Towards NextGen Connectivity for all
5G/6G Advances for Satellite Systems

An Industry perspective

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Major Advances in Satellite Technologies

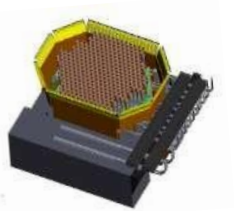
- **Reduce infrastructure costs:**
- More efficient payloads
- Advanced Electric Propulsion
- Lower dry mass – lattice like structures

Increased Payload Flexibility:

Adv. Digital beam forming processors

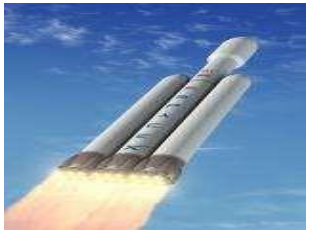
Advanced phased arrays

Ka MPA – lower cost of capacity



- **HTS- 50-200 Gbps to 1 TBps by 2020s**
- **Innovation in ALL Satellite Bands**
  - **Hybrid C/Ku, L/S Bands**
  - **Ka-Band, Q/V Bands**
- **New Constellations – NGSO (1k+ satellites)**
- **Open Architecture (al-IP & 5G)**
- **Higher Speeds 50/5 Mbps**
- **Increased focus on M2M, IoT,**
- **Highly cost effective – terrestrial comparable**
- **Enhanced Utility for rural/remote**
- **Ubiquitous Connectivity Land/Sea/Air**

- **Lower performance/cost launch vehicles**
- Reduce launch mass,
- use lower class launch vehicles to inject
- larger payloads



- **Resilient end to end ground network**
- Higher performance, greater capacity, secure network

Innovative use of new technologies is drastically reducing cost per Mbps

5GPPP vision (www.5G-PPP.eu)

- "**5G wireless will support a heterogeneous set of integrated air interfaces**: from evolutions of current access schemes to brand new technologies. **5G networks will encompass cellular and satellite solutions**. Seamless handover between heterogeneous wireless access technologies will be a native feature of 5G, as well as use of simultaneous radio access technologies to increase reliability and availability."
- "To achieve the expected capacity, coverage, reliability, latency and improvements in energy consumption, the **5G architecture is expected to run over a converged optical-wireless-satellite infrastructure for network access, backhauling and front hauling** with the possibility of transmitting digital and modulated signals over the physical connections."

Many 5G Use Cases supported by Multiple Technologies

Service Category	Deployment Scenario/Services	3GPP SA Use Case (TR 22.891-200)
Multimedia delivery	Mobile Broadcast	5.53 Vehicular Internet & Infotainment 5.56 Broadcasting Support 5.64 User Multi-Connectivity across operators
	Content Caching	5.36 In-network and device caching
	Broadcast to home	5.56 Broadcasting Support
Broadband	Mobile Broadband to users and Vehicles	5.28 Multiple RAT connectivity and RAT selection 5.29 Higher User Mobility 5.53 Vehicular Internet & Infotainment
	Fixed Broadband to homes and enterprises	5.41 Domestic Home Monitoring
	Ubiquitous coverage- Remote areas services	5.30 Connectivity Everywhere 5.10 Mobile broadband services with seamless wide-area coverage
	Backhaul Connectivity	5.30 Connectivity Everywhere 5.10 Mobile broadband services with seamless wide-area coverage
	Broadband to moving platforms- flights, ships etc.	5.30 Connectivity Everywhere 5.12 Connectivity for drones 5.29 Higher User Mobility
Machine Type Communication	Fleet Tracking	5.43 Materials and inventory management and location tracking
	Asset Management	5.43 Materials and inventory management and location tracking
	Wide area sensor management	5.42 Low mobility devices 5.73 Delivery Assurance for High Latency Tolerant Services
Critical Communication	Disaster Management	5.3 Lifeline communications / natural disaster 5.31 Temporary Service for Users of Other Operators in Emergency Case
	Air Traffic Management	
	Reliable Communication	5.73 Delivery Assurance for High Latency Tolerant Services
Vehicular Communication	Traffic Updates and Software Upgrades	5.33 Connected Vehicles
	eCalls and Emergency Notifications	5.3 Lifeline communications / natural disaster 5.31 Temporary Service for Users of Other Operators in Emergency Case

A Mix of Technologies - ….and they are already starting in 5G

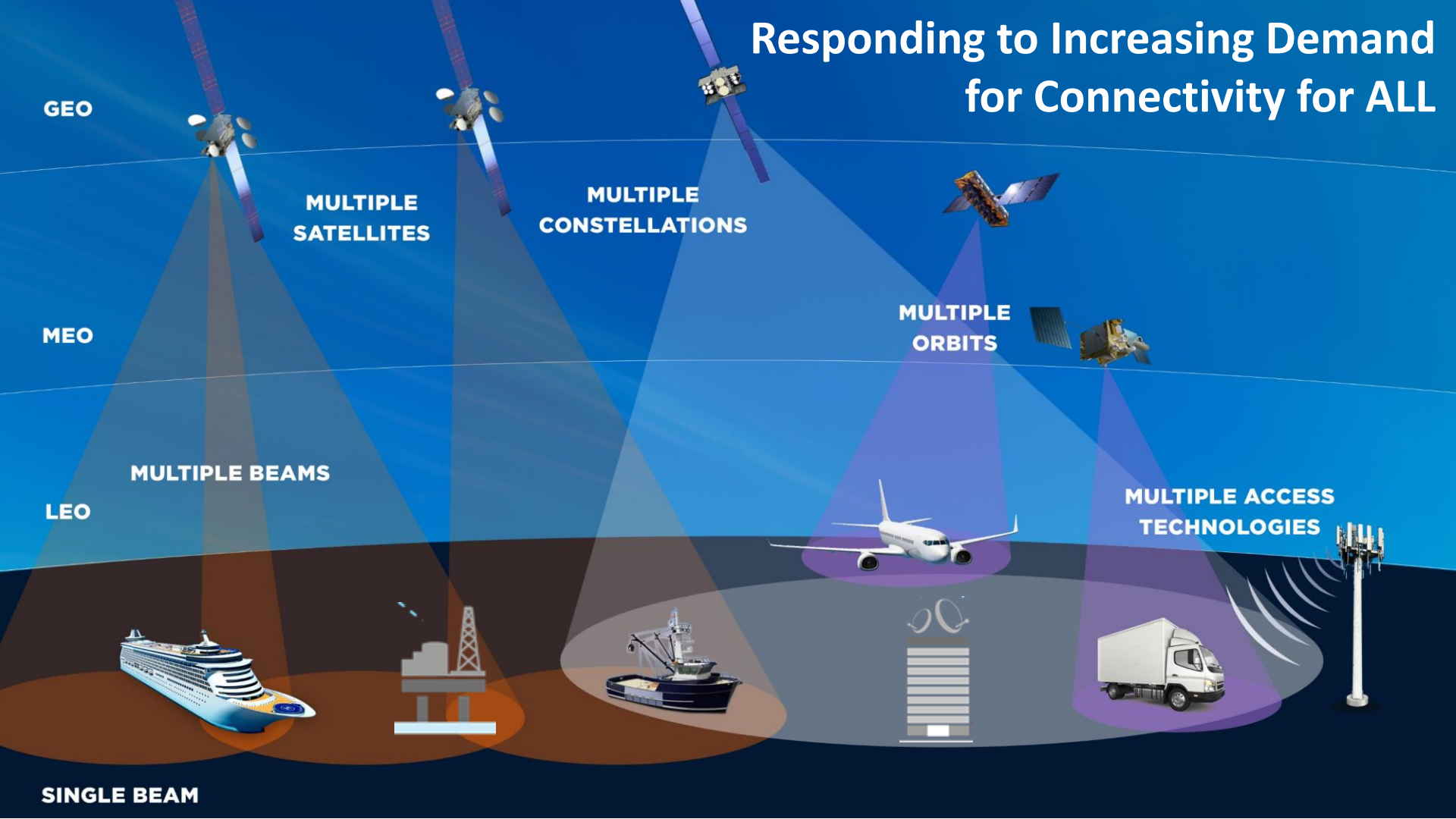
	Access Technology	Development	Spectrum	Data Speeds
	**Wi-Fi Eco-System is Evolving: with 6E now and WiFi 7 under development with much higher capacity**	Gigabit WiFi chips + devices available: 2020 >1bn *"WiGig"* - 20bn+ devices	RLANS – 2.4, 5, 6 / 7 GHz Wi-Gig 60 GHz	20Gbps +
	**Mobile Eco-System will continue to Evolve: LTE / 5G in various Apps / then on to 6G**	MNOs will continue to invest in delivering 1Gbps or more - 5bn+ devices	ITU identified Low, Mid and mmWave bands	5Gbps +
	**Satellite Eco-System is Evolving: HTS, VHTS, GSOs + NGSOs - several Tb of capacity**	High Throughput GSO/NGSO Satellites with steerable beams, global footprint - 2bn+ devices	ITU identified L, S, C, Ku, Ka bands & in future Q, V bands	>20Gbps

• Makes Commercial sense • No interference with other services • Utilise Existing Spectrum •

So having Satellites `in the Mix' is worthwhile

- The **dividing lines between satellite and terrestrial networks are softening**
- Developments in terrestrial wireless networks and services are influencing the prospects for satellite integrated services
- Today, the delivery of services and content over networks, operated by different entities, call for new types of partnership arrangements **and for a unified end-to-end control and management**
- The transition to **Network Function Visualization (NFV)** and S**oftware Defined Networks (SDN)** not only facilitates the integration of network functions of different vendors, it also potentially **facilitates the integration of different technologies onto the same platform** to
  - Enable the delivery of high quality end to end performance to the final users;
  - Differentiate business models (e.g. by introducing inherent flexibility to enable the support of new and innovative services and applications that were not envisaged when the network infrastructure was planned and deployed);
  - Improve business performance (including the reduction of operation costs and end user terminal pricing)
- This means that **satellite technology will "blend in" to the overall 5G network architecture, aligning its NFVs into the edge and core cloud infrastructures. As a consequence:**
  - The network management service will manage the traffic directed to the satellite according to bandwidth, latency and other application requirements
- **Satellite technology could have its functions integrated at NFV level, creating a denser and more operable and scalable platform for a telecom operator. In combination with 5G "network slicing", dedicated VNFs could address different connectivity concerns.**

Responding to Increasing Demand for Connectivity for ALL



5G and Satellites

- *3GPP specifies Satellite Access for 5G*
  - Satellite NG-RAN or non-3GPP satellite access network
  - From 450 MHz to 52.6 GHz

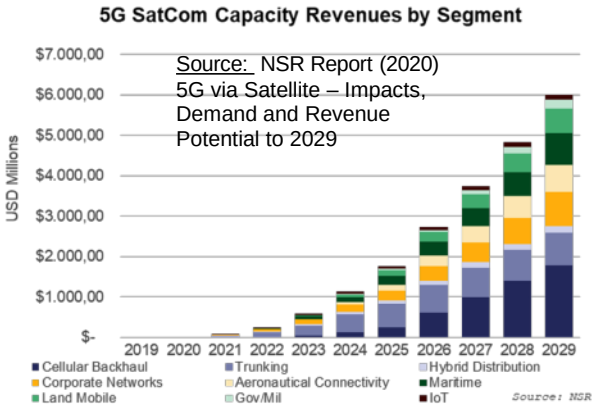
- *Complementarity to terrestrial networks with very distinct advantages*

- *Non-Terrestrial (i.e. satellite) Networks (NTN) can be an integral part of the 5G –B5G – 6G mainstream telecommunications ecosystem*

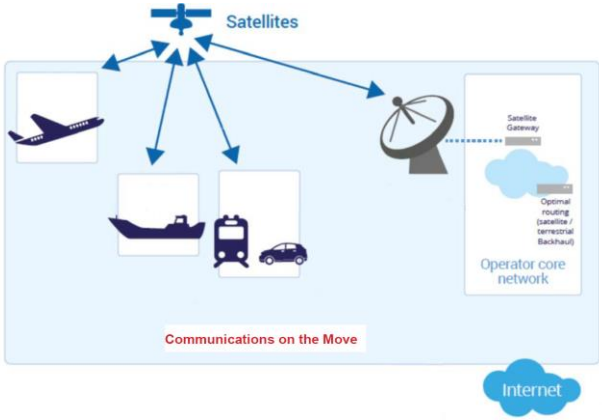
  - 5G integration will make satellite accessible from mainstream devices
  - Dramatic cost reductions through the use of standard chipsets
  - Growth of traditional applications – backhaul and trunking
  - New markets due to new use cases – hybrid networks, IoT, mobility
  - Significant revenue potential beyond 2025

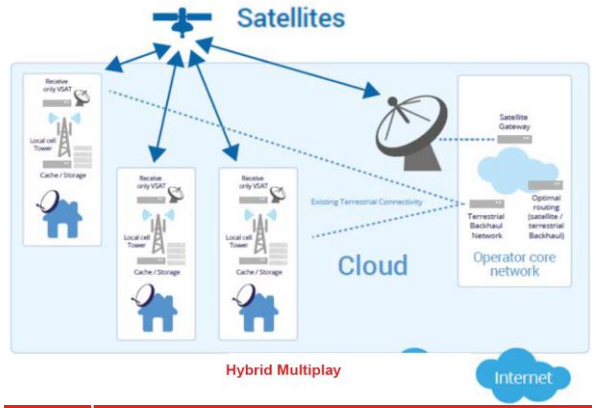
Satellite Benefits

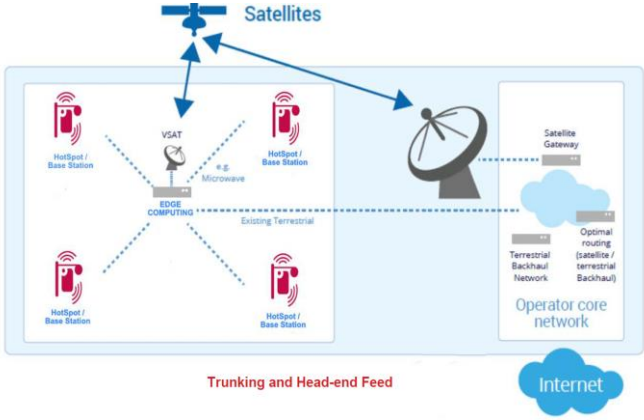
- *Continuity*
- *Ubiquity*
- *Scalability*



Innovation Enabling New Verticals







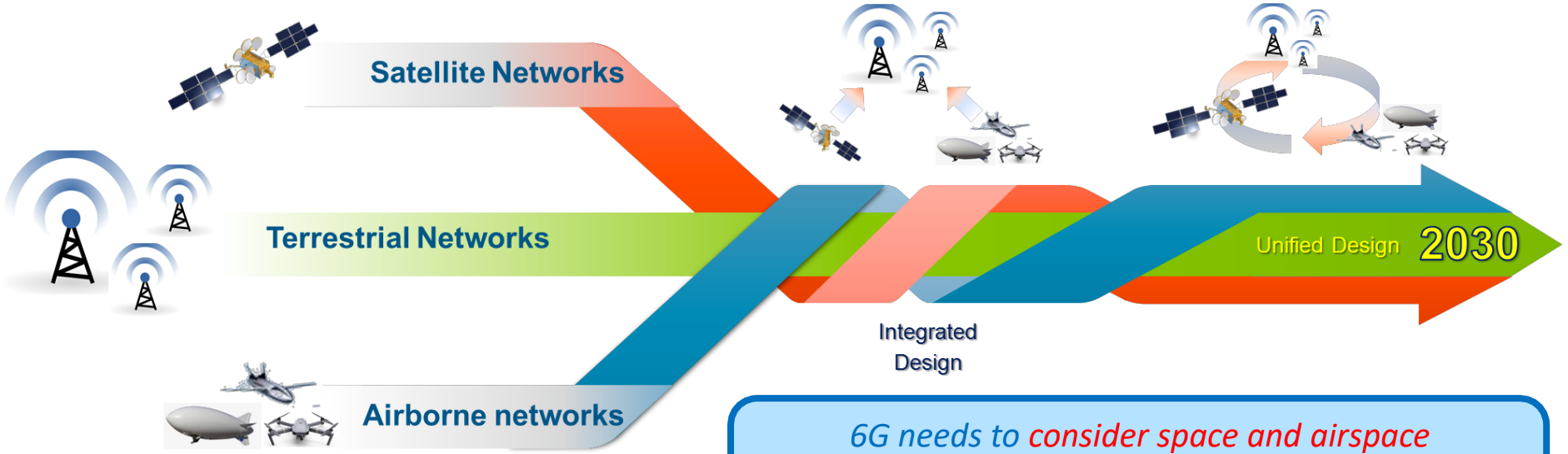
Use cases	Examples
Communications on the Move	In Flight Connectivity for Aircraft; broadband to ships and land vehicles
Hybrid Multiplay	Video and broadband connectivity to home or multi-tenant building with 5G distribution in building
Trunking and Head-end Feed	Service to remote areas; special events
Backhauling and Tower Feed	Surge capacity to overloaded cells, plus content delivery (e.g. video) to local caches; efficient broadcast service to end users

Towards a fully unified 6G

4G & Before
Little or No Integration

5G & B5G
Move towards Partial Integration

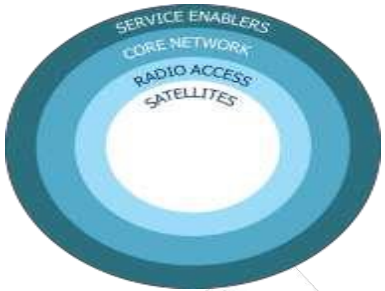
6G & beyond
Full Space & Terrestrial Integration

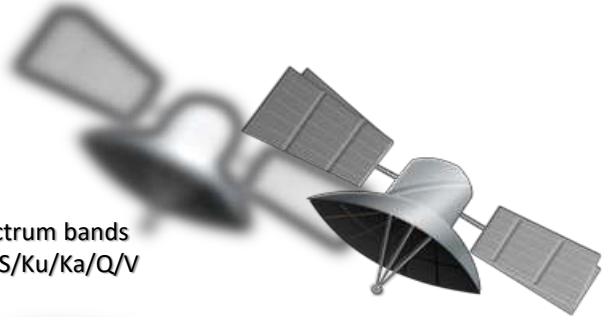


6G needs to consider space and airspace from beginning in definition of NR protocols and network architecture

Towards 6G Integration – Key elements for Unified Design

“Organise to Innovate” model:





Spectrum bands
C/L/S/Ku/Ka/Q/V

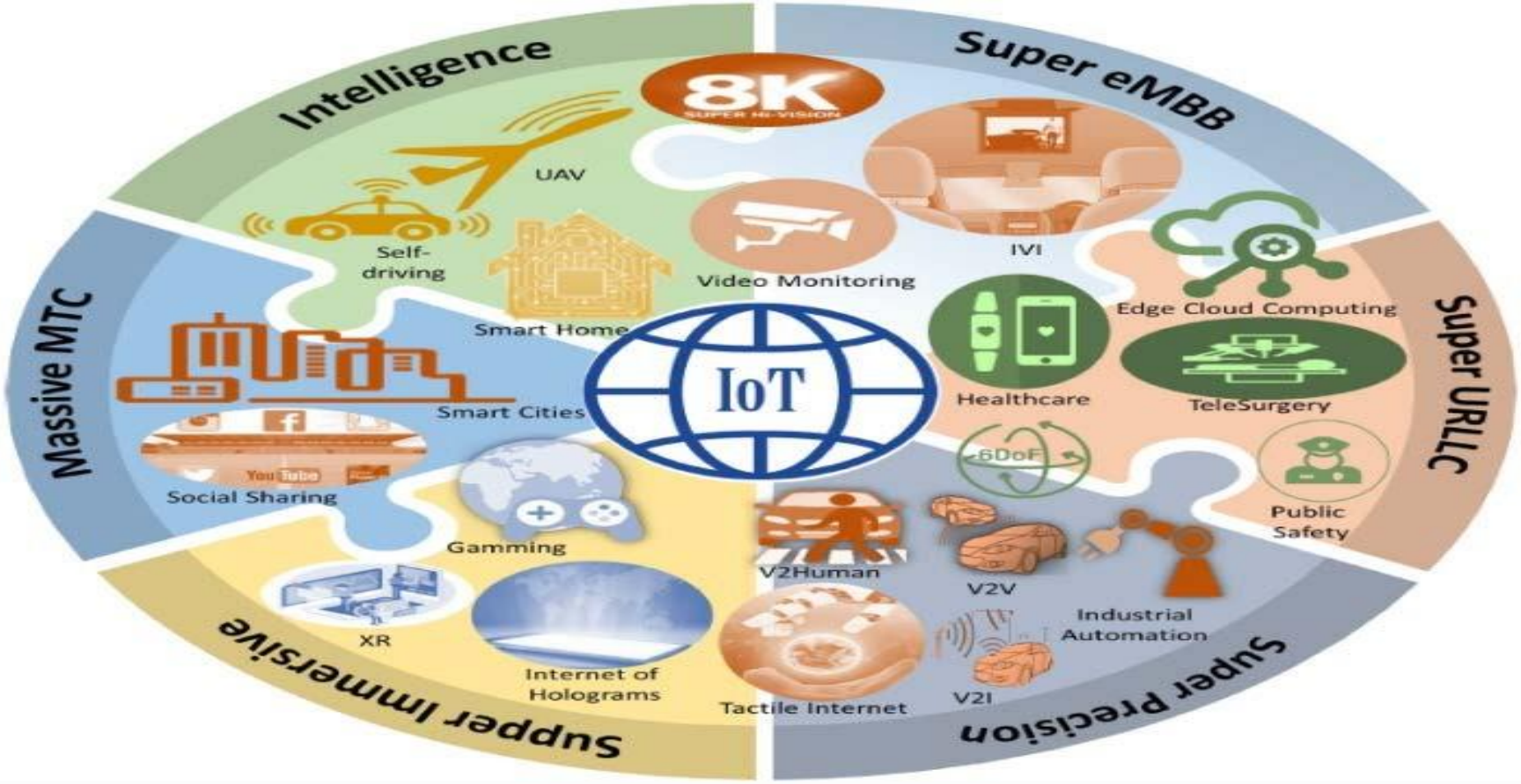
Radio Access Network
(remote modem & SAS modems/controllers)

Core Network
(remote communications stack &
core terrestrial network infrastructure)

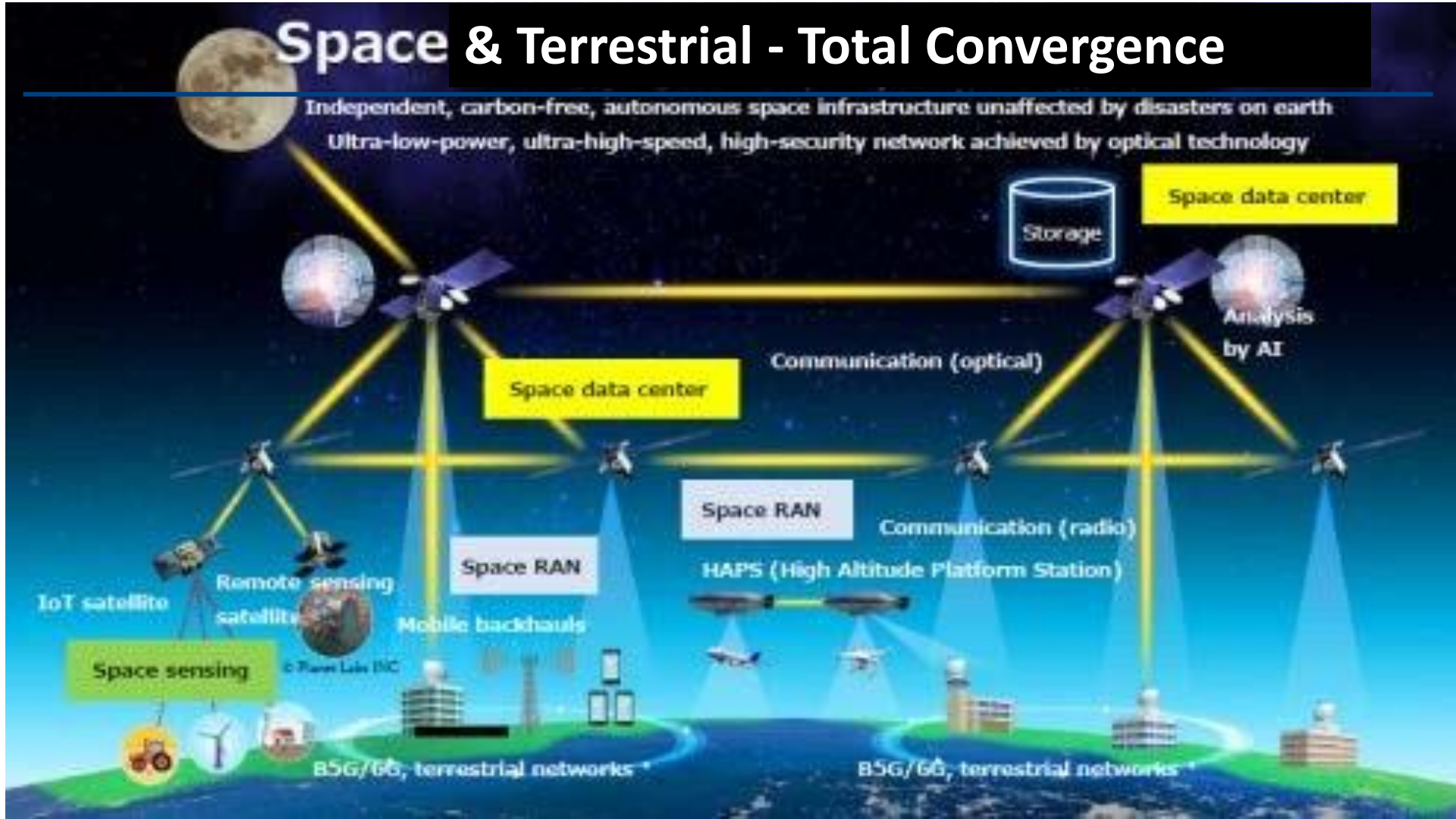
Service Platform
(remote service apps &
core terrestrial service platform infrastructure)

6G – Total Convergence

6G -Technologies integration



Space & Terrestrial - Total Convergence



6G Holistic Approach – Convergence of Functions

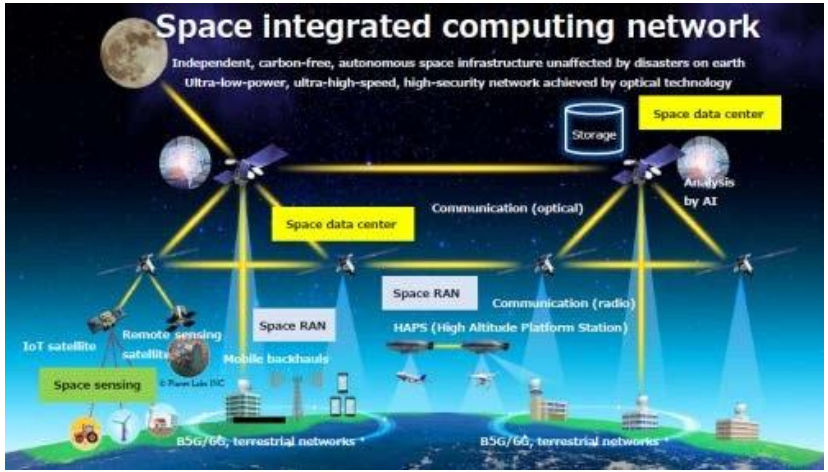
SpaceWideWeb - B5G/6G also as standard for inter satellite communications.

- Satellites always connected – quick commanding, high reactivity
- Earth Observation and Science Satellites as huge data sources
  – data downlink no longer a bottleneck

Integration of Communication, Computing, Caching (C3) and Sensing & Localization

- Use of RF comms signals for environmental monitoring (atmosphere, ground) and precision positioning
- In-orbit data centers for storage and (quantum) computing
- Multi-purpose satellites and fractionated satellite systems

Satellites as nodes (and UEs) in multi-layered 3D networks



Source: NTT-JSAT vision, Press Release „NTT and SKY Perfect JSAT conclude collaboration agreement on new space enterprise to aid realization of a sustainable society, May 20, 2021

Development of 6G – Heterogeneous multi-layer network

Open architecture – flexible reconfigurable – expandable

Full Interoperability

- **Seamless integration** with terrestrial networks
- Full Adoption of 3GPP NTN
- Multi-tenancy and Roaming
- **IAB - Access & Backhaul**

UE – Satellite Air Interface

- **Co-Innovation** with Vertical Market Stakeholders
- Physical and MAC layers
- Link budget optimization

Efficient space infrastructure

- **Different types** of (v)LEO/MEO/GEO nodes
  - Simple, small, single-purpose, transparent sats
  - Larger, complex, flexible, multi-purpose sats with active antennas and software-defined regenerative payloads for **MEC** and **AI**
- Efficient backbone with **optical ISLs** and **GSLs** and QCI/QKD for enhanced security

Control and Management

- SDN/NFV/Orchestration extended to space
- Smart routing and efficient handover
- Frequency sharing and cognitive radio
- **Automated and cooperative Satellite Control**

Network in the Sky

- **6G as a standard also for connecting satellites**
- Efficient, highly reactive TM/TC provision and large volume downlinks

Convergence of Space Functions

- Earth Observation sensing
- Positioning, navigation and timing - Localization

Advanced CONOPS and further standardization

Conclusions

Non-Terrestrial (i.e. satellite) Networks (NTN) can/will be an integral part of the 5G – B5G – 6G mainstream telecommunications ecosystem

- Many use cases require or benefit from **continuous and ubiquitous connectivity for all**
- Analysts see **Satellites** as **enabler** for significantly broadening accessible markets or stimulating new markets in IoT, Backhaul and Trunking, Mobility, Hybrid Content distribution, …

Next generation space communications infrastructure will be

- Much more diverse, flexible, software defined with more capabilities and higher performance
- Integrated with and efficiently serving both **terrestrial and space needs**

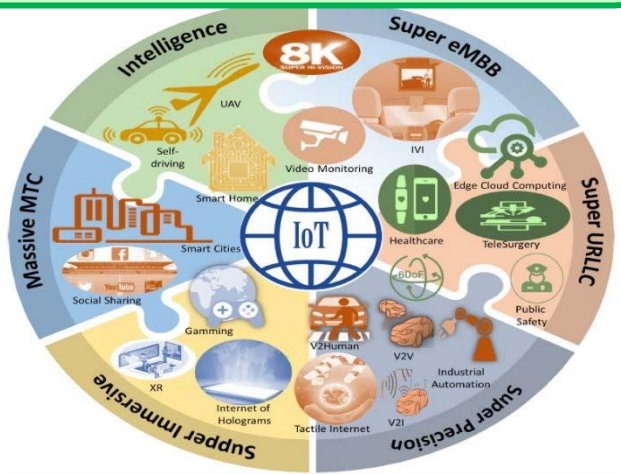
Space needs to strongly engage to shape the 5G/6G future

- Play active role in 3GPP standardization
- Convincing demonstrations as proof of concept and economic viability
- Joint **co-innovation** initiatives with **vertical markets** and MNOs

Tremendous Opportunities for Asia-Pacific to take Lead in 6G Development

Key Success Factors

- *Content = Use Cases with added value*
- *Competitive Pricing –Service &UE*
- *Ease of use and interoperability*
- *Timeliness – available when needed*



Source: M J Piran and D Y Suh 'Learning driven wireless communications, towards 6G," in Proc. Int. Conf. Comput., Electron. Commun. Eng. (iCCECE), Aug. 2019, pp. 219–224.

Satellite Broadband

TRANSFORMING LIVES