Plan B for National Broadband Plan

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Contents

Version Log

Version	Date	Comments
1.0	3rd November 2019	Initial version
1.01	5th November 2019	Added contact details & version log

1. Introduction

In May 2019 the Government announced a National Broadband Plan (NBP) detailing how rural Ireland would be connected to high-speed broadband over the next seven or so years.

In response to widespread public criticism, mainly about cost and ownership issues, the Oireachtas Committee on Communications, Climate Action and Environment decided to "examine the national broadband plan process thus far, how best to proceed and the best means to roll out rural broadband". The Oireachtas Committee's report, published in August 2019, was approved by most of the committee and contained extensive criticisms, and recommended, inter alia, that the entire plan be reviewed by independent experts.

In July 2019, Brian Flanagan, a taxpayer concerned about public finances and services and compiler of this **Plan B for the NBP**, made a detailed submission to the Oireachtas Committee which highlighted the potential of emerging, next-generation satellites to provide broadband services globally, including to rural Ireland, and urged that this potential be fully investigated. The Committee's report failed to mention the potential of satellite broadband despite claims at its launch that no alternative plan was offered as per this quotation:

> *"Nobody, nobody has come up with an alternative, plan B, that is legally viable. Nobody, not even the minister. All the experts that came before us. Not even the recommendation of this all, cross-party, committee report. There is no plan B here."* Chairperson, Oireachtas Committee.

This view was echoed by Minister for Finance, Pascal Donohoe TD, in the Dail on 3rd October 2019:

> *.. in regard to the national broadband plan, for those who think there is a cheaper and quicker way of delivering 100% coverage apart from this plan - perhaps the Deputy is one of them - the time is coming when they will need to spell out how that will happen. I can tell him that I spent the best part of a year trying to establish if that could be done and I reached the conclusion that the plan in front of us was, on balance, the best way of making it happen.*

Plan B for the NBP, is based on the Oireachtas submission. It has been updated and extended to serve as a structured response to the Committee and its report, and to construct a case to the Government for a detailed, independent, expert study of the potential of satellites to help provide, low-cost, high-speed broadband to rural Ireland. While concentrating on high-speed broadband services delivered by satellite (primarily low-Earth orbit), the report acknowledges that the optimal method of delivering high-speed broadband services to rural Ireland is a combination of satellite, fibre, 4G/5G and next-generation fixed wireless.

2. Executive Summary

- This report seeks to build a case for next-generation, satellite-based broadband services to be considered as a complementary technology alongside fibre for the National Broadband Plan.
- Up to now, use of satellites to deliver internet services has been constrained by the need to deploy geostationary satellites located 35,800 kms above the equator. This results in latency problems (delays) in signal transfers between users and satellites.
- New solutions based on low-Earth orbiting satellites operating in large constellations have the potential to eliminate these latency problems and to bring high-speed broadband to rural areas worldwide at competitive prices.
- The leading player is SpaceX's Starlink which recently launched 60 test satellites and plans to launch a further twelve thousand on a phased basis by the mid-2020s. Other key participants include Amazon, OneWeb and Telesat.
- Starlink may have enough satellites in orbit to start servicing rural areas in Ireland and much of Europe by about 2022.
- The EU has published periodic plans to assist the deployment of high-speed broadband. An initial broadband speed target of 30 Mbps for households first proposed in 2013 have been increased to target 100+ Mbps by 2025. Whilst not endorsing unproven, next-generating satellite broadband, the Commission has identified it as a possible future technology.
- The NBP which originated in 2012 has evolved into a plan to offer high-speed broadband using fibre to every rural premises in Ireland not serviced by private sector operators. The expected cost of passing about 540,000 rural premises with fibre will be about €5 billion, including an Exchequer subsidy of about €2.5 billion net of VAT.
- Currently, the NBP's Intervention Area (IA) is being finalised ahead of awarding a 25-year development and operation contract to a preferred bidder who is proposing to offer download speeds in excess of 150 Mbps. For an area to be excluded from the IA, prospective service providers must undertake to exceed a minimum download speed of 30 Mbps and meet other detailed technical, operational and financial criteria. The assessment process makes no provision from new market entrants such as satellite broadband operators.
- Plans for satellite broadband are gathering momentum and have attracted substantial funding. Total funding could ultimately hit US$40 billion and up to 20,000 next-generation satellites could be providing ultra-high-speed, inexpensive broadband as an alternative to fibre-based solutions especially within rural areas worldwide well inside the next decade.
- If these expectations are fully, or even partly, realised, then satellite broadband services could impact significantly on proposals for the NBP in terms of costs, timelines, Exchequer contributions and contracting arrangements.
- **This report recommends that an independent, expert technology assessment be commissioned by the Government and followed, if favourable, by a comprehensive review of the NBP (as was recommended by the Oireachtas Committee). This could give rise to a Plan B which integrates satellite broadband alongside fibre and next-generation fixed wireless to provide high-speed broadband throughout rural Ireland, within existing time scales and at a moderate cost to taxpayers.**

3. Satellite Broadband Services

This section discusses existing satellite broadband services and introduces next-generation services.

3.1. Existing Services

Receipt of internet services via satellite is well established. According to ComReg, there are about four thousand users of such services in Ireland. These services are provided by commercial operators via geostationary satellites orbiting at 35,800 kms about the equator. This altitude enables satellites to appear stationary relative to the Earth. Signals are uploaded from Earth stations and received directly by users using small external disks pointing towards the satellites' fixed positions. Geostationary satellites can cost up to a billion dollars to design, build, launch and deploy. They can be as large as a small bus and take several years from design to deployment.

The main drawback with these services is latency, the time required for signals to roundtrip from/to users. This delay can frustrate real-time interactions, for example audio/video calls and gaming. In addition, services can be disrupted by heavy rain and related climatic conditions. It is noteworthy that the US Federal Communications Commission (FCC)'s proposed US$20.4 billion Rural Digital Opportunities Fund for 2020-2030 has, by applying a penalty score for high latency (over 100 milliseconds), effectively excluded operators of geostationary and even medium-Earth orbit (but not low-Earth) satellites from consideration for funding.

Satellite broadband accounts for less than 1% of fixed broadband subscriptions in most countries[1]. The USA and Australia have the greatest penetration (based on subscriptions per head of population) while lesser developed regions have experienced the greatest growth rates. Overall, satellite broadband subscriptions have grown from 1.2 million in 2008 to 5.2 million in 2017.

End-user charges in Ireland for access to the internet via satellite are modest - €100 to purchase the disk and about €40 per month for a domestic service offering 50 GB per month with unmetered off-peak usage. While speed is limited to approximately 25 Mbps[2] it is more than adequate for email, browsing, streaming etc. and to meet the minimum set of services demanded under the EU's Electronics Communications Code[3].

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[1] The Space Economy in Figures: How Space Contributes to the Global Economy. OECD. July 2019.

[2] While download speeds of 25 Mbps seem slow compared with the proposed speed range of 150-500 Mbps for households serviced by the NBP, it is worth noting that the US Federal Communications Commission suggests that speeds in excess of 25 Mbps are only needed for households which might use four devices simultaneously including more than one very high-demand applications. It also guides that teleworking/student work and streaming Ultra HD 4k Video may need speeds of 5-25 Mbps or greater per user. This begs the question as to how and why in a short number of years, rural households would need bandwidth amounting to, say, ten times more than is currently needed. Obviously, schools, businesses and other organisations are likely to need greater bandwidth than households.

[3] Establishing the European Electronic Communications Code. Annex V identified this minimum set of broadband services:
E-mail, search engines enabling search and finding of all type of information, basic training and education online tools, online newspapers or news, buying or ordering goods or services online, job searching and job searching tools, professional networking, internet banking, eGovernment service use, social media and instant messaging, and calls and video calls (standard quality).

3.2. Next-Generation Services

The value of the global space economy (including satellites and ground equipment) could grow to anywhere between US$600 billion and US$2 trillion by 2040-45. A key driver of this growth will be satellite broadband which according to UBS Bank could hit US$300 billion by 2040 from virtually nothing now. This growth will be driven by falling launch costs[4], advances in technology and increased private investment.

The OECD[5] has identified almost twenty companies that have announced plans to launch satellite constellations to deliver broadband. These will require investments ranging from US$3 to US$12 billion. Some of them will deliver broadband to designated areas (India, China, Japan and Russia) while others will seek to provide broadband to the entire world. Frost & Sullivan projects "that communication satellites represent the fastest growing market segment (within the space industry), increasing demand for the manufacture of high-throughput and constellation communication satellites".

To surmount latency problems, the concept of low-Earth orbit (LEO) satellite services is being aggressively pursued. This envisages satellites orbiting as low as 300 kms. While needing much less rocket power to place in orbit, satellite lives will be much shorter (at about 5+ years) than that for high orbiters. Also, on account of being in such low orbits they will only be visible to end users for short intervals - like the 4-6 minutes per orbit for which the International Space Station at 400 kms can be seen periodically from Ireland.

To provide uninterrupted service, constellations of satellites must be deployed to provide constant coverage above a given point of the Earth. Continuity is provided by adjacent satellites networking with each other, typically via lasers, and synching wirelessly with users and internet gateways on the ground. Perhaps most critically, the latency problem connected with geostationary services is largely solved as signals only round trip about a thousand kms instead of seventy thousand for geostationary satellites.

Several major technology corporations are on record as exploring the possible use of LEO satellites. These include Facebook[6], Boeing, Amazon, SpaceX, Samsung, Telesat, LeoSat and OneWeb. To date, OneWeb has launched six LEO satellites (as at February 2019) and SpaceX has launched sixty (May 2019). It is likely that some of these organisations will be designated as Tier 1 ISPs with direct peering (swapping of traffic) across the entire global internet backbone.

Aside from LEO satellites, Very High-Throughput Satellites (VHTS) will also play increasing important roles in the delivery of high-speed broadband to remote areas and mobile users. While these satellites will operate in geostationary orbits, latency problems will be offset by extensive use of 'spot beam' technologies to focus their power on specific geographic areas. Key players include:

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[4] Thanks to renewable components, launch costs can be as low as US$2,500 per kilogram as compared with upwards of US$50,000 a few years ago. Technological improvements include miniturisation, use of digital comms payloads, advanced modulation schemes, multi-beam steerable antennas, sophisticated frequency reuse schemes and advanced manufacturing processes.

[5] The Space Economy in Figures: How Space Contributes to the Global Economy. OECD. July 2019.

[6] In May 2019 a Facebook-related company, PointView Tech, secured a FCC license to experiment with using high frequency millimeter-wave signals in the E-band from a LEO satellite ("Athena") for the purpose of testing whether ultra-high speed data transmission (71-86 Gbps) could be used to provide broadband to unserved and underserved areas of the world.

- Eutelsat will be launching two Konnect VHTSs being built by Thales Alenia Space later in 2019 (for Africa) and in 2021 (for Western Europe). The latter will have 500 Gbps capacity.
- Viasat is planning to launch a massive Boeing-manufactured Viasat-3 VHTS for use over Europe and Asia by 2022. It is expected to handle more than 1 Tbps of data and to offer speeds of 100+ Mbps to residential customers. Viasat claims that, once its three VHTSs have been deployed, it will be the first satellite operator offering true global broadband access.

Total throughput of planned HTS capacity over the next few years could triple current global bandwidth in space. One major distributor of satellite broadband in Europe, Bigblu Broadband, claims that it will be able to offer 100 Mbps speeds to key European markets by 2020 and 200+ Mbps by 2021.

For completeness, it should be mentioned that aside from satellites, stratospheric-based internet services using kites, balloons and drones have had only limited success in providing internet services in rural areas.

4. Key Satellite Players

The four most advanced networks for LEO satellites - Starlink (targeting 11,800 satellites), Amazon (3,236), OneWeb (1,980) and Telesat (512) - are discussed below in order to highlight their potential to provide high-speed broadband services over the coming decade.

4.1. SpaceX - Starlink

SpaceX is a private-owned company founded by Elon Musk who is also involved with Tesla e-cars and the Boring Company which plans to link major US cities by high-speed, subterranean rail links. SpaceX is a pioneering commercial space operator and is perhaps best known for developing reusable rocket stages. Starlink is its LEO program.

Starlink's website stated in September 2019 that "SpaceX is developing a low latency, broadband internet system to meet the needs of consumers across the globe. Enabled by a constellation of low Earth orbit satellites, Starlink will provide fast, reliable internet to populations with little or no connectivity, including those in rural communities and places where existing services are too expensive or unreliable."

To achieve this, Starlink plans to place almost twelve thousand satellites in orbit within the next five years to provide high-speed, low-cost broadband services to rural, remote and semi-rural communities worldwide. By way of comparison, just ten comms satellites were launched by ten separate rockets in 2016 and only about eight hundred comms satellites are currently operational.

Although somewhat US-centric, this introductory statement by the VP Satellite Government Affairs at SpaceX before the US Senate Committee on Commerce, Science and Technology on May 3rd 2017 describes the objectives and plans for Starlink. The FCC has estimated that 26% of people in rural areas in the US are not covered by terrestrial broadband services. Only about 10-20% of the Earth's landmass is covered by terrestrial cell towers.

SpaceX intends to use revenues from Starlink to help fund cargo missions to the moon (in 2021-2) and Mars (2024). To date it has raised about US$1.3 billion (mainly from Google and Fidelity) and is valued at over 33 billion dollars. The current Starlink program is expected to

initially cost about US$10 billion. SpaceX is targeting a 3% share of the projected trillion-dollar global Internet connectivity market. It expects to achieve revenues of about US$30 billion a year once Starlink is fully operational as compared with just US$3 billion a year generated by its more mature rocket and space transport operations. Analysts suggest that SpaceX could, in the medium-term, be worth anywhere between US$5 billion and US$120 billion, depending on the degree of success or failure of Starlink.

Starting in 2020, SpaceX plans to launch about 60 or more satellites per month into the middle of the next decade with a view to having 5,900 in orbit by end 2024 and the remaining 5,900 orbiting by end 2027. It aims to offer a limited service in the U.S. and Canada after six-eight successful launches each of 60 satellites. Initial coverage of the populated world should be achieved after about 24 launches have deployed 1,440 satellites. This could embrace Ireland and much of Europe by about 2021-2. A world-wide service aimed at low and medium population densities could commence once about three thousand satellites are in orbit. All additional launches will create more capacity and facilitate customised services.

In a revised plan dated August 2019, SpaceX has proposed to the FCC to broaden geographic coverage by dividing the initial 360 satellites between 72 rings (orbital planes) instead of 24 as originally envisaged. This would be achieved by using the satellites to do their own orbit changing using built-in ion engines. The intention is to provide a partial service to the entire USA by the end of the 2020 hurricane season and, more generally, provide wider geographic coverage sooner.

In May this year Starlink placed 60 version 0.9 satellites (payload of 18.5 tonnes) in orbit at 450 kms using a twice-used Falcon 9 rocket. Designated Version 0.9, these satellites lack laser interconnectivity but incorporate many significant features including miniaturisation, single solar sails and solar-powered jets. While ground contact has been lost with three satellites the remainder have propelled themselves into higher orbits at 500 kms for extensive testing with high definition video and high-bandwidth gaming.

A further 120 version 1.0 satellites may be deployed in two launches during the fourth quarter 2019.

By every measure, Starlink is the most advanced network and the most immediately relevant to rural Ireland. More detailed information about Starlink is presented in an Appendix.

4.2. Amazon - Kuiper

In April 2019 Amazon announced that its Project Kuiper (no web presence) would enter the internet satellite business and in July 2019 it filed an application with the FCC to put 3,236 satellites, operating in the Ka frequency band, into low-Earth orbit to target the four billion people in the world without broadband connections.

The proposed service will be confined to mid-latitudes with the satellites grouped in 98 different orbital planes within three orbital shells at 590, 610 and 630 km. Amazon expects, all going well, that it will offer services, sometime in the next few years, once it its first group of 578 satellites are in working orbits. Currently, its “constellation design and implementation plan are well-developed, and Amazon continues to mature its satellite design and operational procedures”.

Little detailed information is available on the design of Kuiper’s satellites which will have a 10-year life and even less is known about its launch plans. However, it should be noted that

Jeff Bezos (CEO and founder of Amazon) is developing the New Shepard reusable rocket through his Blue Origin space transport company.

4.3. OneWeb

UK-based OneWeb is backed by Japan's Softbank and Branson's Virgin Group. It has raised US$3.4 billion in pursuit of its objective to become a global communications business utilising LEO satellites. It aims to provide internet services to rural and remote places as well as to a range of markets including aero, maritime and cellular backhaul. Its plans call for an initial constellation of 648 satellites with 600 actives and 48 on-orbit spares orbiting at1,200 kms in 12 planes. The number could grow to 1,980. Ground equipment could comprise fifty or so gateways each with up to ten antennas. Because OneWeb will not be using inter-satellite links, services will only be offered in regions where users and ground stations are simultaneously within line-of-sight of satellites.

OneWeb has contracted Airbus to construct its satellites and has launch deals with Virgin Galactic and Arianespace to use 21 Suyez rockets each carrying over thirty satellites.

On February 27, 2019, OneWeb successfully launched its first six, washing machine-sized satellites into low-Earth orbit from French Guiana using a Russian Suyez rocket. Initial testing under 'ideal' conditions has achieved data speeds of up to 400 Mbps and a latency time averaging 32 milliseconds.

In September 2019, OneWeb sought FCC approval for up to 1.5 million customer terminals with 18-inch wide antennas.

OneWeb plans to launch 30 satellites per month starting in late 2019. It expects to deliver a partial service in 2020 in Artic areas and a fully functioning commercial one in 2021. Provision of rural broadband to domestic consumers may not be highest priority for OneWeb.

4.4. Telesat

The Ottawa-based Telesat is mentioned here specifically because it has reached an agreement with the Canadian government to bring high-speed broadband to the country's one million most remote citizens.

Telesat will deploy 300 LEO satellites to provide a global service by 2022-3 starting with download speeds of 50 Mbps and eventually reaching gigabit speeds. The satellites will be placed in polar and inclined orbits at a thousand kilometres from the Earth and will utilise about fifty Earth stations worldwide with about two hundred 3.5 metre antennas.

The Canadian government intends to buy capacity for ten years at a reported cost of CAN$600 million and to invest CAN$85 million in Telesat's R&D. It is anticipated that the satellites will be manufactured in Canada.

5. Developments to Date

5.1. EU Targets

Published in 2010, the Europe 2020 Strategy (EU2020) and the related Digital Agenda for Europe (DAE) initiative highlighted the importance of broadband deployment to promote competitiveness, social inclusion and employment. These set the following targets for broadband development in Europe:

i. Bring basic broadband access to all Europeans by 2013.

ii. All Europeans to have access to internet speeds above 30 Mbps by 2020 and for 50% or more of the European households to have internet connections above 100 Mbps by then.

In 2016, the Commission adopted the Communication Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society. It further developed the DAE and defined the following strategic objectives for 2025:

i. 100% coverage of all households with download speeds of at least 100 Mbps, upgradeable to 1 Gbps.

ii. One Gbps symmetric speeds for all main socio-economic drivers such as schools, transport hubs and main providers of public services as well as digitally intensive enterprises.

iii. Uninterrupted 5G coverage for all urban areas and all major terrestrial transport paths (as intermediate objective for 2020: 5G connectivity available as a fully-fledged commercial service in at least one major city in each Member State, building on commercial introduction in 2018).

5.2. EU & Satellite Broadband

A key EU document giving Guidelines for the application of State aid rules in relation to the rapid deployment of broadband networks treated satellite systems as "basic broadband networks" rather than Next Generation Access (NGA) networks at which State aid should be directed. Published in 2013 and still applicable in 2019, it viewed NGA networks as being fibre-based, advanced cable or advanced wireless and it presumed that the provision of high-speed broadband would entrail very substantial and costly civil works.

Certainly, satellite broadband would have been justifiably considered very 'basic' back in 2013 and recent developments and plans for high-speed broadband by satellite could not have been anticipated when these guidelines were being prepared. Presumably, the EU will update its view once high-speed broadband via next-generation satellites starts becoming widely available.

The EU's DG Connect's team has confirmed in recent correspondence that low-Earth orbit satellites and Very high Throughput Satellites have not been "considered in detail so far, because they must first prove their functionality in the provision of high-speed broadband to rural and underserved semi-urban areas. But they are considered under possible upcoming

future technologies". Specifically, it has classified LEO satellites as a potential new technology for the delivery of broadband[7].

It is worth recording that the EU had proclaimed (in about 2014 or 2015) in a Digital Single Market policy statement ("Broadband for all via satellite") that "satellite broadband is available to provide fast internet connectivity throughout every European Member State" at a time when last-generation geostationary satellites were offering download speeds of about 22 Mbps.

5.3. NBP's Development

The NBP was conceived back in 2012 as a limited fibre-based rural broadband service. Since then, it mushroomed into an all-compassing universal service costing about €5 billion to develop. The plan will have a life of at least 25 years and envisages that fibre will be laid to pass 540,000 rural premises by 2027.

NBP planners have pursued a completely fibre-based solution albeit consideration was given to 4G/5G mobile as an alternative solution as per a report FTTP or 4G/5G for Ireland's NBP? dated 5th December 2018 and published by the Department of Communications, Climate Action and Environment (DCCAE) along with other background documents in May 2019.

No consideration appears to have been given by planners to satellite broadband. In its press release dated 7th May 2019, the DCCAE referenced the need for future proofing based on the EC's strategic document Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society (cited above). This made no reference to satellite broadband. Also referenced in the same press release was a ComReg report entitled Meeting Consumers' Connectivity Needs. Dated November 2018, this report made a single reference (page 53) to last-generation satellite networks which are currently available in Ireland albeit with restricted performances.

Whilst the NBP planners have pursued a technology-neutral approach, they have focused on a fibre solution and have not considered emerging new satellite-based alternatives either standalone or complementary to a fibre-based network. Also, the proposed NBP technology has been driven by suppliers which are exclusively engaged in delivery of terrestrial services (via fibre, ADSL etc.). And, in fairness, the potential of satellite broadband wouldn't have been high on any broadband planner's agenda until very recently.

The estimated cost of providing fibre to pass 540,000 rural premises will be about €5 billion, including an Exchequer subsidy of about €2.5 billion net of VAT. On this basis, the cost per premise passed would be about €9,000. Assuming a 30% uptake of services, the subsidy equates to about €15,000 per subscriber.

The EU's criteria for NGA networks have been carried through into the NBP's Criteria for assessment of investment plans (prepared in 2015 but still applicable in 2019) where the detailed technical assessments focused on wired and wireless platforms, the physical roll-out of the network and deployment of substantial managerial and contracted resources. Obviously, much of this activity would be irrelevant to a next-gen satellite-based network as national availability would be instantaneous once satellite constellations embracing Ireland have been fully deployed.

[7] Digital Single Market – Broadband Technologies.

The NBP's Intervention Area and premises to be passed by State-aided fibre is currently being defined by a detailed Departmental mapping exercise[8] and will be incorporated in the proposed NBP contract. Premises will be excluded from the Intervention Area where service providers undertake to provide broadband to premises/areas within the next seven years in line with the technical criteria set out in the EU's Digital Agenda for Europe, namely a minimum down/up speeds of 30/6 Mbps, rather than the more ambitious targets set out in Towards a European Gigabit Society. Nonetheless, the Government's preferred bidder for the NBP contract has indicated that, using predominately fibre-to-the-premises, it will offer basic connections to households in the Intervention Area of 150 Mbps from the outset, rising to 500 Mbps after ten years, as well as business connections of up to 1Gbps.

The departmental mapping exercise has made no provision for any possible encroachment by future new entrants such as satellite broadband services. Apparently, the proposed NBP operator could be compensated by taxpayers where it loses prospective customers who opt to receive broadband via satellite or other new unanticipated service providers.

Finally, it is ironic that having passed over Fixed Wireless Access and 5G, the NBP intends to deploy wireless to provide broadband to 350 key strategic community points within the first twelve months following signing of the NBP contract. A spokesman for a consortium member told the Sunday Business Post (8th September 2019) that "this is wireless, which is kind of funny to be starting the NBP by rolling out wireless points, but it's bringing broadband connectivity to parts of the country that haven't had it. As fibre gets rolled out, these will be removed".

6. Future Role for Satellites

In February 2018 the OECD published Bridging the Rural Digital Divide which recognised satellites as "a key technology for providing rural and remote broadband access". This referenced an earlier OECD technical report entitled The Evolving Role of Satellite Networks in Rural and Remote Broadband Access. Although published back in December 2016, and in need of a major update, the latter delved into the potentially significant roles of low- and middle-Earth orbit satellites and referenced several proposed systems including SpaceX's Starlink.

The main targets for next generation satellite services will be unserved and underserved regions within both developed and underdeveloped countries; communities in inaccessible locations; and ships, aircraft and other mobile assets. According to the UN's State of Broadband Report for 2018, 49% of the world's population have access to reliable, affordable broadband. Regional variations range from 80% for Europe to 22% for Africa. Definitions of acceptable broadband speeds range from 25 Mbps by the FCC in the US to lower benchmarks used by the UN.

The imminence of new technologies for broadband delivery cannot be ignored in Ireland. By the mid-2020s, the total number of operational comms satellites will have increased tenfold from the current eight hundred; many major internet, space and comms corporations will be offering competing services; billions will have been invested in satellite broadband services to address unserved and underserved users worldwide; and surging satellite technology developments and break throughs will further enhance satellite performances and applications.

[8] NBP Mapping Consultation.

Whilst it is very early days for satellite broadband, the pace of development is undoubtedly accelerating at the very same time that the NBP is rolling out its fibre network and incurring major fixed costs.

In judging the future, it is important to bear in mind the impact of increases in microprocessor power on satellite technologies and that new generations of mobile technology seem to appear every ten years (roughly). At the same time, it is essential to avoid excessive overreliance on any single new technology as some new technologies and solutions get over-hyped, disappear without trace and are overtaken by newer, better technologies. It is worth noting that, when first proposed in the nineties, several LEO system plans were cancelled even before launch (e.g. Teledesic, Celestri, Skybridge) and others declared bankrupt after commencing operations (e.g. Iridium, Globalstar, Orbcomm). Looking ahead, the next gen LEO satellite industry could hit a funding inflection point within the next few years as up to US$40 billion of risk capital will be needed to realise all proposed services.

For discussion purposes, here are two diametrically opposite and extreme views of satellite broadband from an Irish perspective:

1. Starlink and its competitors will be successful in delivering world-wide broadband on time, to the required performance standards and at competitive prices to users. If adopted in Ireland, its service would require no funding by Irish taxpayers; would offer all the benefits, without the costs, as set out in the NBP cost/benefit analyses; would be deliverable without any Irish intervention or Exchequer funding; and would become a competitive and disruptive alternative to the NBP's service.
2. Starlink and its competitors will all run into major technical problems; their fund-raising will be disrupted; performances will be inferior and major delays in offering services will be encountered leading to considerable doubt and uncertainty about satellite broadband.

The middle-ground view might be that full-scale satellite services will become available, with acceptable performances and pricing somewhat more slowly than expected. However, their progress will clearly demonstrate their potential to provide full-scale services well inside the next decade.

Set against that view are the facts that the current NBP would be the biggest capital project undertaken in the State (costing over half the expected cost of the Starlink program); is widely accepted as entailing considerable financial and operational risk; requires a net injection of €2.5 billion by the State in addition to substantial private funding; offers marginal value-for-money based on detailed cost-benefit analyses; and entails a multi-year construction phase.

During the NBP's 25+ year operational phase, the performances of digital technologies could increase by a factor of hundreds or thousands and mobile tech could be entering its G7 generation. This technological progression could pose major challenges to fixed fibre services as has already happened in the case of traditional telephone lines and fax.

7. Recommendations & Plan B

7.1. Recommendations

Based on the foregoing assessments of satellite broadband plans and bearing in mind that the NBP has already been evolving for seven years, this report aims to make a compelling case for

the Government to commission an independent review of the potential of satellite broadband before committing to an entirely fibre-based NBP for the next three decades.

At worst, this review might delay implementation of the NBP by months and, at best, it could lead to the NBP's underlying objectives being achieved at a much lower Exchequer cost and in line with or even ahead of existing timelines.

Our central recommendation is that the Government should commission independent experts in space communication technologies and space economics to update the already cited OECD's report on The Evolving Role of Satellite Networks in Rural and Remote Broadband Access from an Irish perspective and to critically examine short-medium term plans by satellite broadband service providers (deploying low-Earth orbit and high-throughput satellites) and to assess of their likely impact on Ireland.

Other specific recommendations to Government are as follows:

1. For completeness and to avoid excluding any alternatives to satellite, an independent study should be undertaken to assess the potential of advanced Fixed Wireless Access (FWA) to provide rural broadband services at moderate costs and with acceptable contention rates and up/down speeds particularly at peak usage times. This work should involve consultation with ComReg and the DCCAE as regards spectrum allocations and would help clarify the extent to which satellite broadband and FWA would be complementary or competing within the Intervention Area.

2. It would be beneficial for key agencies involved in the NBP to tap in local satellite-related expertise including the Space Enterprise Coordination Group being formed under the auspices of the Department of Business, Enterprise and Innovation; National Space Centre (independent teleport operator near Midleton, Co Cork); Arralis (developer of beam steering antennas based in Limerick); Taoglas (antenna specialist based in Wexford); and space-related technology departments within higher education and research institutes.

3. In parallel with the foregoing external studies, relevant departments and agencies should closely monitor fast-moving developments in satellite broadband. And, State agencies like the IDA should be vigilant to employment opportunities arising from the need to mass produce thousands of highly complex satellites every year; satellite Earth gateways that would benefit from proximity to data centres in Ireland; demand for millions of high tech antennas; and provision of financial services to commercial space operators.

7.2. Plan B for NBP

In theory and *in extremis*, it would be possible to suspend the entire NBP until satellite broadband becomes fully commercial at moderate costs and with proven performances. Exchequer support might be limited to, say, subsidisation, at a cost of tens of millions, of user antennas to incentivise uptake. This approach would be very high risk and politically, economically and socially unacceptable even though the benefit/cost ratio would be almost infinite.

More realistically and assuming a relatively positive outcome from the recommended technology study, a practical next step would be to develop a multi-tech approach embracing fibre, satellite, wireless and 4G/5G technologies. It is possible to envisage that this would offer

the NBP's full benefits while dramatically scaling back timelines, and altering roll-out strategies and timing, costs, contractual arrangements, structures and Exchequer funding/ownership as summarised in the table below. This should also include a *value-for-money* review of so-called "red lines", e.g. coverage, speed, service levels with a view to securing optimal flexibility and realism having regard to demand/needs and limited funding.

The key elements of this alternative approach to the NBP can be summarised as follows:

1. Proceed immediately to roll-out fibre to the 1,000+ broadband connection points as proposed by the NBP and interdepartmental reviews. This could be done most quickly by setting up a State-funded Special Purpose Vehicle and inviting tenders from existing telcos, ISPs etc. on a concession basis.
2. In parallel, undertake independent, expert studies to confirm the potential of emerging satellite-based and fixed wireless broadband services to complement fibre in rural areas. This work would need the services of specialists in space communications/economics and could be appended to the Oireachtas Committee's Recommendation #2 urging the Government to commission an external, independent review of the NBP.
3. Roll-out high-speed broadband nationally using a combination of fibre, satellite, 4G/5G and fixed wireless with the latter two technologies being used for more remote premises. Whilst this would entail a fundamental restructuring and re-orientation of the NBP, its mission should be completed more quickly and at lower overall cost than proposed in the current NBP.

These elements are expanded on in the table and footnotes overleaf:

Phase	Intervention Areas	Main Technologies (Possible Order of Importance)[2]	Premises Passed	Exchequer Contribution	Key Orgs	Timing Years
1[1]	300 broadband connection points (BCP/PoPs)	Fibre	N/A	Modest[4]	Public	1-2
2[1]	Additional 1,000 BCP/PoPs	Fibre	N/A	Modest[4]	Public	2-3
2	Less remote	Fibre/Fixed Wireless/Satellite	c.270k[3]	Moderate[5]	Public/ Private	2-3[6]
3	Most remote	Satellite/Fixed Wireless/Mobile	c.270k	Minimal[5]	Private	3-5

1. These phases could be State funded/owned and accessible to private broadband service providers on a concession basis for building out using fibre and/or fixed wireless.
2. Final order of importance would be based on geography and cost, performance and technical progress by fixed wireless and satellite broadband.
3. Takes no account of premises within the intervention area already receiving, or potentially getting, broadband via fixed wireless from regional WISPs or fibre through national operators. ComReg has estimated that many of the 47k premises currently using fixed wireless are located in rural areas. The general expectation is that this number will increase significantly as technology develops and private WISP operators step up their operations using 'fibre to the tower' along with 'wireless to the home'.
4. Based on the cost estimate of less than one hundred million euro for "Plan Z" developed by the DCCAE and DPER to provide fibre to 1,800 key sites for an initial five years – see appendix to Briefing on the National Broadband Plan for Meeting with Minister Bruton dated 21st February 2019.
5. For details about proposals for Exchequer support towards the expansion of next-generation Fixed Wireless Access broadband services, see submission to the Oireachtas Committee by the Regional Internet Service Providers Association which seeks a combination of moderate capital grants, subsidies and loan supports to achieve full coverage within the intervention area.
   In the case of satellite, an Exchequer contribution towards the initial high cost of antennas of €200 per user might cost the Exchequer a once-off twenty million euro if, say, a hundred thousand users opt for satellite broadband.
6. Assumes that commercial satellite broadband becomes available in Ireland by early/mid-twenties.

This approach opens up additional options to complement those explored in a detailed paper entitled Contingency Plan Options 2019 prepared by the DCCAE following discussions with the DPER. This considered three "Plan B" options as follows:

- A phased approach to the provision of fibre services based on experiences in two selected deployment areas.
- Separate build and operate contracts within a €1 billion budget.
- Subsidised rollout of fibre to multiple locations in order to provide backhaul facilities for commercial operators who would deliver broadband locally.

This departmental "Plan B" did not consider satellite broadband and almost all key financial and related data was heavily redacted in the published version.

8. Conclusion

In summary, **Plan B for the NBP** proposes the immediate build-out of fibre to about 1,300 broadband connection points. This would be followed by the provision of further fibre for additional connectivity and backhaul alongside the deployment of emerging satellite and fixed wireless broadband technologies to service individual premises. The objective would be to achieve complete rural coverage to an optimal standard and at a moderate cost to the Exchequer.

It is entirely possible that celestial-based broadband services will eventually become serious, long-term disruptors/alternatives to fibre-based services for rural households just as has already happened with mobiles vs. landlines and satellite-based GPS vs. paper maps. Obviously, fibre should continue, for the foreseeable future, to be the preferred option for high-intensity users such as schools, SMEs, libraries, backhaul etc.

It is inexplicable that our heavily-borrowed State would spend up to €2.5 billion on a 25+year technology-related project when emerging new solutions could undermine the NBP's finances and plans within a matter of years. While some limited State funding might be desirable towards the cost of accessing Very High-Throughput Satellite spot-beam services, subsidising user antennas for satellites and fixed wireless by means of vouchers and possibly contributing towards a limited fixed wireless infrastructure, the total cost would be a small fraction of the €5 billion to be expended on the NBP.

Given that the NBP has been in gestation for several years, that almost €30 million has been expended on external advice to date and that execution could cost the Exchequer well over €2 billion, the Government is urged to make a modest investment to facilitate independent, detailed assessment of the proposals in this report.

Rural Ireland needs, arguably even more than urban Ireland, access to the benefits of high-quality, universal broadband services. Hopefully, this report contributes to this objective while offering a cost-effective solution.

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Plan B for the NBP *has been compiled by Brian Flanagan who has been concerned about aspects of the NBP and the state of public finances and services generally. He completely favours the extension of broadband throughout rural Ireland but has reservations about the pre-eminent role of fibre in the NBP on cost grounds and from a technological perspective. His letters published in the Irish Times in May and August 2019 reflected these concerns.*

Brian is semi-retired having worked as a management consultant for about four decades. He is an Honorary Fellow of the Institute of Management Consultants and Advisers in Ireland. His consulting experience has embraced business planning, operational reviews, financial modelling and strategic planning with start-ups, SMEs, larger businesses and incubators. In addition to consulting, he has operated an internet-based business developing and selling business planning tools to users in about 120 countries. He has no links to any commercial interests discussed in this report.

Appendix – Supplementary Starlink Details

These forward-looking and speculative observations about SpaceX's Starlink have been derived from media reports, company statements, interviews and multiple other sources. Some details are also likely to apply in one form or another to competing services.

- The Federal Communications Commission has given SpaceX permission to launch 11,800 Starlink satellites to operate in the Ku-band (11-14 GHz) and Ka-band (17-31 GHz) spectrums in orbits ranging from 335 to 1,325 kilometres. Outside the US, SpaceX is working country-by-country to secure regulatory approvals, including Australia where a national broadband plan is being implemented.
- In October 2019, SpaceX filed for spectrum rights from the International Telecommunications Union for an additional tranche of 30,000 LEO satellites. If accepted, this application would give SpaceX seven years in which to bring requested frequencies into use by launching and operating at least one satellite. SpaceX stated that "as demand escalates for fast, reliable internet around the world, especially for those where connectivity is non-existent, too expensive or unreliable, SpaceX is taking steps to responsibly scale Starlink's total network capacity and data density to meet the growth in users' anticipated needs."
- Morgan Stanley Research has estimated it currently costs about US$50 million to launch 60 satellites, each weighing 227 kilograms and costing about US$1 million, using a partly reusable Falcon 9 rocket. In later years, SpaceX's Falcon Heavy (about 200 satellites per launch) or even the fully reusable Starship Super Heavy (400 satellites) vehicles could slash launch costs to just labour, recovery, refurbishment and propellent.
- Ground equipment for Starlink will comprise a small number of control stations with 5-metre antennas plus over a hundred ground stations, containing thousands of gateway antennas, distributed globally and close to or co-located with major internet peering points.
- End users will access Starlink using terminals incorporating externally-mounted phased-array, beam-forming antennas about the size and shape of a pizza box. Mounted externally on walls or even vehicles, the antennas are software-driven, contain no moving parts and are not directional. The initial manufacturing cost could be about US$300-500 per unit (as compared with US$100,000 when first developed) and should drop sharply once mass production commences.
- The domestic installation of user terminals will be like that for existing satellite services except that antennas will not need to be aligned. Aside from an antenna, a terminal could have a built-in WiFi router along with software for operations, flight, antenna and modem control. A 'Starlink Mobile' app is being developed to monitor devices and performances, and for account access and billing.
- Each full-operational Starlink satellite will use four laser-based, inter-satellite links (ISL) to minimise overall latency especially for long-distance traffic. However, initial versions will have higher latency and lower throughput as they will lack ISLs and use 'bent pipe' communications.
- Once Starlink's ISLs are operational, maximum bandwidth per satellite could be about 20 Gbps (equivalent to four thousand users simultaneously streaming 4K videos) shared between about eight shapeable, steerable beams each with service areas of about 2,500

square kms. Technical assessments[9] suggest that Ireland at 53 degrees would always have about 40 satellites within 'line-of-sight' once Starlink is fully operational. That equates to about 800 Gbps of bandwidth. These performance projections are highly indicative, and it is unclear as to how they will translate into bandwidth available per user in rural Ireland.

- Simulations[10] suggest that Starlink communications greater than 3,000 kilometres will be twice as fast as through terrestrial fibre cable because signals will use line-of-sight, travel much more quickly in space and pass through fewer nodes. This could open a premium market for Starlink amongst financial institutions engaged in global trading.
- Starlink's worldwide throughput could exceed 20,000 Gbps based on up to 300 ground stations and about 3,500 gateway antennas. As a point of reference, the world's total internet capacity was about 400,000 Gbps in 2018.
- Starlink will initially target rural and remote areas on account of the limited number of orbiting satellites. SpaceX claims that it will ultimately offer download speeds of up to one Gbps per user with latency of under 20 milliseconds. Data throughput at 610 Mbps to an inflight aircraft was recently achieved using the test satellites launched in May 2019.
- Starlink performances and services will expand, in an increasingly competitive marketplace, as technologies are upgraded 'on the fly' and additional satellites are launched. In addition, satellites will be de-orbited every five or so years and replaced by more powerful versions.
- SpaceX plans to transform Starlink from a tech company into a consumer business. While pricing, packages and billing arrangements for Starlink have not yet been disclosed, speculation suggests that pricing will be competitive with terrestrial networks. Packages could be offered directly to consumers by SpaceX which could undertake its own billing and use DIY or local partners for the installation of user terminals/antennas.
- Starlink satellites will incorporate collision avoidance mechanisms to help counter any occurrence of the Kessler Syndrome and they will be capable of being de-orbited remotely using on-board propulsion systems and achieving 100% destruction on re-entry.
- Unresolved but soluble issues about Starlink (and other LEO satellite broadband services) include the impact of satellite swarms on night sky brightness and astronomical observations; unexpected collisions with debris and other satellites; blocking of signals by governments; effectiveness of full-scale inter-satellite links; initial cost of user terminals; and signal interference between competing systems.

[9] A Technical Comparison of Three Low-Earth Orbit Satellite Constellation Systems to Provide Global Broadband. Del Portillo, Cameron & Crawley. Massachusetts Institute of Technology. 1st October 2018.

[10] Simulating Starlink. Mark Hanley. Systems and Networks Research Group. University College London. A video based on the simulations here. It generated the graphic used on this report's cover.