Integrating Satellite and Mobil Networks

Panel Discussion

Jet Propulsion Laboratory
California Institute of Technology

Discussion Topics

- Salvador Marti – European Space Agency
  - Satellite/5G: collaboration and competition
  - Operations of Constellation – Would AI operate satellite in the future?
- Giovanni Giambene – University of Siena
  - Satellite 5G: architecture, Mega LEOs, roadmap activities
- Phil Krix – Nova Systems
  - LEO/MEO Gateways
- Timothy Pham – Jet Propulsion Laboratory
  - Constellations debris?
  - Global handset?

Constellations Debris?

- Starlink (https://www.businessinsider.com/spacex-starlink-microsat-launch-global-internet-2018-2?r=US&IR=T)
  - In the coming years, the company hopes to launch 4,425 interlinked broadband-internet satellites into orbit some 700 to 800 miles above Earth, plus another 7,500 spacecraft into lower orbits.
  - About 1,740 active satellites orbit Earth, according to a database compiled by the Union of Concerned Scientists, and roughly 2,600 dead satellites are probably floating in space. But even adding those together, SpaceX's planned fleet of about 12,000 satellites would be nearly three times as large.

- What happens if business closes? Would satcom company be obligated to de-orbit their satellites?

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5G Global Handset?

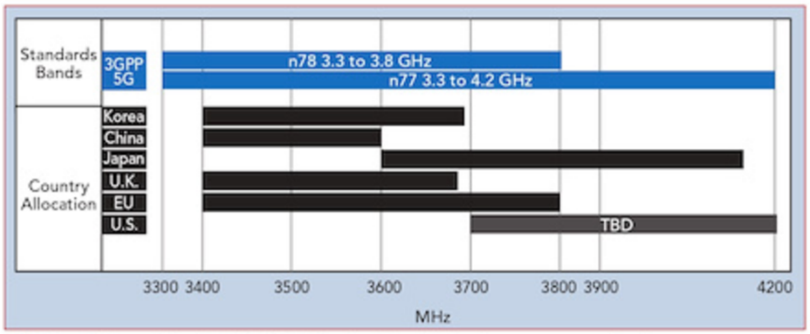

Fig. 2 Use of the "global" n77 and n78 mid-band spectrum varies by country.

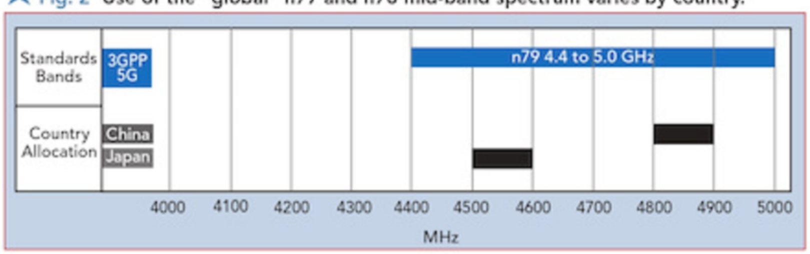

Fig. 3 China and Japan plan to use small and different portions of the n79 band.

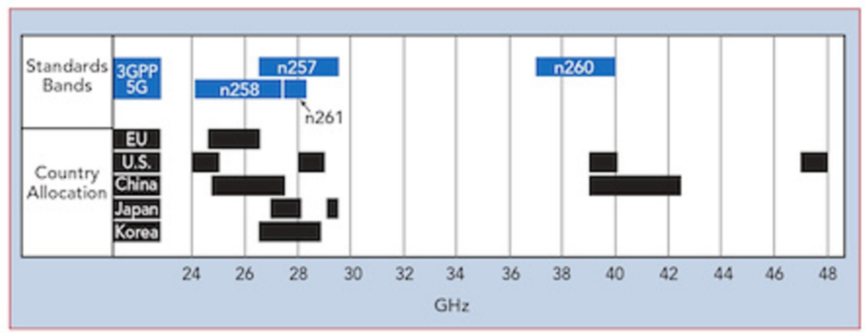

Fig. 4 Use of the mmWave 5G bands will also be fragmented by country.

[B. Thomas, Global 5G Rush but No Global 5G handsets, http://digital.microwavejournal.com/?issueID=16&pageID=101](http://digital.microwavejournal.com/?issueID=16&pageID=101)

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Satellite 5G

Panel on Space Communications

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Introduction

Recent activity on satellite communications:

- **Participant to the SatNex IV project financed by ESA (https://satnex4.org/)**
  - Coordinator, Prof. Ana Perez, CTTC, Spain

- **Participant to Satellite 5G Roadmap WG of IEEE (https://futurenetworks.ieee.org/roadmap/)**
  - Chair, Dr. Sastri Kota, email: sastri.kota@gmail.com

5G KPIs

- We can consider a set of quantitative Key Performance Indicators (KPI) for 5G that have been proposed by 5G-PPP (https://5g-ppp.eu/kpis/) and that have been widely accepted by industry and academia:
  - 1000 times higher mobile data volume per geographical area.
  - 10 to 100 times more connected devices.
  - 10 times to 100 times higher typical user data rate.
  - 10 times lower energy consumption.
  - End-to-End latency of < 1ms.
  - Ubiquitous 5G access including in low density areas.

A Vision on 'Satellite for 5G' by ESA

- Satellite communications will play a key role in the deployment and full realization of 5G
- Terrestrial and satellite solutions complement each other
- New developments in the satellite communications ecosystem have overcome previous limitations.
  - The introduction of very High Throughput Satellites (HTS)
  - New generation of Low Earth Orbit (LEO) constellations that dramatically reduce latency in satellite communications.
- As a result, satcoms has narrowed the gap with terrestrial counterparts, resulting in competitive solutions.
- There is the need for unified management and operation of hybrid terrestrial-satellite 5G networks.
- It would be important to define integrated SDN/NVF-enabled system architectures to allow the efficient delivery of Machine to Machine/Internet of Things and future 5G services, such as media and entertainment.

https://artes.esa.int/news/new-artes-funded-whitepaper-looks-role-satcoms-5g-context

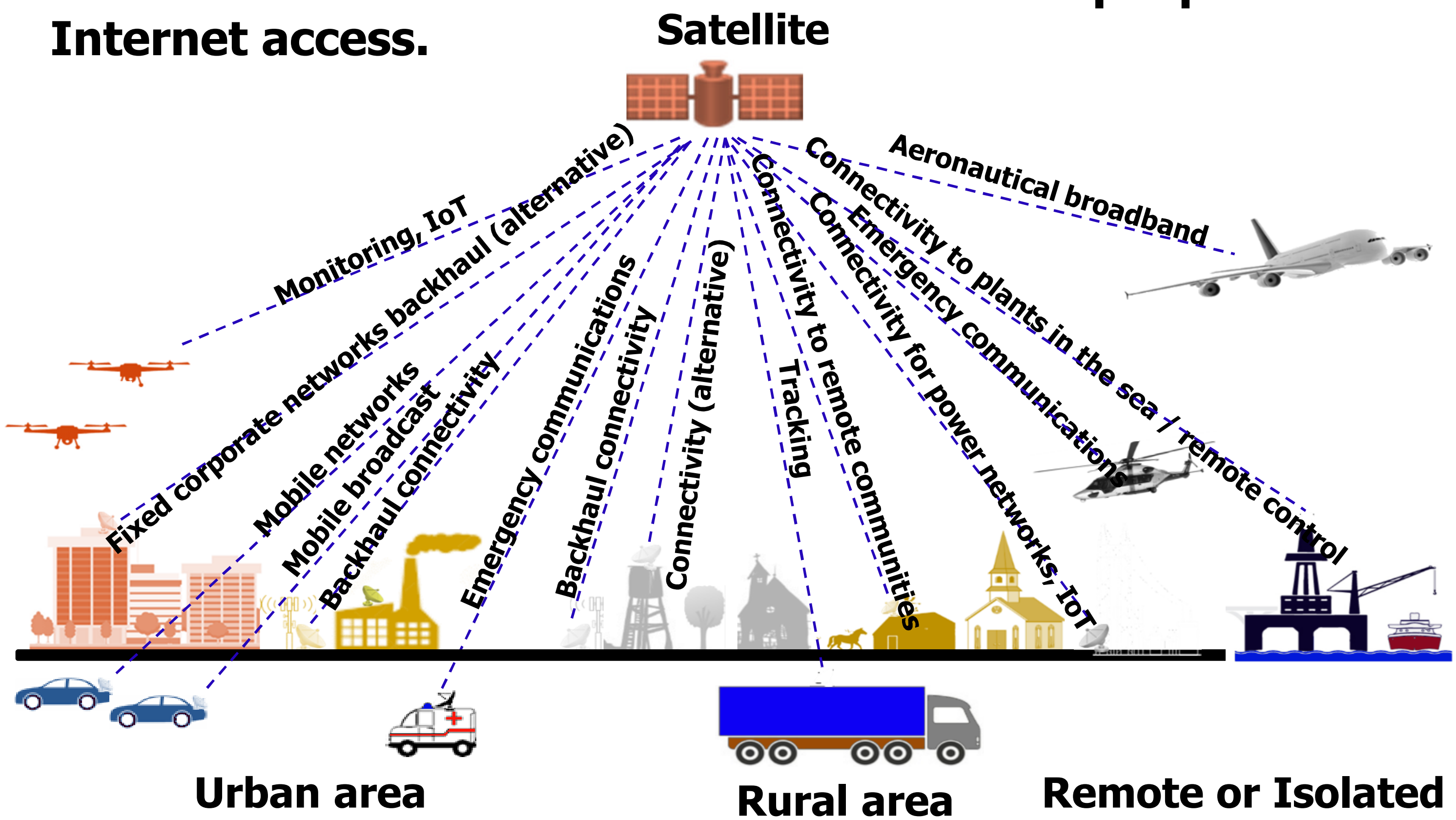
Enabling Technologies for Satellite 5G

- Use of new bands at high frequencies (Q/V/W)
- Precoding for full-frequency reuse
- Beam-hopping
- MIMO
- New waveforms and new multiple access schemes
- Network coding for reliability and multicast applications
- PEPs for transport layer acceleration
- Network virtualization (control plane)
- New mega LEO satellite constellations (e.g., LeoSat, OneWeb, SpaceX)
- Possible use of HAPs.

G. Giambene, S. Kota, P. Pillai, "Satellite - 5G Integration: A Network Perspective", IEEE Network, September/October 2018, pp. 25-31, No. 5, DOI: 10.1109/MNET.2018.1800037

5G via Satellite, Possible Scenarios

- Recent studies estimate that about 4 billion people still lack Internet access.



Report on "World Internet Users Statistics and 2018 World Population Stats", available at the following URL [retrieved: March, 2019]: https://www.internetworldstats.com/stats.htm

Identified Use Cases for Satellite 5G

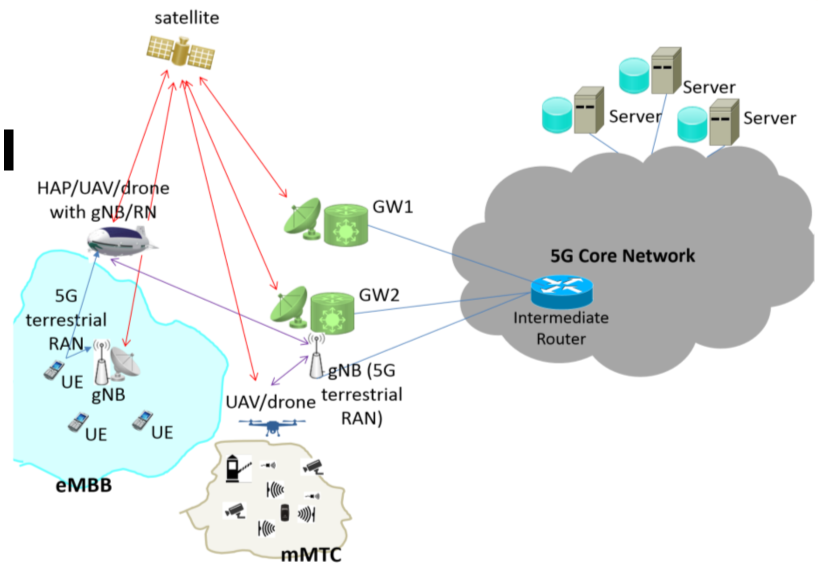
5G is expected to deliver services at unprecedented bit-rate and quality of service levels.

We have eMBB (Enhanced Mobile BroadBand), mMTC (massive Machine-Type Communications) and Ultra Reliable Low Latency (URLL) scenarios with the following applications and services:

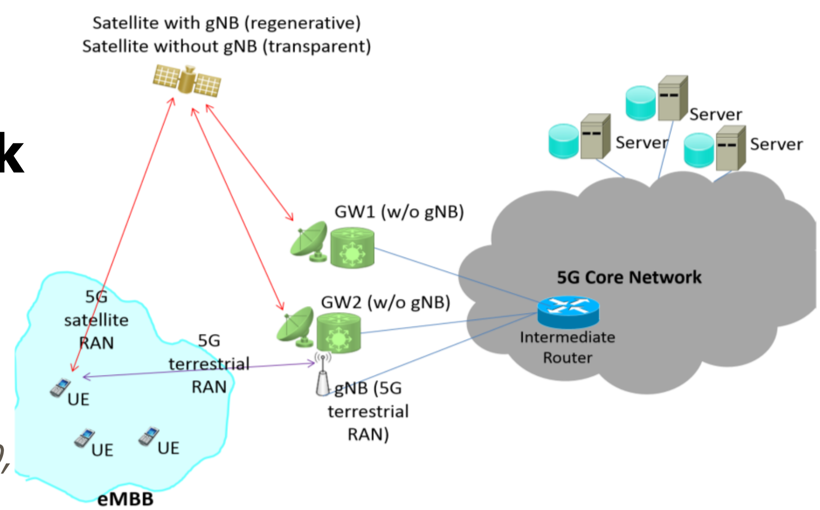
- **Satellite for eMBB**: Users in underserved areas, passengers on board vessels or aircrafts, deploy or restore (disaster relief) 5G service, emergency communications, Media, and entertainment content broadcasts, Passengers on board public transport vehicles.
- **Satellite for mMTC**: Global continuity of service for telematic applications based on a group of sensors/actuators. Services for rural areas.
- **Ultra Reliable Low Latency (URLL)**, only for availability and reliability aspects.

Satellite 5G Architectural Alternatives

- The satellite providing the backhaul connection for a local terrestrial 5G RAN.



- The satellite providing a RAN (the satellite can act as a gNB if it has on-board processing capabilities) with direct 5G link to mobile users.



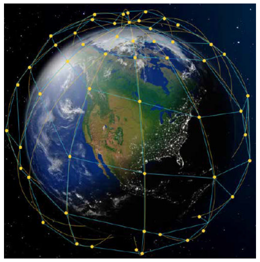
New Satellite Systems

- A High Throughput Satellite (HTS) has many times the throughput of a traditional Fixed Satellite System (FSS) for the same amount of allocated frequency in orbit. These GEO satellites can take advantage of full frequency reuse (channel estimation and precoding) among multiple spot-beams to increase the throughput.
-
  - **ViaSat-2** is a commercial-communication GEO HTS with a throughput of 300 Gbit/s.

- The propagation delay from a GEO satellite to the earth is about 256 ms.

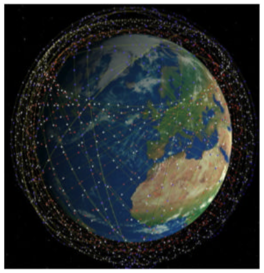
New Satellite Systems (cont'd)

- Mega-LEO satellite constellations are being developed with services foreseen by 2020. A dedicated terrestrial network of GW is needed and, in some cases, inter-satellite links allow the direct exchange of data among neighbor satellites in the sky. The frequencies currently adopted are in Ku and Ka bands, but higher frequency bands (Q/V/W) will be used in the future.
  - **LeoSat** entails 78-108 high-throughput Ka (26.5 to 40 GHz) band satellites in LEO polar circular orbits at an altitude of approximately 1,400 km. One terminal can use a bandwidth of up to 500 MHz on both uplink and downlink. Satellites can communicate each other via optical inter-satellite links.



  - **OneWeb** system consists of a constellation of 720 LEO satellites in near-polar circular orbits at an altitude of 1,200 km. OneWeb will provide the users with high speed up to 50 Mbit/s and low latency lower than 50 ms. OneWeb has recently launched with success the first 6 satellites of its constellation.

  - The **Starlink** system consists of two LEO sub-constellations of satellites. A first LEO constellation is composed of 4,425 satellites in Ku (12 to 18 GHz) and Ka bands at an altitudes of 1,110 km. The second component will be based on another LEO constellation operating in the V (40 to 75 GHz) band, comprising 7,518 satellites at altitudes around 340 km.



A Survey of Satellite 5G Projects in Europe

- **EU H2020 projects:**
  - Shared Access Terrestrial-Satellite Backhaul Network enabled by Smart Antennas (SANSA) project has envisaged seamless integration of the satellite segment to boost the performance of mobile wireless networks.
  - Virtualized Hybrid Satellite-Terrestrial Systems for Resilient and Flexible Future Networks (VITAL) project proposed novel ways of using **network functions virtualization (NFV) and software-defined networking (SDN)** for federated satellite-terrestrial networks.
  - Sat5G project is also looking at implementing 5G SDN and NFV in satellite networks.
- **ESA projects:**
  - CloudSat project also addressed key issues for the inclusion of a satellite component in future federated 5G virtualized networks.
  - SATis5 project aims to build a comprehensive 5G testbed **to demonstrate the feasibility of satellite 5G.**
  - The European Space Agency (ESA) launched the Satellite for 5G initiative (ARTES framework) encompassing development projects, service trials, and testbeds for the achievement of the satellite 5G component.

Satellite 5G Standardization Activities

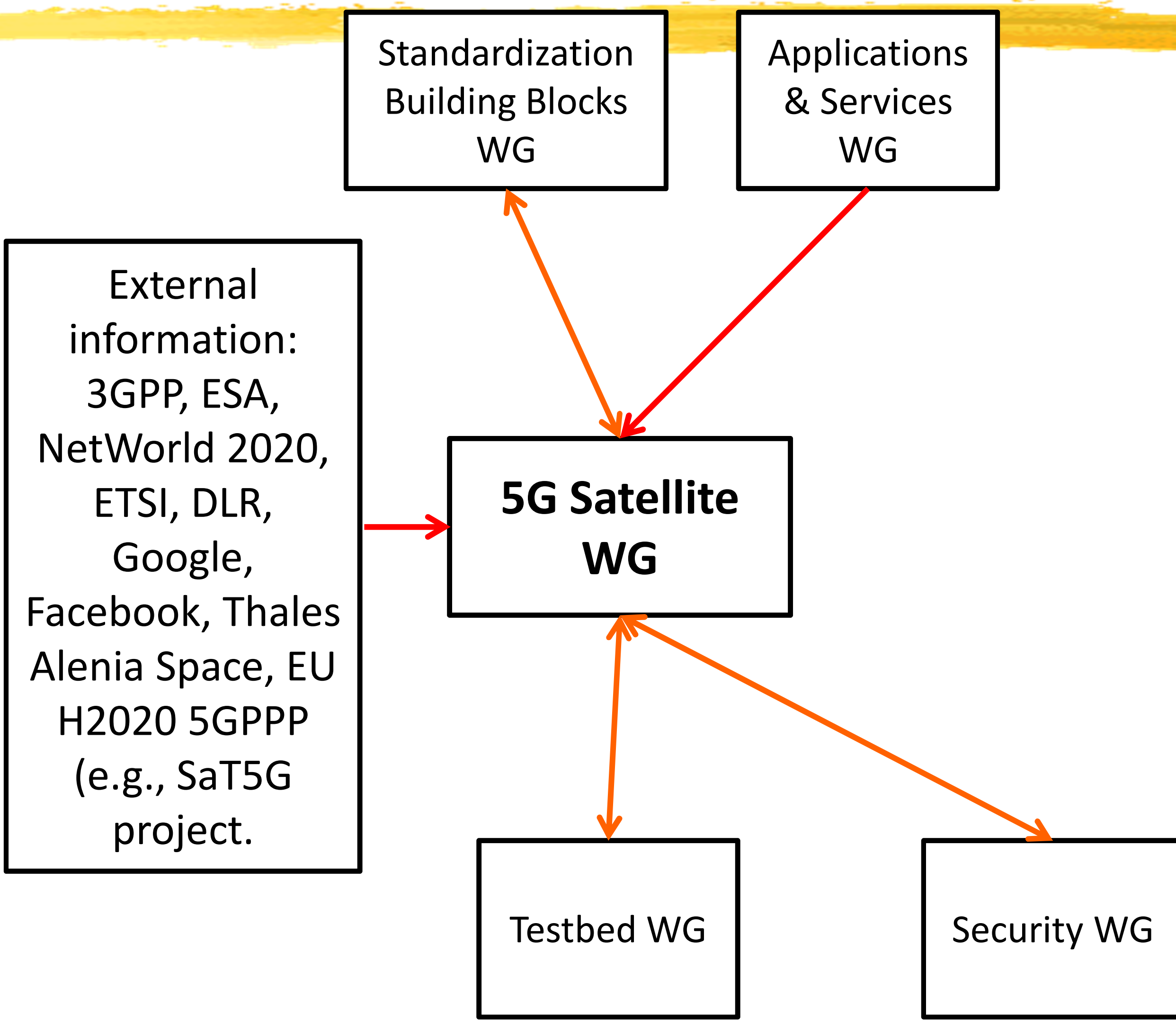
- **Standardization:**
  - The focal point for the development of mobile systems beyond 3G has become the **3rd Generation Partnership Project (3GPP)**.
  - **Release 15** and the new Release 16 are dealing with the **satellite 5G**.
  - 3GPP has recently completed a normative specification on “Service Requirements for the 5G System” considering fixed, mobile, wireless, and satellite access technologies together.
  - The 3GPP approved study items address solutions for **Non Terrestrial Networks (NTNs), including constellations based on different or combined orbits or platform types (i.e. GEO, MEO, LEO, HAPs and combinations thereof)**.
    - Connectivity scenarios, architectures and services span a wide range of applications, from backhaul, broadcast/multicast, and enterprise networks to direct connectivity for IoT and public safety [3GPP TR 38.811].

IEEE 5G Roadmap Activity

- Presents the technical roadmaps and the assessments for critical challenges and needs to be resolved for positive industry growth, innovation, and development.
- Reports are in preparation (including the satellite case) on the 5G roadmap, including:
  - Vision
  - Scope
  - Current and Future State
  - Technology Needs, Challenges, and Enablers/Potential Solutions
  - Conclusions and Recommendations

https://futurenetworks.ieee.org/roadmap/

IEEE 5G Roadmap Activity: The Satellite WG



Thank you

SPACOMM2019: Integrating Satellites and Mobile Networks

Salvador Marti

25/03/2019

Friend or Foe

- Satellite and terrestrial networks can collaborate or compete
  - Compete for use of RF spectrum (S Band, 26 GHz band)
  - Compete as alternative to provide access
  - Satellite as a part of broader network
- Complementary capabilities: Satellite has advantage
  - High speed to remote or hard to reach areas
    - (target of OneWeb is 1..5% users where internet is too expensive)
  - Better fit for Multicast/Broadcast
  - Easier to cover comms on the move (plains, ships or even trains and cars)
  - Complement terrestrial broadband
  - Immediate cellular backhaul

New systems, new challenges

Satellite systems for mobile communications introduce new challenges

- Global coverage requires large number of satellites
- One Web:
  - 648 .. 882 satellites (18 planes with 36, 40 and finally 49 sats)
  - 55 to 75 Satellite Network Portals (SNP) or Gateways
  - 30satellites per launch
  - Management of interferences with GSO (use of Ku Band)
- New operations concepts (automated ops, A.I., ...)
- Need of building partnerships with local ISPs

The Nova Group of Companies

Experience Knowledge Independence

Space Communications
Integrating Satellites and Mobile Network

March 2019

Phil Krix – Nova Systems

The Nova Group of Companies
Experience Knowledge Independence

- Program Manager Communications for Nova Systems
- 100% Australian owned company formed in 2000
- Now Australia's largest Owned and Operated Australian Defence Force Professional Service Provider – but also serving Government and Industry
- >550 Permanent Employees
- Predominately provide technical support to assure successful delivery of capability for clients – we ensure things work
  - Underpinned by a strong System Engineering capability
- Communications is just one of a number of programs/capabilities within Nova Systems
  - Aerospace, Maritime, Test and Evaluation etc
- Communications Program encompasses SATCOM, Terrestrial Comms and the Space initiative
- A partner of the Australian Space Agency formed in July 2018
- Developing an Australian based ground network focused on optimised support for LEO/MEO constellations and indigenous Australian requirements

LEO/MEO Gateways

- Trends
  - Demand for LEO/MEO connectivity growing
  - Bandwidths demands increasing and driving a push to higher frequency bands to support the required throughputs
    - Optical a natural progression
  - Ground stations as a "service" concept flourishing i.e. Amazon
  - Intersatellite links – both RF and Optical
    - Reduce ground station reliance
  - Move to phased array with electronic beaming forming capability
  - Ground Stations becoming a less "specialised" service with more competition so cost of service a greater consideration

Issues

- Frequency co-ordination/licensing for ground station can be difficult – more so than GEO ground station
  - Some countries more problematic than others
  - Often pushes ground station sites to more remote RF isolated locations, counter to connectivity requirements
- Fight for frequency bands with terrestrial services
- Bandwidth driven push to higher frequency bands is not without impact – i.e. increased rain attenuation
- Move to optical predicated on requisite pointing accuracy of satellite and atmospheric issues (space to ground)
- Phased array technology still maturing in terms of its place in the commercial LEO/MEO ground station market
  - $$ and reliability (little history) trade-off against advantages

Discussion