Institution: Liverpool Hope University (LHU)		
Unit of Assessment: B11: Computer Science and Informatics (CS&I)		
Title of case study: Influencing Spectrum Policy for Additional HAPS Bandwidth, critical for Rural Broadband Connectivity		
Period when the underpinning research was undertaken: May 2016 – December 2020.		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Prof. Atulya K. Nagar	**Role(s) (e.g. job title):** Professor & Research-theme Lead	**Period(s) employed by submitting HEI:** Sept 2001 – present.
Dr. Philip B. Charlesworth	Visiting Professor	Aug 2015 – present.
Dr. Gurvinder S. Baicher	Visiting Professor	Aug 2015 – present.
Dr. Ogbonnaya Anicho.	Lecturer (PhD student)	July 2019 – present (May 2016-May 2019).
Period when the claimed impact occurred: June 2019 – December 2020.		
Is this case study continued from a case study submitted in 2014? No.		

1. Summary of the impact (indicative maximum 100 words)

Wireless communications technologies depend on international agreement for the allocation of radio frequency spectrum. High Altitude Platform Stations (HAPS) are an emerging technology with potentials of extending mobile broadband coverage; greater international consensus on more HAPS spectrum is critical for HAPS operational, technical, and business viability, especially for rural coverage on a global scale. Through insights from its research on solar-powered HAPS for communications area coverage, the LHU team have:

a) improved awareness of the significance and potential of HAPS among policymakers, journalists and the general public, and

b) influenced the position of government representatives, policymakers and regulators to favourably support the allocation of additional HAPS spectrum during the 2019 World Radio Conference (WRC-2019), using the platform of the Commonwealth Telecommunications Organisation (CTO), with a membership of 53 countries.

2. Underpinning research (indicative maximum 500 words)

According to the International Telecommunications Union (ITU), approximately 3,700,000,000 people are currently offline, with a significant concentration of this population in least developed countries where rural dwellers are severely impacted. The need to address communications infrastructure issues in rural and unserved parts of the world has created the urgency to look at options like HAPS as likely candidate for this mission. One main reason for this challenge is the economic cost, terrain and logistics of deploying satellite or terrestrial infrastructure. It is therefore important to develop cost-effective and technically viable options like HAPS to bridge the coverage gap.

HAPS is defined by the International Telecommunications Union (ITU) as “a station located on an object at an altitude of 20 to 50km and at a specified, nominal, fixed point relative to the earth”. At this stratospheric altitude, wind profile is described as mild and suitable for hosting platforms with minimal station-keeping requirements. HAPS can be used to provide persistent communications coverage to mobile and fixed users (see **Figure 1**), leveraging its unique technical strengths, which combine those of terrestrial and satellite communication systems **[R1]**, **[R2]**. The capacity to offer large footprints with signal latency similar to terrestrial systems further places it as a dominant aerial infrastructure. As an aerial platform, it can be easily recovered and redeployed to meet various

operational scenarios, an additional capability that neither satellite nor terrestrial systems can offer effectively **[R2]**.

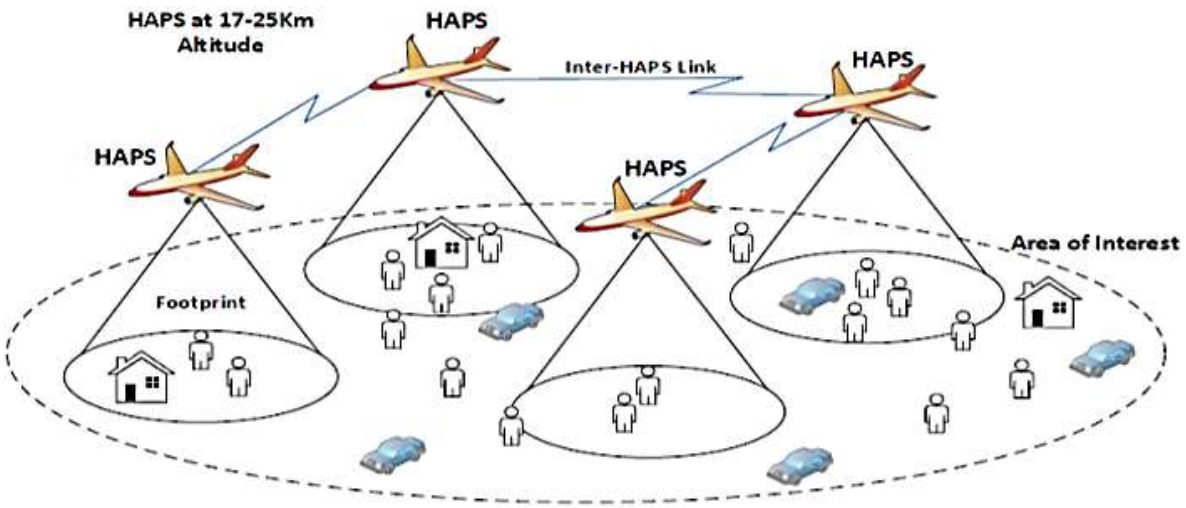

Figure 1 – HAPS Network

The HAPS team at LHU is a multi-disciplinary team of researchers looking at various aspects of the problem. For instance, Dr. Charlesworth is an ex-Airbus specialist with expertise in unmanned aerial vehicles (UAVs) and satellite communications, bringing a wealth of industry experience. Prof Nagar, who leads the team has several decades of experience in mathematics and its application to research problems; while Drs. Gurvinder and Anicho also come with industry experience and broad understanding of telecommunications, and application of algorithms within the domain. Anicho also has expertise in the policy and regulatory dimension and uses this to track changes within that domain.

Different technology-related challenges hinder the maturity of HAPS as a communications infrastructure solution. These research challenges range from addressing what form the HAPS should assume (e.g. fixed-wing aircraft, balloon or aerostats), security, energy, payload designs, integration with aviation traffic, autonomy & coordination of platforms and spectrum allocation issues. At LHU we have focused on developing computer-based HAPS models and simulation platforms to address some of the earlier mentioned problems **[R1] [R2]**. Specifically, our HAPS simulation platform enables us to investigate the viability of solar-powered fixed-wing variants of HAPS. We also investigate algorithms and techniques for developing autonomous behaviours in HAPS specifically for semi or full autonomous coordination of multiple HAPS **[R4]**.

However, one overarching challenge looming over all HAPS research efforts especially for rural broadband connectivity is the spectrum policy issue. Spectrum availability or scarcity has the potential to either make or break HAPS as a viable communications infrastructure. Without more spectrum identification for HAPS at the ITU organised WRC, investors, governments and other stakeholders may change their positions on the technical or commercial viability of the technology. LHU through its HAPS research continued to communicate the viability of HAPS and ensured that key policymakers and Commonwealth government representatives were adequately informed on the potential of HAPS. Armed with insights from our research, we maintained a channel to communicate and influence the perception and policy positions of stakeholders on the need to address the spectrum allocation issues central to the success of HAPS globally.

3. References to the research (indicative maximum of six references)

The underpinning research, listed below in **[R1-R4],** has been published in international, high-quality, peer-reviewed outlets and receives citations from across the research areas. For instance, reference **[R4]** was published by Springer as part of a book featuring outcomes of the *9th International Conference on Soft Computing for Problem Solving,* (SocProS 2019), which brought together the world's leading scientists in the interdisciplinary areas of Soft Computing and AI, and associated applications (Scopus-indexed). These publications also invited much media attention and coverage as well as invitation from leading organisations working in the areas of HAPS and UAVs.

R1. Anicho, O., Charlesworth, P., Baicher, G., and Nagar, A.K. (2019). Geographical Considerations for Implementing Autonomous Unmanned Solar-HAPS for Communications Area Coverage. *Data Science: Journal of Computing and Applied Informatics*, 3(1):1–18., 2019. doi: https://doi.org/10.32734/jocai.v3.i1-636.
R2. Anicho, O., Charlesworth, P., Baicher, G., and Nagar, A.K. (2018). Conflicts in Routing and UAV Autonomy: Algorithms for Ad-hoc & Infrastructure-based UAV Networks. *Journal of Telecommunications and the Digital Economy*, 6(4), 96-108. https://doi.org/10.18080/jtde.v6n4.169.
R3. Anicho, O., Charlesworth, P., Baicher, G., and Nagar, A.K. (2018). 'Integrating Routing Schemes and Platform Autonomy Algorithms for UAV Ad-hoc & Infrastructure based networks', *28th International Telecommunication Networks and Applications Conference (ITNAC)*, Sydney, NSW, Australia, 2018, pp. 1-5, doi: 10.1109/ATNAC.2018.8615237.
R4. Anicho O., Charlesworth P.B., Baicher G.S., Nagar A.K. (2020). Reinforcement Learning for Multiple HAPS/UAV Coordination: Impact of Exploration–Exploitation Dilemma on Convergence. In: Nagar A.K., Deep K., Bansal J., Das K. (eds) *Soft Computing for Problem Solving 2019. Advances in Intelligent Systems and Computing*, vol 1138. Springer, Singapore. https://doi.org/10.1007/978-981-15-3290-0_12

4. Details of the impact (indicative maximum 750 words)

Our underpinning research described in **Section 2** has two major routes to the four distinct and material impacts being claimed below. For instance, our public engagement activities improved policymakers' perception and awareness of HAPS and subsequently translated to concrete policy positions favourable to the technology and its benefits. The impact also extended beyond decision-makers and included improving the awareness of HAPS and its benefits for journalists and the general public through media-based routes ensuring inclusion in the policy formulation process.

(a) Shaping Perception and Improving the Awareness of HAPS among Policymakers: LHU HAPS research influenced policy positions of Commonwealth countries on HAPS spectrum allocations by shaping perception, improving awareness and knowledge of the technology, especially in the context of addressing rural connectivity issues. It has also contributed to disseminating the awareness of this technology to the public through deliberate public engagement activities and media interest.

CTO invited LHU to take up the challenge of engaging the participating countries and making a case for HAPS by addressing specific and general perception, and knowledge and policy issues surrounding the technology. This invitation came as a result of CTO noticing our contribution to the development of HAPS and its potentials for addressing rural connectivity challenges. The goal was for us to use our expertise and insights on HAPS to influence and guide policy positions of policymakers from various Commonwealth countries in preparation for the 2019 World Radio Conference (WRC-2019). To ensure maximal impact from our engagement with CTO member countries/delegates we communicated our views and guidance using effective communication

methods especially by using non-technical and easily understandable language. We also put HAPS in the right context for rural connectivity challenges and contemporary solutions, clearly defining HAPS's uniqueness and potentials to address the digital divide. The platform enabled us to create awareness and influence policy positions of delegates from different continents and setting the agenda for HAPS that would likely project into the future, affecting how thousands or even millions of people access connectivity in their rural locations.

(b) Translating Improved Awareness and Clarity into tangible adjustments in HAPS Policy Positions: The former Group Director of UK Spectrum Policy at Ofcom, who currently advises various governments, regulators and ministers on ICT matters, affirmed his familiarity with the policy positions of Commonwealth nations' delegates and their stance on HAPS and related issues, and stated that *"Dr. Anicho's work and presentations on HAPS at these Commonwealth forums is helping policymakers adjust their attitudes towards HAPS as reflected in their positive policy positions on spectrum identifications for HAPS – particularly across Africa";* **[S1].**

It is important that policymakers and regulators understand the HAPS technology better and how it may impact existing fixed satellite services (FSS) or other applications. HAPS adoption and general success depended on favourable adoption of the proposed HAPS spectrum identifications at the 2019 WRC. The Acting Secretary-General of the CTO **[S3]**, confirmed the usefulness of the LHU HAPS research *"in terms of providing awareness of the technology and its various applications and use cases."* She further noted that the LHU presentations and panel discussions had struck chords with key policymakers and cited exemplar feedback from these delegates (including ministers, deputy ministers and directors from a range of countries) **[S3]:**

- *"I have a better appreciation for satellites and HAPS solution"*
- *"New knowledge on HAPs will be used to finalise World Radio Conference (WRC-19) preparation"*
- *"Clarity formulating policy around spectrum pricing and HAPs".*

The CTO Acting Secretary-General also affirmed that *"as a result of these engagements delegates and by extension member countries have more clarity on their HAPS policy directions especially as the global telecommunications community prepare for the WRC-19 in Egypt."* **[S3].** She expressed confidence on behalf of CTO that the work would "*ultimately contribute favourably to the policy positions on HAPS from Commonwealth states*". As she further noted, these states "*make up a sizeable chunk of the global telecommunications community*".

(c) Influence on Policymakers from the Commonwealth bloc yields the desired HAPS Policy outcome at the 2019 World Radio Conference (WRC-19) in Egypt: Our HAPS research contributed to keeping the HAPS discussion at the very centre of policy and regulatory deliberations leading up to the 2019 World Radio Conference (WRC) in Egypt. Through our input at the CTO organised forums, we were able to share insights and provide guidance to policymakers and regulators from the Commonwealth bloc. The outcome of LHU's contribution ultimately resulted in favourable HAPS policy by the Commonwealth countries and supported the approval of the HAPS spectrum allocation proposal at WRC-2019.

As confirmed by the Managing Director of Jamaica Spectrum Management Authority (SMA), a member of the Jamaica delegation to WRC-2019, and one of the policymakers we engaged at CTO, HAPS proposal at WRC-2019 was a success **[S4].** The current and previous HAPS spectrum allocations before WRC-2019 is shown in **Figure 2**; the additional spectrum allocated to HAPS is

significant considering the difficulty involved in shaping and aligning international consensus along this direction.

Frequency Band **Before** WRC 2019	Bandwidth Allocated **Before** WRC 2019	Frequency Band **After** WRC 2019	Bandwidth Allocated **After** WRC 2019
6 440-6 520 MHz	80 MHz (Regional)	6 440-6 520 MHz	80 MHz (Regional)
6 560-6 640 MHz	80 MHz (Regional)	6 560-6 640 MHz	80 MHz (Regional)
27.9-28.2 GHz	300 MHz (Regional)	27.9-28.2 GHz	300 MHz (Regional)
31-31.3 GHz	300 MHz (Regional)	31-31.3 GHz	300 MHz (Worldwide)
47.2-47.5 GHz	300 MHz (Worldwide)	47.2-47.5 GHz	300 MHz (Worldwide)
47.9-48.2 GHz	300 MHz (Worldwide)	47.9-48.2 GHz	300 MHz (Worldwide)
		38-39.5 GHz	1500 MHz (Worldwide)
		21.4-22 GHz	600 MHz (Worldwide)
		24.25-27.5 GHz	3250 MHz (Regional)

Figure 2 – Pre and Post WRC 19 HAPS Spectrum Allocations

(d) Improving Awareness and Perspective of HAPS among Media Practitioners (and by extension the General Public) as well as HAPS Industry; resulting in an important chain in Policy formulation and continued support: The LHU research through its public engagement activities, and particularly media interest in the research has resulted in HAPS awareness reaching different segments of the public across countries; **[S5-S6].** For instance, a technology writer for *The National*, UAE (circulation: 65,000), mentioned our research in his write-up **[S5].** The journalist stated that our engagement was *"invaluable in improving my awareness of the technology and the realities of its development"*; considering the role of journalists and the media in shaping and informing policy, we consider our work having an impact within this important demography as significant **[S5].** As a result of these press coverages, which was widely circulated, we were approached by the Director of Regulatory Affairs at Avealto Plc. (a UK based HAPS manufacturer) for collaborative work and advice; the Director commented **[S7]** that: "*The awareness and policy framing content of the LHU research around the implementation of HAPS is helping AVEALTO to reassess our perspective of current challenges and alternative ways of thinking about the problems*." This demonstrates the reach and significance of the impact on the technical work with the industry and continued support.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1]. Statement from former Group Director of UK Spectrum Policy at Ofcom; (5 November 2019).
[S2]. Statement from Acting Secretary-General of the Commonwealth Telecommunications Organisation (CTO), London, UK; (15 October 2019).
[S3]. Statement from the Managing Director, Spectrum Management Authority (SMA), Jamaica; (25 October 2019).
[S4]. Communication from a member of the Jamaica Delegation to the 2019 World Radio Conference in Egypt; (21 November 2019).
[S5]. Statement from Technology Correspondent for The National (a leading English language newspaper in the UAE); (2 November 2020).
[S6]. Several Press Releases covering the Research and its Impact – *Press_Releases_LHU_HAPS.pdf* (press release containing clips from Advanced-television.com; Vanillaplus.com; Iot-now.com & The National).
[S7]. Statement from Director, Regulatory Affairs, Avealto Limited, UK; (22 December 2020).