & Affordable and Accessible Connectivity Solutions

Cenerva unapologetically believes in the emergence of low-cost, affordable and accessible technologies/solutions for connecting the other 4 Billion broadband-unconnected. **Cenerva is also passionate about (i) SPECTRUM towards affordable and accessible connectivity like HAPS, more Wi-Fi, TVWS, etc. (ii) affordable and accessible TECHNOLOGIES and (iii) PUBLIC POLICY ranging from reduced taxes, incise duties, etc. to public policy, e.g. universal service policy**

In this vein, our experts are engaged in the accessible and affordable connectivity debate around the World. We offer bespoke advisory, technical and training solutions to help our clients maximize the opportunities and minimise digital divide in various countries.

- Evaluating the economic impact of connectivity services.
- Giving insights into experiences and practices on affordability and accessibility globally.
- Providing options and recommendations to our clients to address connectivity (universal service) policy issues.
- Technical assistance to support impact evaluation and policy development.
- Assessing local legislation against the dynamic global connectivity regulatory landscape
- Training, and sharing of expertise and international best practice. Training on affordable and accessible connectivity services like Wi-Fi, low-cost 2G/4G, HAPS, low-cost satellite solutions, low-cost power, TV Whitespaces, 450MHz LTE, etc.
- Thought leadership whitepapers and position papers on different models to achieve accessible and affordable connectivity.

9. Acknowledgements

Cenerva (and its lead author) completely acknowledge that this paper has been pulled together from several other published papers presentations on HAPS. The “value-add” here is in the collation for (hopefully) easier readability and understanding of what could otherwise be seen as an esoteric subject – whilst it is very important for developing economies and the other 4 Billion.

The author also acknowledges some important clarifications from Dr Azar Zarrebini of Access Partnership Ltd, UK – and well as some very helpful peer-review comments from others at Access Partnership including Luca Elmosi, Alexis Martin and Chris Casarrubias. Interactions and questions with regulators have helped improve the clarity of various sections of the paper including additions.

Cenerva acknowledges (with thanks) collaboration with Facebook, but notes that this paper was done independently. The views in this white paper do not necessarily represent the views of Facebook Inc. and other HAPS players.

All opinions in this paper and errors are the responsibility of the author.

10. Appendix I – Ongoing Sharing/Compatibility Studies in Existing HAPS Bands

	Frequency Bands with Existing HAPS Identification					
Impacted services and WP	6.44-6.52 GHz	6.56-6.64 GHz	27.9-28.2 GHz	31.0-31.3 GHz	47.2-47.5 GHz	47.9-48.2 GHz
FS (WP 5C)	✓	✓	✓	✓	✓	✓
FSS (WP 4A)	✓	✓	✓*	✓ (adjacent band FSS & MSS)	✓*	✓*
MS (WP 5A / WP 5D)	✓	✓	✓	✓	✓*	✓*
ARS/ARSS (WP 5A)					✓ (adjacent band)	
EESS (WP 7B / WP 7C)			✓ (adjacent band)	✓ (adjacent band)		
SRS (WP 7B / WP 7C)			✓ (adjacent band)	✓ (adjacent band)		
ISS (WP 7B)			✓ (adjacent band)			
RAS (WP 7D)				✓ (adjacent band)		✓ (adjacent band)

11. Appendix II – Ongoing Sharing/Compatibility Studies in Candidate HAPS Bands

	Frequency Bands with Candidate HAPS Identification		
Impacted services and Relevant Working Party	21.4-22.2 GHz	24.25-27.5 GHz	38-39.5GHz
FS (WP 5C)	✓	✓	✓
FSS (WP 4A)			✓*
NGSO FSS (WP 4A)			✓
EESS (WP 7C)	✓ (adjacent band)	✓	
ISS (WP 4A)		✓	
Radionavigation (WP 5B)		✓	
MS (WP 5A / WP 5D)	✓	✓*	✓*
AMS (WP 5B)		✓	
Radiolocation-Satellite (WP 5B)		✓	
BSS (WP 4A)	✓		
SRS (WP 7B)	✓ (adjacent band)	✓ (in-band and adjacent band)	✓ (adjacent band)
RAS (WP 7D)	✓ (adjacent band)	✓ (adjacent band)	

12. Biography of Lead Author

Prof. H Sama Nwana, CITP, FBCS, FIET, CEng, BSc (Hons), MSc (Dist), PhD, MA (Cambridge), MBA (Dist.) (London Business School).
Managing Partner, Cenerva Ltd (www.cenerva.com)
Senior Executive Advisor, TMT[22] Regulation and Sector re-design, Spectrum & Wireless Technologies. Senior Advisor KPMG Consultants

Prof. Nwana is Managing Partner of Cenerva Ltd, UK, concentrating on advising Emerging Economies to re-design their TMT sectors. As a senior Executive Board Member, ex Managing Director (thrice), ex-Regulator and Multiple award-winning technologist and **respected thought leader,** he trains, mentors and advices/ advised Business Corporations such as Facebook, Microsoft and VC firms, Governments and Regulators.

He was formerly Group Director of Spectrum Policy at Ofcom from 2008/9 to late 2013 and led its Spectrum Policy Group - which oversees all UK spectrum for broadcast, mobile, satellite and other communications services. Previous roles include Managing Director at UK TV and Radio transmission Arqiva, Executive Managing Director at Quadriga responsible for turnaround of the £75M Worldwide digital business; and Senior Manager at BT Plc. Where he built and led several award-winning teams.

Professor Nwana holds an MA in Computer Science Education from Queens' College, Cambridge, a first degree in Computer Science & Electronic Engineering from the University of Birmingham, an MSc in Computer Science, a PhD in Artificial Intelligence & Computer Science from Aston University, Birmingham. He also holds an **MBA with distinction** from the London Business School, University of London. He has published several scientific tomes and is heavily cited in Computer Science. Googling for him returns hundreds of hits. He concluded 2.5 years as Executive Director/CEO of the Dynamic Spectrum Alliance in October 2016. (www.dynamicspectrumalliance.org). He is also a Senior Advisor with KPMG in Africa in particular.

[22] Telecommunications Media and Technology

Prof H Sama Nwana, has dual UK Cameroon citizenship and is also a French speaker. He leads on and is delivering major projects and is a trainer who has trained industry professionals all over Africa, Asia & LATAM (Nigeria, Kenya, Ghana, Cameroon, Mozambique, Chad, Benin, Myanmar, Malaysia, etc.). Indeed, Prof H Sama Nwana has published a book entitled Telecommunications, Media & Technology (TMT) for Developing Economies: *How TMT can Improve Developing Economies in Africa and Elsewhere for the 2020s* [23].

His new consulting company Cenerva has just bought the **training assets** of renowned telecoms trainer ICC (www.icc-uk.com).

[23] Nwana, H. S. (2014), Telecommunications, Media & Technology (TMT) for Developing Economies: *How TMT can Improve Developing Economies in Africa and Elsewhere for the 2020s*, London: Gigalen Press, 550+ pages. http://www.amazon.co.uk/Telecommunications-Media-Technology-Developing-Economies/dp/099282110X, 550+ pages.

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- On this white paper on HAPS, Cenerva acknowledges (with thanks) collaboration with Facebook, but notes that this paper was done independently. The views do not necessarily represent the views of Facebook Inc. and other HAPS players.
- Cenerva has published a recent white paper on Over the Top (OTT) Services published in March 2018. See https://www.cenerva.com/category/ott/
- Its next white paper will be on Blockchains for Developing Markets – and how to introduce them via country pilots and more.