IMDA CONSULTATION PAPER ON
"5G MOBILE SERVICES AND NETWORKS"

I. INTRODUCTION

The Asia-Pacific Satellite Communications Council (ASPCC), CASBAA, the Global VSAT Forum (GVF), and the EMEA Satellite Operators Association (ESOA), hereby submit on behalf of their satellite operator members the following comments on the "5G Mobile Services and Networks" consultation paper issued by the Info-communications Media Development Authority (IMDA) of Singapore.[1]

Satellite-enabled services have enriched the daily life of millions of people around the globe for decades, by broadcasting news and events worldwide, by cost-effectively extending the reach terrestrial networks, and by connecting remote places on land, at sea or in the air that could not otherwise be connected by terrestrial options. The satellite industry is therefore vitally concerned about the regulatory decisions being made today that will shape the future of 5G mobile services and networks. This is especially the case when 5G will be a network of networks – an ecosystem – with multiple technologies supporting a global infrastructure consisting of fixed lines, traditional mobile networks, small cells, Wi-Fi/WiGig, and satellites, among others.

In these comments on the IMDA Consultation Paper, we explain the important role that satellites will play in the 5G ecosystem, and thus the need to consider all parts of the 5G ecosystem when making spectrum decisions. We also provide in Appendix 1 our responses to the specific questions set out in the IMDA Consultation Paper.

II. THE ROLE OF SATELLITE IN THE 5G ECOSYSTEM

A. What is 5G?

As the IMDA notes, the mobile industry and ITU WP5D have developed visions of the potential applications that will be a part of 5G. These generally include three key usage scenarios – (a) enhanced mobile broadband; (b) massive machine-type communications; and (c) ultra-reliable and low-latency communications.[2] These 5G usage scenarios are quite diverse in their technical characteristics, as illustrated by the following diagram from the GSMA:[3]

---

[1] IMDA Consultation Paper, *5G Mobile Services and Networks* (May 2017), *available at* https://www.imda.gov.sg/regulations-licensing-and-consultations/consultations/consultation%20papers/2017/public-consultation-on-5g-mobile-services-and-networks (hereinafter "IMDA Consultation Paper").

[2] IMDA Consultation Paper at 5-6.

[3] GSMA Intelligence, *Analysis: Understanding 5G: Perspectives on future technological advancements in mobile*, at 9 (Dec. 2014) (hereinafter "GSMA, *Understanding 5G*").

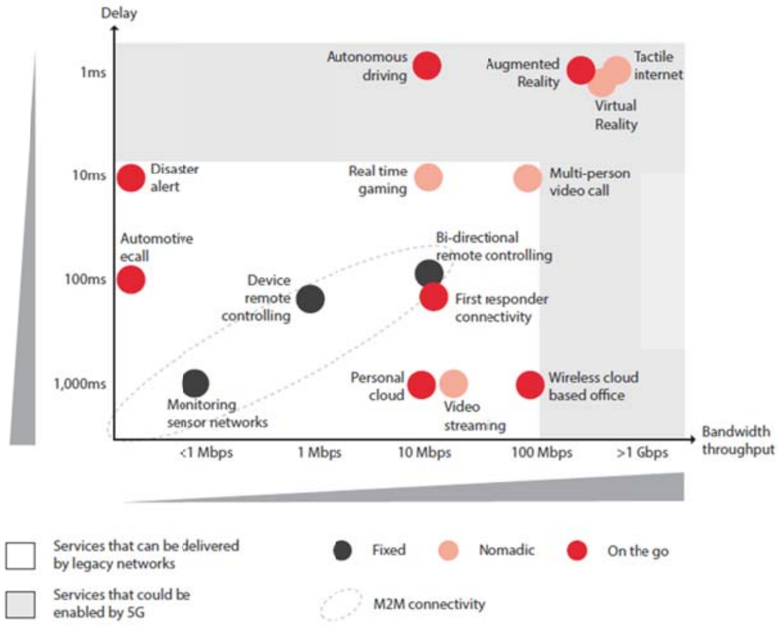


Figure 1: Bandwidth and latency requirements of potential 5G use cases
Source: GSMA Intelligence

Notably, most 5G use cases do not have the extreme bandwidth and/or latency requirements that will only be supported by future 5G terrestrial technologies. As a result, satellites – both geostationary and non-geostationary – can and will play important roles in supporting the key 5G usage scenarios, including emerging 5G applications (as explained below), just as satellites support 2G, 3G and 4G/LTE networks today.

B. Satellite's Role in 5G

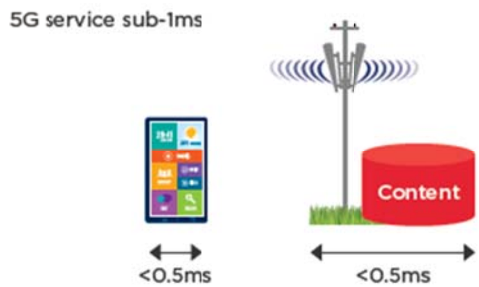
The ability of satellites to support the key 5G usage scenarios is a self-evident and can be extrapolated from present satellite capabilities and the trend of satellite technology developments:

<u>Enhanced mobile broadband ("eMBB")</u>. Satellites can support multi-gigabit per second data rates envisaged for enhanced mobile broadband services. Satellites today are capable of carrying thousands of channels high-bandwidth HD and UHD content, and that same high bandwidth can be used to support the mobile networks tomorrow. Indeed, just as satellites today support 2G/3G mobile backhaul in many parts of the world, current- and next-generation High Throughput Satellites (HTS) in both geostationary and non-geostationary orbits will support the 4G/LTE and the 5G mobile networks tomorrow.

<u>Massive Machine-Type Communications ("mMTC")</u>. Satellites already support SCADA and global asset tracking applications today, and can scale to support expanded M2M (Internet-of-Things or IoT) communications tomorrow – whether directly to or as a means of backhauling M2M communications from remote locations or connected planes, ships, or other vehicles. Investments in new ground segment technologies, such as smaller, lower cost, electronically steerable, and/or phased-array satellite transceivers are making ubiquitous deployment of the "Internet-of-Things" via satellite eminently feasible and cost-effective.

> Ultra-reliable and Low-latency Communications ("uRLLC"). Satellite systems are known for their reliability. In fact, our customers today – international broadcasters, MNOs, governments – depend on us every day to ensure mission-critical, ultra-reliable communications. The latency of geostationary satellites will be acceptable for many 5G applications. More latency-sensitive applications can be supported by the new medium Earth orbit and low Earth orbit networks that have been (or which will soon be) deployed.

Even for the small number of emerging 5G applications that have very low latency requirements (e.g. tactile Internet, VR, autonomous driving), satellites can play a role in helping terrestrial networks to deliver such applications. Extremely low latency (sub-1ms) requirements are challenging even for terrestrial mobile networks to meet. As the GSMA itself has acknowledged, "[a]chieving the sub-1ms latency rate … will likely prove to be a significant undertaking in terms of technological development and investment in infrastructure."[4] Specifically, "services requiring a delay time of less than 1 millisecond must have all of their content served from a physical position very close to the user's device. … possibly at the base of every cell, including the many small cells that are predicted to be fundamental to meeting densification requirements."[5] This is illustrated by the following figure from GSMA's report:[6]



This means that efficient, multicast distribution of commonly accessed content to data caches located at each cell and small cell is going to be essential if terrestrial 5G networks are to support applications that require very low (sub-1ms) latency. Fortunately, point-to-multipoint distribution of common content is something at which satellites excels, as is evident from satellite's historical success as a video distribution platform.

Indeed, such point-to-multipoint distribution has been identified as one of the satellite "sweet spots" in the global 5G ecosystem, a natural combination of satellite's proven strength in content distribution and its role in providing trunking and backhaul for mobile networks around the world.[7] As one ITU official has observed:

> *Both geostationary and non-geostationary satellite systems have specific benefits for integration of satellite-based solutions into 5G networks, such as providing:*
>
> - *high speed backhaul connectivity to multiple sites on land, at sea or in the air, with the ability to multicast the same content across large areas*

[4] GSMA, *Understanding 5G*, at 12.
[5] GSMA, *Understanding 5G*, at 12.
[6] GSMA, *Understanding 5G*, at 13.
[7] *See*, *e.g.*, SES, *Role of Satellite in 5G*, delivered at Satellite Connectivity Workshop, Nadi, Fiji (Apr. 2017) (describing in detail four satellite "sweet spots" in the 5G ecosystem – (1) Trunking and Head-End Feed, (2) Backhauling and Tower Feed, (3) Comms on the Move, and (4) Hybrid Multiplay), *available at* http://www.apt.int/2017-WS-Satellite.

- *high speed, multicast-enabled, communications direct to the home, office, plane, train or vessel as a complement to existing terrestrial connectivity where available*
- *efficient backhauling of aggregated IoT traffic from multiple sites on land, at sea or in the air*[8]

It is therefore not surprising that the CEPT, for example, has included consideration of satellite solutions in its 5G roadmap.[9] The satellite industry is participating extensively in public and private technical groups, such as CEPT/ECC Working Group FM 44, 3GPP, and 5GPPP/5GIA to integrate satellite technologies into the future 5G ecosystem. We expect that innovations in satellite technologies will enable satellite broadband capabilities to be integrated directly and seamlessly in to future 5G networks, and allow for satellite's inherent advantages in ubiquity, reliability, and point-to-multipoint economics, to be fully leveraged.

III. INTEGRATING SATELLITES INTO 5G SPECTRUM DECISIONS

Thus, because satellite technology will be integrated into the future 5G ecosystem, satellite spectrum requirements must also be taken into account as part of Singapore's spectrum planning process. 5G mobile spectrum requirements need not be, and should not be, mutually exclusive of satellite spectrum requirements since both will have a role to play in tomorrow's communications infrastructure.

Today's High Throughput Satellite ("HTS") systems operate in the C-, Ku- and Ka-band frequencies,[10] and continued, sustainable access to these frequencies will be necessary for satellites to continue playing their role in the 5G ecosystem. Next-generation HTS and Very High Throughput Satellite ("VHTS") systems will also operate in more of the Ku-band, Ka-band, and in parts of the Q/V-band, including some of the bands being examined for 5G terrestrial used under WRC-19 Agenda Item 1.13. In addition, essential aeronautical and maritime safety and connectivity services are also being provided by satellite in certain L-band frequencies.

Together, these existing and imminent satellite spectrum uses have implications for a number of the spectrum bands being considered by IMDA in this consultation.

A. Above 6 GHz Bands

i. 28 GHz Band (27.5-29.5 GHz)

It is neither necessary nor appropriate to consider the 28 GHz band for future 5G mobile services and networks, given (a) the low probability of international harmonization, (b) the ample other spectrum available to meet the IMDA's spectrum estimates with a greater chance of being harmonized (*e.g.*, portions of the 26 GHz, 32 GHz, 66 GHz and 81 GHz bands), (c) the extensive satellite investments and

---

[8] Mario Maniewicz, *Delivering the standards and spectrum to fuel 5G*, delivered at CEPT Workshop on 5G Mobile Communications, 12 (Nov. 2016), *available at* https://cept.org/Documents/ecc/33231/keynote-1_global-context.
[9] *See* ECC(16)110 Annex 17, Item D.1 (Nov. 2016) ("CEPT Roadmap"). *See also* WP4B, Annex 3 to Document 4B/44-E, *Key requirements for integration of satellite systems into IMT-2020 networks* (Oct. 2016).
[10] Today's HTS systems include, for example, IPStar (Ku/Ka), Intelsat EPIC (C/Ku), Inmarsat Global Xpress (Ka), and O3b (Ka). Several more HTS systems are due to be launched in the APAC region within the next two years, including SES-12 (Ku/Ka) and Kacific-1 (Ka).

recent deployments in the 28 GHz band, and (d) the interference issues, notably from transmitting earth stations located in neighbouring countries, associated with deploying 5G in this band in a small geographic area given the likely lack of international harmonization.

The 28 GHz band will *not* be internationally harmonized for 5G mobile services. WRC-19 Agenda Item 1.13 identified over 31 GHz worth of spectrum as potential 5G bands, and the ITU Member States did not include the 28 GHz in recognition of the satellite deployments in the band that have and will continue to take place. Instead of the 28 GHz, many countries are focusing on the 5G candidate bands specified in Resolution 238 (WRC-15) for study under WRC-19 Agenda Item 1.13.[11] Of these bands, as the IMDA itself has observed, "[t]he 32 GHz and 66 GHz bands received support from all Regions at WRC-15, which is a possible indication that these two bands are most like[ly] to be globally harmonised."[12] Thus, Singapore would be better off focusing on the bands with the greater potential for global harmonization than the 28 GHz bands.

Ample spectrum has been identified for study as potential 5G mobile spectrum under WRC-19 Agenda Item 1.13 without having to consider the 28 GHz. Based on the IMDA's own surveys, estimates of future mobile 5G spectrum requirements vary widely from less than 1.5 GHz (based on traffic growth forecasts) to 20 GHz (based on pure technical performance and/or future application usage) worth of additional spectrum – indicating great uncertainty about likely future spectrum requirements.[13] Moreover, at least half of this traffic growth may be offloaded on to Wi-Fi networks (and future WiGig networks),[14] thus substantially reducing mobile spectrum requirements. For Singapore itself, IMDA has estimated that about 3.4 GHz of spectrum may be needed by 2022-2025 to support 5G deployments, once actual mobile traffic trends, Wi-Fi offload rates, higher-than-average site densities, and an assumed increase in bandwidth consumption from new 5G applications have been taken into account.[15] Whether or not this estimate turns out to be accurate,[16] WRC-19 Agenda Item 1.13 will study more than 31 GHz of spectrum for 5G, which clearly indicates that there is no need to look beyond the Agenda Item 1.13 bands. In fact, if the 32 GHz and 66 GHz bands, which IMDA recognizes as "most likely to be globally harmonised"[17] are added to 24.25-24.45 GHz, 25.05-25.25 GHz and 42-42.5 GHz bands that IMDA also considers "most likely to be globally harmonised,"[18] there will be more than enough spectrum above 6 GHz to meet IMDA's estimated spectrum requirements for 5G without having to look at the 28 GHz band.

It is particularly inappropriate to go beyond the WRC-19 Agenda Item and to look at the 28 GHz band because it is already in use for satellite services around the world. This band is one of the key uplink bands for current and future commercial Ka-band satellites, including the HTS-type of satellites. Over

[11] For the 48 countries in the CEPT, *see* CEPT Roadmap, Item B.1 (prioritizing consideration of 24.25-27.5 GHz, 31.8-33.4 GHz and 40.5-43.5 GHz bands in WRC-19 Agenda 1.13) and Item B.4 (indicating that the 27.5-29.5 GHz band is "not available for 5G" because it has been harmonized for broadband satellite and will be used for ESIMs).
[12] IMDA Consultation Paper at 18. It is unfortunate that a few countries (the U.S. and Korea) seem determined to deviate from the scope of Agenda Item 1.13 by considering the 28 GHz band. It is unclear why those countries have chosen such a path, but the reasons appear tied to the peculiar regulatory or technical histories of the 28 GHz band in those countries.
[13] IMDA Consultation Paper at 23.
[14] IMDA Consultation Paper at 23 ("We have projected the percentage of Wi-Fi offload to continue to remain at about 50% over the next few years…").
[15] IMDA Consultation Paper at 25 (estimating a 5G spectrum requirement of 3360 MHz by 2022, inclusive of spectrum below 6 GHz).
[16] *See* Appendix 1, Response to Questions 13 & 14, below.
[17] IMDA Consultation Paper at 18.
[18] IMDA Consultation Paper at 25 Figure 5.

twenty satellites using the 28 GHz band have been launched in just the last five years.[19] In addition, at least a dozen more have been procured for launch in the near future.[20] Several companies, including OneWeb and SpaceX, have also announced next-generation, non-geostationary satellite systems using this band. This represents tens of billions of dollars of sustained, expanding, and planned investments in the 28 GHz, including on HTS designs that will support the future 5G ecosystem. Every effort should be made to avoid disrupting such investments, especially when there is ample other spectrum under consideration that is more likely to be globally harmonized.

Finally, if Singapore were to deploy 5G in the 28 GHz band, it would have to consider the potential for interference from satellite deployments in neighbouring countries. Within a small geographical area like that of Singapore, interference from transmitting Earth stations (e.g. in Malaysia or Indonesia) into 5G receivers would be likely to occur, especially given the low probability of international harmonization in this band. There is also the potential for interference to be caused by terrestrial 5G transmitters into the receivers on the GSO and non-GSO satellites. Satellite users inside and outside of Singapore could be impacted by harmful interference in the satellite uplink beams.

ii. Other Bands Above 6 GHz

Q- and V-band. WRC-19 Agenda Item 1.13 will consider a number of satellite bands in the Q- and V-band range (37-52 GHz) for future 5G mobile deployments. Multiple satellite companies have announced plans to deploy next-generation VHTS systems – including six global NGSO constellations – using portions of the Q- and V-bands.[21] There is also WRC-19 Agenda Item 9.1.9 that seeks additional uplink spectrum for future VHTS systems. A careful review of the planned satellite uses and the available spectrum will be necessary to determine the extent to which future 5G mobile deployments can also be accommodated within the Q-/V-bands. To the extent that satellite and future 5G mobile networks will share the same band, studies are currently underway internationally to consider the extent to which satellite and IMT may be compatible, taking into account the very different interference mechanisms for satellite bands for Earth-to-space and space-to-Earth transmissions. Accordingly, IMDA may want to await the outcome of the international process before considering which portions of these bands to potentially designate for 5G.

26 GHz band. WRC-19 Agenda Item 1.13 will also consider the 26 GHz band (24.25-27.5 GHz) for future 5G deployments. Portions of this band are allocated to satellite services, such as the 24.75-25.25 GHz band which is to be used primarily for Broadcasting Satellite Service (BSS) feeder links. A number of satellites have been recently deployed in this band in the United States (e.g. DIRECTV 14 and 15). In addition, Australia's NBN has deployed satellites in the 27-27.5 GHz. We would urge IMDA to prioritize the portions of the 26 GHz band that are least likely to involve actual satellite deployments in the future, as these are the ones most likely to be internationally harmonized. Again, to the extent that satellite and future 5G mobile networks will share the same band in the 26 GHz, IMDA will need to consider the

[19] These include twelve O3b MEO satellites; four Inmarsat F5 Global Xpress satellites; the ViaSat-2, Jupiter-2, Hylas-2, JCSat-16, and Amazonas-3 satellites. This list is not exhaustive and does not include the many 28 GHz satellites launched before 2013, including ViaSat-1, Jupiter-1 and Spaceway 3, Hylas-1, Wildblue-1, Superbird 4, AMC-15 and -16, and several DIRECTV satellites.
[20] These include eight more O3b MEO satellites, SES-12, Superbird 8, Kacific-1/JCSAT 18, and ViaSat-3.
[21] For example, in 2016, six companies – Boeing, O3b, OneWeb, SpaceX, Telesat and Theia – filed applications with the U.S. Federal Communications Commission to deploy large constellations of non-geostationary satellites using portions of the Q-/V-bands.

international studies currently being undertaken to ensure compatibility between co-frequency mobile and satellite services in these bands.

Other WRC-19 Agenda Item 1.13 Bands. A number of other mmWave and higher frequency bands will be considered for 5G mobile services under WRC-19 Agenda Item 1.13, including the 31.8-33.4 GHz (32 GHz), 66-71 GHz (66 GHz) and the 81-86 GHz (81 GHz) bands. As IMDA has already noted, the 32 GHz and 66 GHz bands are considered good prospects for international harmonization, and the same may be true for the 81-86 GHz, given their limited existing and planned use. As a result, these bands may be more promising candidates for near term 5G deployment than the 28 GHz.

The 32 GHz band, for instance, is in the same "low" category of mmWave bands as the 28 GHz, but without the same heavy incumbent use. The 66 and 81 GHz band in the "high" mmWave bands should yield about 15 GHz of spectrum in contiguous blocks of at least 5 GHz, which could support very wide-band carriers. These high mmWave bands should support the development of 5G mobile networks in high-density indoor and outdoor scenarios, such as stadiums, campuses or shopping malls and should be well suited for use in Singapore. The use of these bands could also benefit from synergies with WiGig – currently being deployed at 61 GHz – for which chipsets are already being manufactured.[22] We would urge IMDA to focus its attention on these lightly encumbered bands than on the occupied 28 GHz band.

B. Bands Between 1 and 6 GHz

i. Extended C-band (3.4-3.6 GHz)

Singapore's interest in the use of the 3.4-3.6 GHz band for 5G is understandable given the light use of the band in Singapore itself. However, given Singapore's geography, any decision by Singapore to deploy mobile services in the 3.4-3.6 GHz band will have to ensure that co-frequency satellite users in neighbouring countries are protected. Malaysia and Indonesia, for example, have together launched four satellites with the 3.4-3.6 GHz band on-board (Measat-3, Palapa D, Telkom 1 and Telkom 3S), and the users of this band in those countries will need protection. As the IMDA recognizes, deployments in the 3.4-3.6 GHz band would have to be constrained to meet the cross-border PFD limits prescribed by the ITU Radio Regulations and/or bilateral agreements will have to be reached with neighbouring countries.[23] As the IMDA correctly notes, under the methodologies developed by the ITU-R Joint Task Group ("JTG") 4-5-6-7, the "calculated separation distances required to protect FSS earth stations when operating co-channel are such that macro-cell deployment is not feasible." This suggests that 3.4-3.6 GHz deployments in Singapore may need to be limited to small cells, and then possibly only for indoor use in order to minimize the potential for aggregate co-channel interference.

In addition, adjacent band interference concerns will have to be addressed. The 3.6-4.2 GHz band is more heavily used throughout the Asia-Pacific region, including in Singapore. This was clearly evident from the outcome of the WRC-15, which resulted in no IMT identification in the C-band above 3.6 GHz. The risk of adjacent band interference (in the form of out-of-band emissions or overdrive of the LNA/LNB) from Fixed Wireless Access transmitters in the 3.4-3.6 GHz into satellite receivers in 3.6-4.2 GHz is significant from practical experience, and can be very hard to mitigate, especially in cross-border

[22] ABI Research, *Mobile and Computing Markets Catapult 60 GHz WiGig into the Mainstream in 2017, at* https://www.abiresearch.com/press/mobile-and-computing-markets-catapult-60-ghz-wigig/ (Aug. 2016) (forecasting that 180 million WiGig chipsets will ship to the smartphone market in 2017, with smartphone chipsets accounting for almost half of the 1.5 billion total market shipments by 2021).

[23] IMDA Consultation Paper at 16.

situations and especially when aggregate interference is considered. ITU and APT studies have shown that the separation distances required to offer adequate protection to FSS receivers in respect of out-of-band emissions of 5G transmitters, assuming no guard band between the satellite and 5G signals, are in the range of: less than a kilometre for 5G small-cell indoor deployment; a few kilometres for 5G small-cell outdoor deployment; and tens of kilometres for 5G macro-cell outdoor deployment. In addition to limiting mobile deployments in the 3.6-4.2 GHz band to small cells, IMDA may want to consider further limiting such deployments to indoor use only and/or introducing out-of-band emission limits to protect adjacent band satellite operations.

It remains to be seen whether it is practicable for satellite users in Singapore to migrate from the 3.4-3.6 GHz band (and possibly the 3.6-3.7 GHz band) to higher bands in order to avoid interference from 5G deployments at 3.4-3.6 GHz. But even if practicable, this is only a solution that IMDA can enforce for Singapore users of these bands. Satellite users of these bands in neighbouring countries would still need to be protected in the manner discussed above. In any event, the satellite industry's continued and sustainable access to the rest of the C-band above 3.6 GHz is essential in order to meet continuing demand and to support the latest HTS systems built on such frequencies (*e.g.*, Intelsat EPIC, Horizons 3e).

ii. L-band (1427-1518 MHz)

If IMDA were to proceed with making the 1427-1518 MHz band available for mobile broadband, careful consideration will need to be given to potential interference into Mobile Satellite Service (MSS) operations in the adjacent band 1518-1559 MHz. This band is used by thousands on MSS terminals operating throughout the world, including on most wide-bodied airliners and on many ships and vessels. IMDA would need to address the potential interference, in particular with respect to ships operating in waters in and around Singapore, and with respect to aircraft operating in and out of Singapore's airports. Conditions for compatibility will likely require a frequency guard band to be applied to the mobile frequency arrangements below 1518 MHz, and will require deployment constraints on mobile base stations. Studies are on-going in the ITU-R on this issue, and IMDA may wish to wait until those studies are complete before taking further steps on L-band.

C. Other Bands

If additional bands are needed for 5G, then IMDA may want to consider certain other bands for possible 5G deployments that present much less of a conflict with satellite services. For example, the frequency bands 3.3-3.4 and 4.8-4.99 GHz are currently being considered by several countries in the region for 5G. In the 4.8-4.99 GHz band, the mobile service already has a primary allocation. For the 3.3-3.4 GHz band, Singapore could consider adding itself to footnote No. 5.429 for that band where several Region 3 countries have already identified mobile service as primary (RR No. 5.429). Both bands are under study by the APT Wireless Group, and neither band has a satellite allocation.

IV. CONCLUSION

The 5G network of the future promises much in terms of new applications, high bandwidth and low latency. But that network will not consist of only one type of infrastructure or technology. Instead, the realization of that future depends on many network technologies – a "network of networks" – working together as one integrated ecosystem. As we have demonstrated, satellites can and will play an important part in that ecosystem. This means that the regulatory decisions that Singapore makes today must necessarily take into account the spectrum required by the satellite industry to provide services today and to power the latest and next-generation HTS and VHTS systems that will support the 5G networks of tomorrow.

In summary, with respect to the specific frequency bands being considered in the IMDA Consultation:

- 28 GHz band (27.5-29.5 GHz): It is neither necessary nor appropriate to consider the 28 GHz band for future 5G mobile services and networks given (1) the low probability of international harmonization, (b) the ample other spectrum that is available to meet IMDA's spectrum requirements with a greater chance of being harmonized (*e.g.*, portions of the 26 GHz, 32 GHz, 66 GHz and 81 GHz bands), (c) the extensive satellite investments and recent deployments in the 28 GHz band, and (d) the interference issues, notably from transmitting earth stations in neighbouring countries, associated with deploying 5G in this band in a small geographic area given the likely lack of international harmonization.
- Q- and V-band (37-52 GHz): Multiple satellite companies have announced plans to deploy next-generation Very High Throughput Satellite systems in portions of the Q- and V-bands (37-52 GHz), including six global NGSO constellations. In fact, WRC-19 Agenda Item 9.1.9 will consider providing additional uplink spectrum in the V-band to support such systems. As a result, a careful review of the planned satellite uses and the available Q- and V-band spectrum will have to be undertaken to determine the extent to which future 5G mobile deployments can be accommodated. Compatibility studies are currently underway to determine the extent to which satellite and IMT may share the spectrum in these bands.
- 26 GHz band (24.25-27.5 GHz): Satellite deployments have already occurred in some portions of the 26 GHz band in various parts of the world. At the same time, the IMDA has noted that portions of this band may have a high probability of being internationally harmonized. We would urge the IMDA to prioritize the portions of the 26 GHz band that are least likely to involve actual satellite deployments, as these are the sub-bands most likely to be internationally harmonized. Compatibility studies are also underway on satellite-IMT spectrum sharing in this band.
- Other WRC-19 Agenda Item 1.13 bands: As the IMDA has recognized, the 32 GHz and 66 GHz bands have a good chance of being internationally harmonized. The same may be true of the 81 GHz band, given the light incumbent use today. The higher 66-76 GHz and 81-86 GHz frequencies, in particular, would facilitate the development of high density 5G terrestrial networks in urban and suburban areas and which can also efficiently re-use spectrum.
- Extended C-band (3.4-3.6 GHz): While the 3.4-3.6 GHz may be lightly used in Singapore, neighbouring countries have launched a number of satellites that make use of this band more extensively and measures will have to put in place to ensure cross-border protection of co-frequency satellite earth stations. Deployments in Singapore would need to be limited to small cells (and possibly limited to indoor use) to ensure that cross-border PFD limits are met. It remains to be seen whether it is practicable for Singapore satellite users in the 3.4-3.6 GHz band to migrate to higher bands given capacity and other constraints. In any event, the satellite industry's continued access to the remainder of the C-band above 3.6 GHz will be essential in order to meet continuing demand and to support the latest HTS systems built on such frequencies.
- L-band (1427-1518 MHz): If the IMDA does proceed to make parts of the 1427-1518 MHz available for 5G or other mobile broadband systems, it is vital that protection measures be carefully defined and enforced to ensure computability with aeronautical and maritime MSS operations in the adjacent 1518-1559 MHz frequency band.

Asia-Pacific Satellite Communications Council
Gregg Daffner, President
Daniel Mah, VP Regulatory Affairs
Suite T-1602 Poonglim Iwantplus 255-1
Seohyun-dong, Bundang-gu
Seongnam, Gyeonggi-do
463-862 Republic of Korea
gregg@gapsat.com

CASBAA
Christopher Slaughter, Chief Executive Officer
John Medeiros, Chief Policy Officer
802 Wilson House
19-27 Wyndham Street
Central, Hong Kong SAR
China
john@casbaa.com

Global VSAT Forum
David Hartshorn, Secretary General
Fountain Court
2 Victoria Sq, Victoria St
St Albans, Hertfordshire
United Kingdom, AL1 3TF
david.hartshorn@gvf.org

EMEA Satellite Operators Association
Aarti Holla-Maini
Secretary General
Bastion Tower, 20th floor
5 Place de Champ de Mars, 1050 Brussels
Belgium
sg@esoa.net

APPENDIX 1: RESPONSES TO QUESTIONS RAISED BY IMDA CONSULTATION

Topic / Questions	Satellite Responses
5G Technology and Use Cases	
1) IMDA would like to seek views and comments on the estimated timeline for the deployment of 5G. Besides ensuring that spectrum is made available in a timely manner, what other regulatory measures could assist in facilitating the deployment of 5G technology and applications? What other use cases should IMDA take note of when developing the regulatory framework?	1) Before finding additional spectrum for 5G, IMDA should consider regulatory measures for increasing mobile network densification, such as greater deployment of small cells, within existing spectrum. Such network densification is already an essential part of key 5G usage cases, especially those requiring ultra-low latency,[24] and may relieve future 5G mobile spectrum requirements.
2) To facilitate and understand potential spectrum requirements for IoT deployments in Singapore, IMDA would like to seek views on the following: i) Based on the current spectrum allocated for mobile services in the sub-1 GHz frequency bands, are there further suitable spectrum resources that could be released to support both IoT and LTE services? ii) How will future generations of mobile networks (e.g. high capacity, low latency) support the growth of IoT and what would be the spectrum requirements?	2) The vast majority of IoT applications do not require extremely high bandwidths and are latency insensitive.[25] Thus, IoT should not be the main driver of 5G spectrum requirements. Autonomous Driving is perhaps the only IoT application that requires very low latency, and network densification is much more important for meeting such latency requirements than spectrum. Indeed, "[t]he Internet of Things has already begun to gain significant momentum, independent of the arrival of 5G,"[26] and many of the IoT networks today, *e.g.* remote or mobile asset tracking, are enabled or served directly by satellite.
3) IMDA would like to seek views and comments from industry on what they consider will be the key	3) 5G will be a network of networks – an ecosystem – with multiple technologies supporting a global infrastructure. Satellites will play an

[24] *See* GSMA, *Understanding 5G*, at 12.
[25] *See* Satellite Comments, above, at 2.
[26] *See* GSMA, *Understanding 5G*, at 7. There is a question as to whether IoT is a key differentiator for 5G or even 4G networks. *See* GSMA, *Understanding 5G*, at 5 ("The Internet of Things (IoT) has also been discussed as a key differentiator for 4G, but in reality the challenge of providing low power, low frequency networks to meet the demand for widespread M2M deployment is not specific to 4G or indeed 5G. As Table 1 suggests, it is currently unclear what the opportunity or 'weakness' that 5G should address is.").

Topic / Questions	Satellite Responses
technologies for 5G and whether current regulatory frameworks sufficiently facilitate the deployment of such technologies.	important role in that ecosystem, and regulatory decisions must take into account the spectrum requirements of all parts of that ecosystem, not just the mobile component.[27]
Below 1 GHz Frequency Bands 4) IMDA would like to seek views and comments on whether going forward, there is a need for further spectrum below 1 GHz to be identified and release for mobile services?	4) The satellite industry expresses no view on this question, but would ask IMDA to consider whether mobile spectrum has been released but it not yet fully utilized.
1 – 6 GHz Frequency Bands 5) IMDA would like to seek views and comments on following: i) The frequency arrangement that is better suited for adoption in Singapore for the L band (i.e. SDL, TDD or FDD) and the supporting reasons; and ii) The timeline for access to the L band and the availability of the equipment (specifically whether it will be available earlier or later than 2020). 6) Considering the spectrum bands within the range of 1-6 GHz to support the deployment of enhanced mobile broadband services, IMDA would like to seek views on whether all of the 91 MHz of spectrum in the L-band should be allocated for IMT to address Singapore's data demand and growth.	5) The satellite industry expresses no view on this question. 6) If IMDA were to allocate any part of the 1427-1518 MHz band to IMT, it will have to ensure protection for MSS operations in the adjacent band 1518-1559 MHz, which is used by thousands on MSS terminals on airliners, and ships worldwide. Studies are being conducted at the ITU-R on this very issue.[28]

[27] *See* Satellite Comments, at Parts I and II, above (explaining satellite's role in the 5G ecosystem).
[28] *See also* Satellite Comments, at Part III.B.ii, above (discussing the adjacent band MSS compatibility issue in the L-band).

Topic / Questions	Satellite Responses
7) If it is only the extended C-band that is considered for IMT, would the migration of existing satellite users to the other parts of the C-band (i.e. 3.7-4.2 GHz) impact their service provisioning?	7) The extent to which existing satellite users in the 3.4-3.6 GHz band can be migrated to other parts of the C-band is uncertain. Capacity may not be available or more expensive, and antenna repointing may not be practicable because of other services being received from the same satellite.
8) Considering the challenges of co-channel deployment of FSS and IMT services in the extended C-band, IMDA would like to seek views and comments on the coexistence measures for adjacent bands and cross border operations.	8) Co-frequency deployment of IMT and FSS in the 3.4-3.6 GHz band within Singapore is practically impossible given required separation distances to protect the FSS. For the same reasons, IMT deployments in this band will have to be limited to small cells and/or indoor use in order protect FSS deployments in neighbouring countries from aggregate interference.
9) IMDA would like to seek views and comments on whether there are other frequency bands in the 1-6 GHz frequency band that IMDA should consider for IMT / 5G.	9) The APT Wireless Group is currently studying the 3.3-3.4 GHz and 4.8-4.99 GHz band for IMT. Neither band has an allocation for satellite services.
<u>Above 6 GHz Frequency Bands</u> 10) IMDA would like to seek your views and comments on the following: i) The role mmWave bands will play in delivering the vision of 5G, in particular, what services could not be delivered by alternative frequency bands and / or technologies; ii) The amount of spectrum required in the mmWave spectrum bands to meet 5G applications that will require higher bandwidths; and	10) i) The satellite industry is not aware of any particular 5G mobile services that require the use of the mmWave bands or any particular portion of those bands. The mobile industry has indicated that 5G will be deployed in the bands above and below 6 GHz. We would note that many 5G usage scenarios do not require wide bandwidths and thus could be delivered by some combination of narrower frequency bands. We do note that billions of dollars have already been invested in the latest HTS and VHTS systems in multiple bands that will support 5G.[29] ii) The satellite industry urges caution in over-projecting future spectrum requirements based on the bandwidth consumption of still-emerging 5G applications.

[29] *See* Satellite Comments at 5, above.

Topic / Questions	Satellite Responses
iii) The specific mmWave bands that you consider should be a priority in Singapore for IMT services and why?	iii) Singapore should focus on the mmWave bands that have the highest probability of international harmonization, such as those listed in WRC-19 Agenda Item **1**.13 (e.g. portions of the 26 GHz, 32 GHz, 66 GHz, 81 GHz bands).
11) Considering that there are 11 candidate bands under consideration at WRC-19, how would making available the 28 GHz band help in the deployment of 5G services in Singapore? Would this band play a significant role in achieving the targets set out for 5G (i.e. higher throughput, ultra-low latency)?	11) Singapore should focus on the mmWave bands that have the highest probability of international harmonization. More than 31 GHz worth of mmWave spectrum has been identified as potential candidates for internationally harmonized 5G spectrum, but the 28 GHz is not one of those bands. Instead, the 28 GHz is heavily used worldwide on the latest and next-generation of HTS and VHTS systems that will support key 5G usage (including very-low latency applications).[30] There is simply no need to look at the heavily used 28 GHz band when there is more than enough spectrum in other bands more "likely to be globally harmonised"[31] to meet IMDA's estimated spectrum requirements.[32]
12) If the 28 GHz band is opened for IMT services in Singapore, would there be any future competing services that may be deployed in this band which may cause interference issues?	12) If the 28 GHz band is opened for IMT services in Singapore, Fixed Satellite Service and Fixed Service deployments in neighbouring countries may cause interference issues for IMT deployments in Singapore, especially since the 28 GHz is not on the list of candidate 5G bands and therefore will not be internationally harmonized.

[30] *See* Satellite Comments at 3, above (recounting GSMA's explanation of how ultra-low latency 5G applications can only be delivered if the content is served from the base of every mobile base station or small cell, and satellite's ability to efficiently multicasting commonly accessed content to multiple cell sites).
[31] *See, e.g.*, IMDA Consultation at 18 (noting that the 32 GHz and 66 GHz bands received support from all Regions at WRC-15 which is a possible indication that these two bands are most like[ly] to be globally harmonized), at 25 Fig. 5 ("Projected supply > 6GHz includes the 24.25-24.45 GHz, 25.05-25.25 GHz and 42-42.5 GHz which are most likely to be globally harmonized.").
[32] As for whether IMDA's estimated spectrum requirements are accurate, please see Response to Question 13 below.

Topic / Questions	Satellite Responses
Future Spectrum Estimation 13) IMDA seeks views and comments on the estimated spectrum demand of 3360 MHz by 2025 and whether this estimate is realistic?	13) While mobile data consumption will no doubt grow, projections about that growth and the spectrum needed to meet that growth have varied wildly. The satellite industry commends the IMDA for making more realistic projections than the ITU, but would suggest that its estimates could be even more realistic by considering the following factors: • Figure 5 of the IMDA Consultation suggests that there is already a significant shortage of spectrum to meet demand in 2017. Yet, existing spectrum allocations have been able and are continuing to accommodate recent mobile traffic growth, perhaps due to increased spectrum efficiency from network densification. This shows that there is no spectrum shortage at present. The above divergence between observed reality and the spectrum demand model suggests that the method for translating mobile data consumption into spectrum requirements needs to be re-examined. A change in this methodology will affect IMDA's projections of spectrum demand and supply both before and after the introduction of 5G, and whether there is (or will be) a shortage. • In this regard, we would encourage IMDA to review additional cross-country data sources and analyses to test the realism of its methodology and estimates. For instance, Tefficient has recently produced a comparison of mobile data consumption across countries (including Singapore).[33] This data could be correlated against European Commission and European Communications Office data on the amount of mobile spectrum that has been assigned as a means of ascertaining the mobile data consumption that a given amount of spectrum may be able support.[34] In Finland,

[33] *See* Tefficient, Industry Analysis #5 2016, *Mobile data 1H 2016: Unlimited pushes data usage to new heights*, http://media.tefficient.com/2016/12/tefficient-industry-analysis-5-2016-mobile-data-usage-and-pricing-1H-2016-ver-2.pdf (Dec. 2016) (hereinafter "Tefficient").

[34] *See* European Commission, *Europe's Digital Progress Report 2017 country profiles - Telecom country reports*, https://ec.europa.eu/digital-single-market/en/news/europes-digital-progress-report-2017-country-profiles-telecom-country-reports (May 2017) (hereinafter EC, *Telecom country reports 2017*); European Communications Office, *ECO Report 03 Information*, http://www.efis.dk/views2/report03.jsp.

Topic / Questions	Satellite Responses
	a country with a similar population to Singapore, 830 MHz of assigned spectrum have enabled five MNOs to support (on average) more than 7 gigabytes of data consumption per SIM per month.[35] This suggests that the 550 MHz assigned to Singapore's three MNOs would enable them to support more than the ~3 gigabytes per SIM per month of mobile data consumption in Singapore.[36] • Most of the anticipated increase in spectrum demand comes from an assumed spike in data consumption from the introduction of 5G applications. Given that such applications are still nascent, some care must be taken to avoid assuming too much. Moreover, the estimated 2 GHz of additional spectrum above 6 GHz that is required is based on estimates from other countries,[37] and the IMDA's own data suggests that Singapore's situation is quite different, *e.g.*, in the number of cell sites, including small cells, that will be deployed in Singapore's densely built-up environment.[38] These differences need to be fully accounted for. • In addition, it will be important to make explicit any assumptions about pricing models that will come with the introduction of 5G. Mobile data consumption (and thus spectrum demand) is very likely to be driven by the per-GB price of data.[39]
14) Noting that several regulators have made available mmWave bands for IMT services, IMDA would like	14) The timing of decisions to make available mmWave spectrum for IMT services should not be driven by what other regulators are doing, but should instead be driven by a sober analysis of the best data available

[35] Tefficient at 2 ("With 7.2 GB per month per any SIM, Finland continued to lead the world in usage."); EC, *Telecom country reports 2017: Finland*, at 3-4 (showing 5 MNOs and 830 MHz of assigned mobile spectrum), http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=44463.

[36] Tefficient at 7 Fig. 5 (showing mobile data consumption of Singtel and M1 at less than 3 gigabytes per SIM per month); IMDA Consultation at 25 Fig. 5 (showing 550 MHz of assigned mobile spectrum in 2017).

[37] *See* IMDA Consultation Paper at 24 n.46 ("The estimated amount of 2 GHz bandwidth was the minimum amount derived from various countries spectrum estimation which were submitted to WP5D … ").

[38] *See* IMDA Consultation at 24 ("[I]n Singapore's densely built-up environment, the numbers of sites are higher than these estimates for the countries considered.").

[39] *See* Tefficient at 12 (showing inverse correlation between revenue per GB and data consumption).

Topic / Questions	Satellite Responses
your views and comments on whether access to the mmWave spectrum should be provided earlier than 2022 for commercial network deployment?	and a consideration of international developments. To the extent that such other regulators have chosen the 28 GHz band, the satellite industry believes that such actions have been premature and unwise given (1) the lack of international harmonization, (2) the existing satellite users in the band, and (3) the ample other spectrum available. The ITU will complete its study of 5G candidate bands at WRC-19, at which point the globally harmonized bands for 5G will be clear, and Singapore should be able to make such bands available prior to 2022.
<u>Use of Licence-Exempt Spectrum</u> 15) Considering the current regulations/policies for licence-exempt use and the possibility of LTE-U interfering with Wi-Fi users, IMDA would like to seek views and comments on the following: i) The adoption of LBT to facilitate sharing of licence-exempt spectrum and whether there would be any implication arising from such a requirement; ii) The need for further technical requirements and regulatory measures to facilitate the sharing of licence-exempt spectrum in an efficient and fair manner; and iii) The need for companies with commercial LTE-U networks to upgrade to LAA once the software/hardware products are commercially available. 16) During the interim period before regulations are finalised, IMDA plans to facilitate industry trials for LAA/LTE-U technologies. As such IMDA would like to seek views and comments on the following: i) Besides the information listed in Para 80,	 15-19) The satellite industry expresses no view on questions 15-19, other than to note that they underscore the "network of networks" nature of the 5G ecosystem, and thus the need to consider the spectrum requirements of all parts of that ecosystem, including the satellite component.

Topic / Questions	Satellite Responses
should MNOs/MVNOs interested in conducting LTE-U trials submit any further information for IMDA's assessment; and ii) To minimise impact to Wi-Fi users, should IMDA limit LAA/LTE-U trials to parts of the 5 GHz licence-exempt spectrum? 17) IMDA would like to seek views and comments on the following: i) The possibility of deploying LAA and / or MuLTEfire in other frequency bands besides the licence-exempt 5 GHz band; and ii) The regulatory and coexistence measures that should be adopted for MuLTEfire. 18) Considering that the LWA approach would not create coexistence issue with Wi-Fi users, would this approach be better suited for countries with extensive Wi-Fi usage? 19) IMDA would like to seek views on how the above approaches (i.e. LAA, MuLTEfire and LWA) would enhance the capacity of the mobile network in ways that Wi-Fi offloading is not able to achieve.	