CHALLENGES IN SATELLITE TESTING

CHANGES IN THE SATELLITE INDUSTRY IMPACTING SATELLITE TESTING

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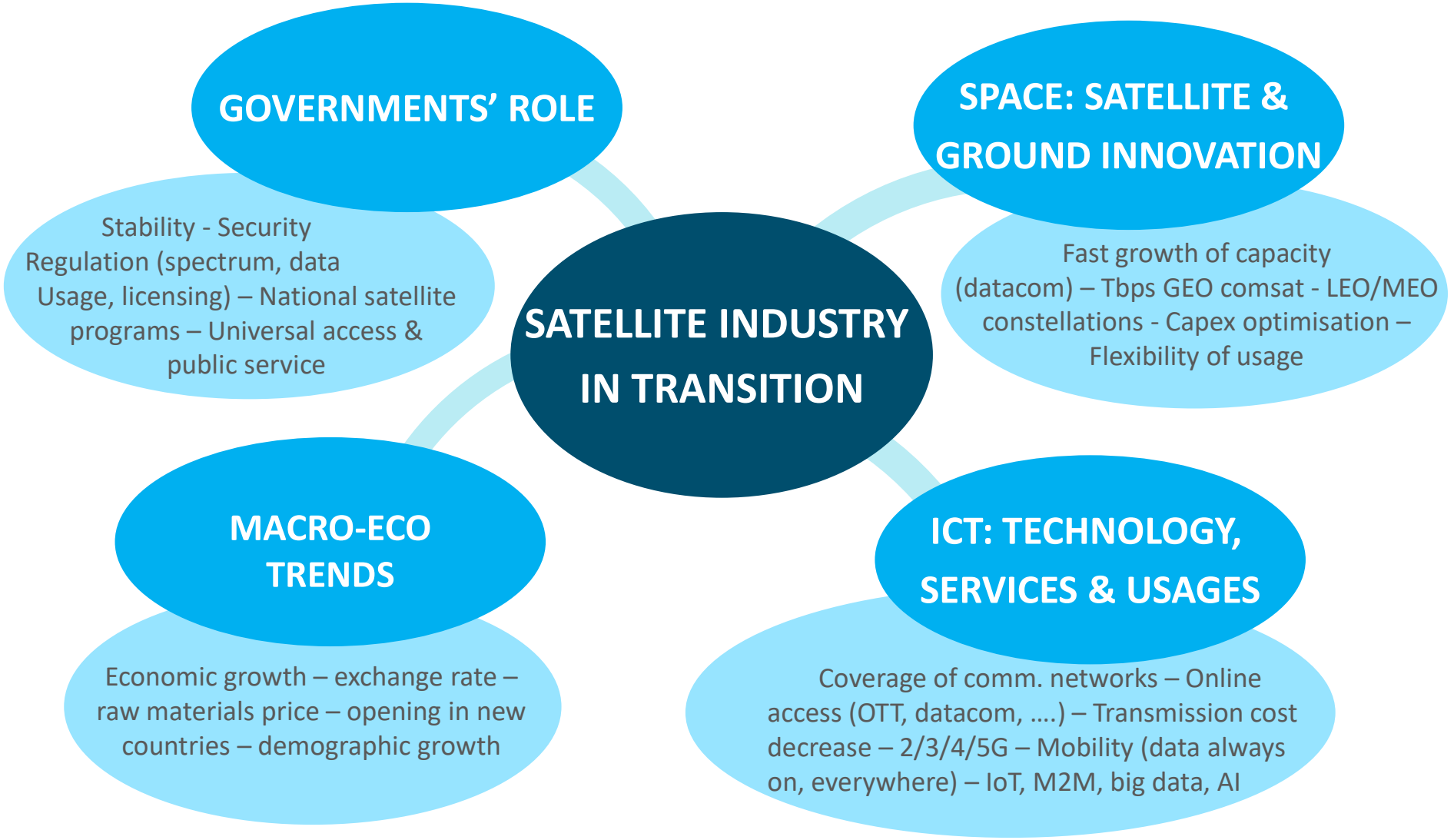
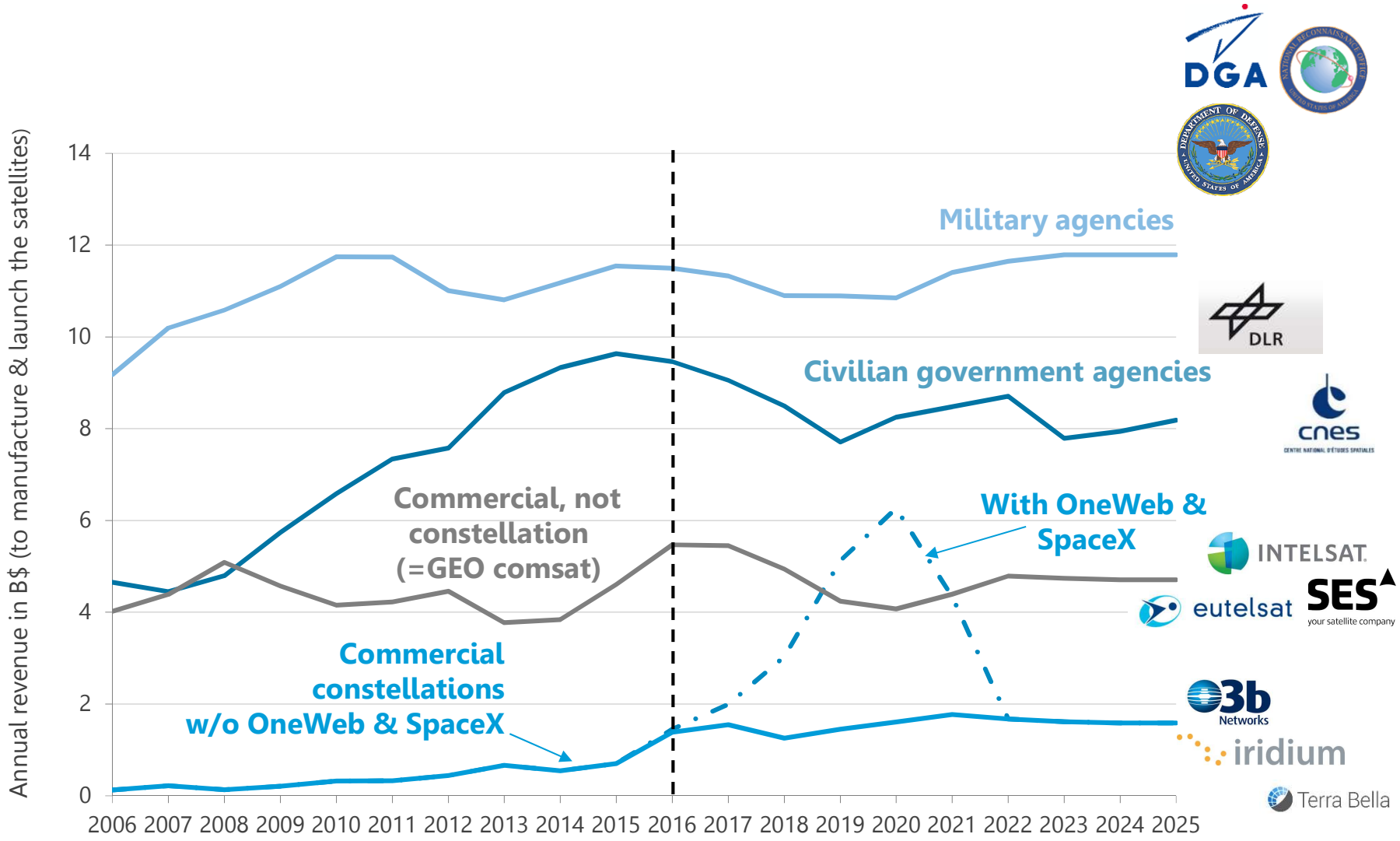
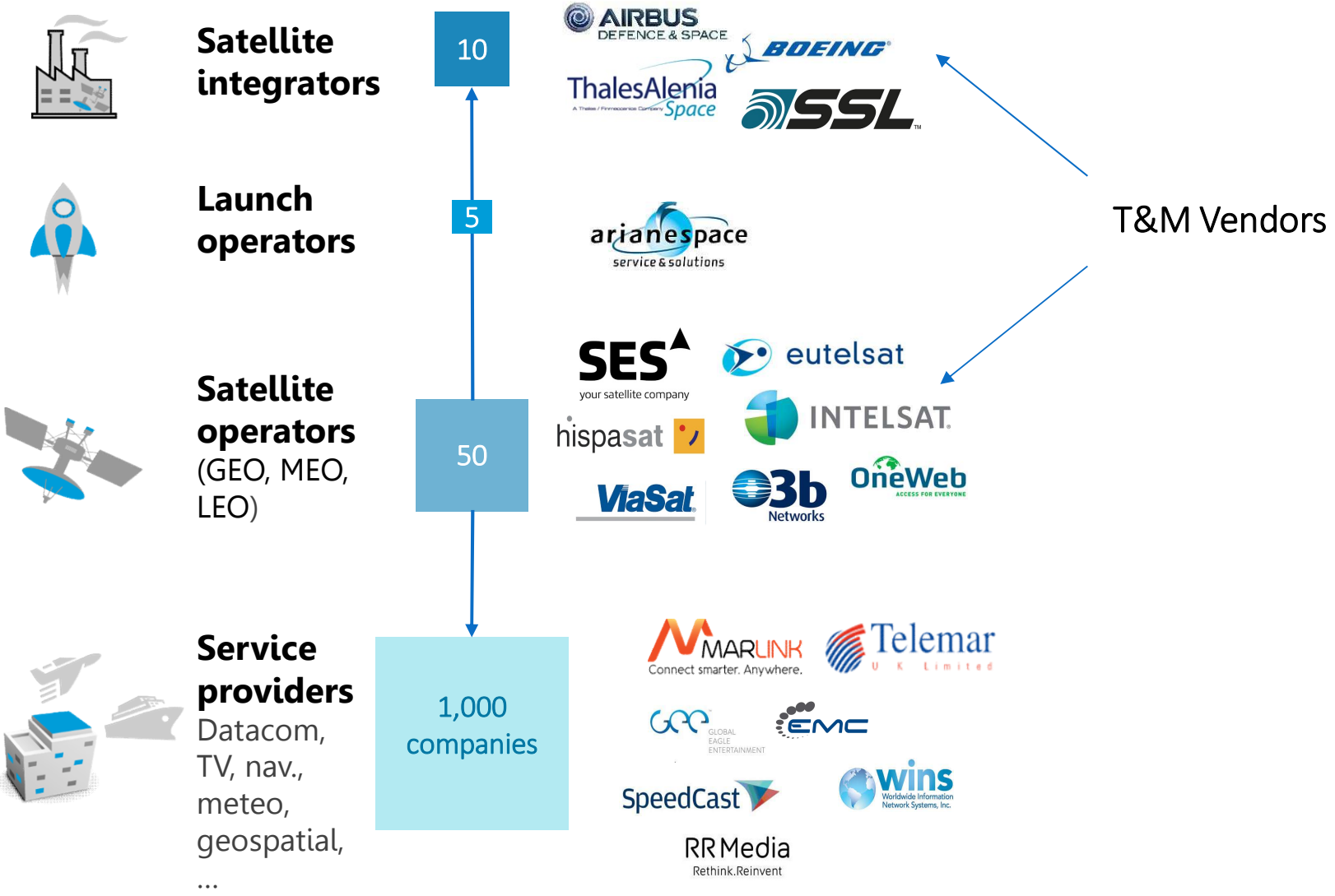
GLOBAL CONTEXT FOR SATELLITE INDUSTRY: CHANGE, INNOVATION, OPPORTUNITY & CHALLENGE



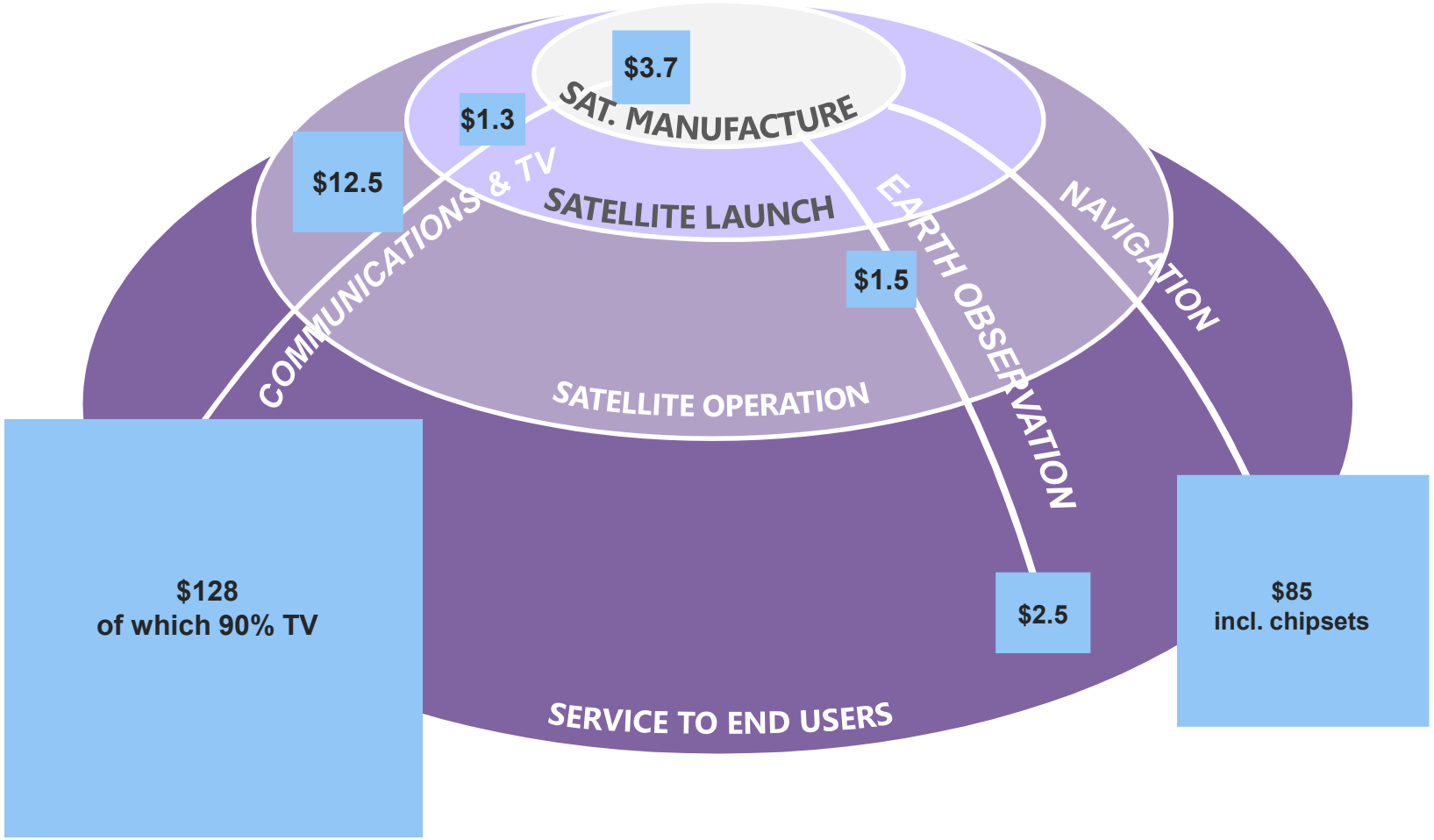
WHO ARE THE CLIENTS OF THE SATELLITES?



COMMERCIAL VALUE CHAIN: FROM SATELLITE SYSTEMS (UPSTREAM) TO SATELLITE SERVICES (DOWNSTREAM)



COMSAT DOMINATE IN THE COMMERCIAL VALUE CHAIN (2015 sales in billions $)



Euroconsult for Rohde & Schwarz A&D Symposium – March 2017

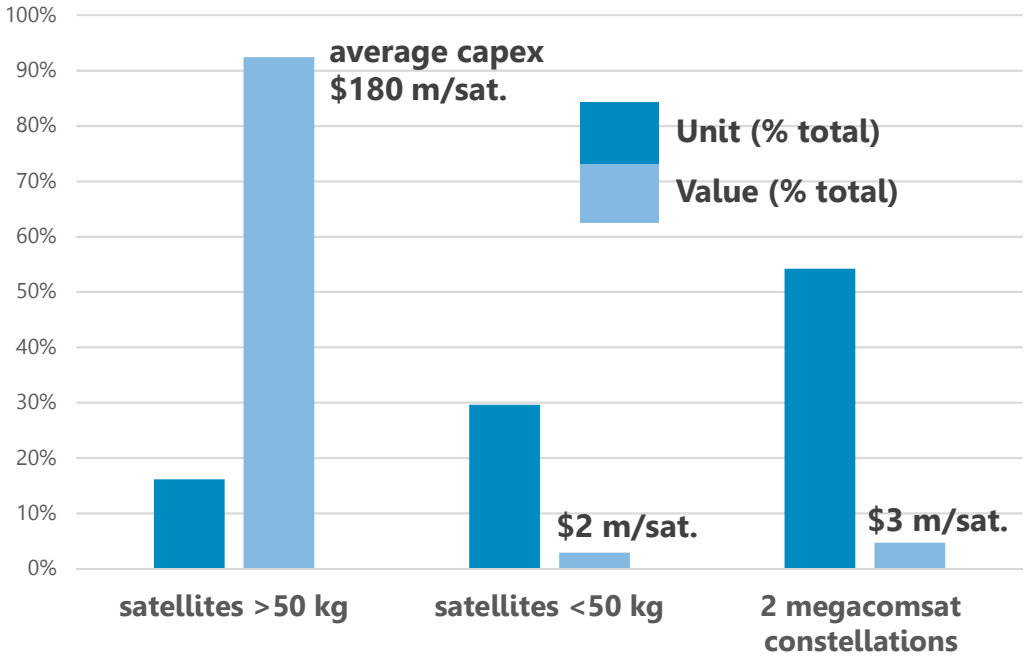
MORE SATELLITES IN FUTURE BUT…
….SMALLER AND LESS COSTLY ON AVERAGE BECAUSE OF THE CONSTELLATIONS

# of satellites past & future

	2006–2015	2016–2025	GROWTH
>50 KG (EXCL. 2 CONSTELLATIONS)	**950**	**1,500**	**58%**
< 50 KG	535	2,700	x 5
TOTAL	**1,485**	**4,200**	**x 2.8**
2 MEGA COMSAT CONSTELLATIONS	0	5,000	ns
GRAND TOTAL	**1,485**	**9,200**	**x 6**

much higher growth if we include

- cubesat/nanosat (<50 kg)
- 2 mega-comsat constellations (OneWeb with 1K sat. + SpaceX with 4K sat.)



Distribution in sat. # opposite of value

- cubesats/nanosats have a low unit cost, the mere reason of their success
- 2 mega-constellations with capex of about $15b billion, i.e. $3m/satellite
- Both have started to revolutionize satellite design, testing and production

SATELLITE CONSTELLATIONS – THE BIG JUMP?

BROADBAND COMMUNICATIONS

- 5-10 projects
- From tens to thousands of satellites (2K for OneWeb)
- More than 5 Tbps of capacity in orbit by 2025 ?

EARTH OBSERVATION

- 10-15 projects
- Possibly >2000 sat. to be manufactured and launch by 2025
- 75% of them below 10kg

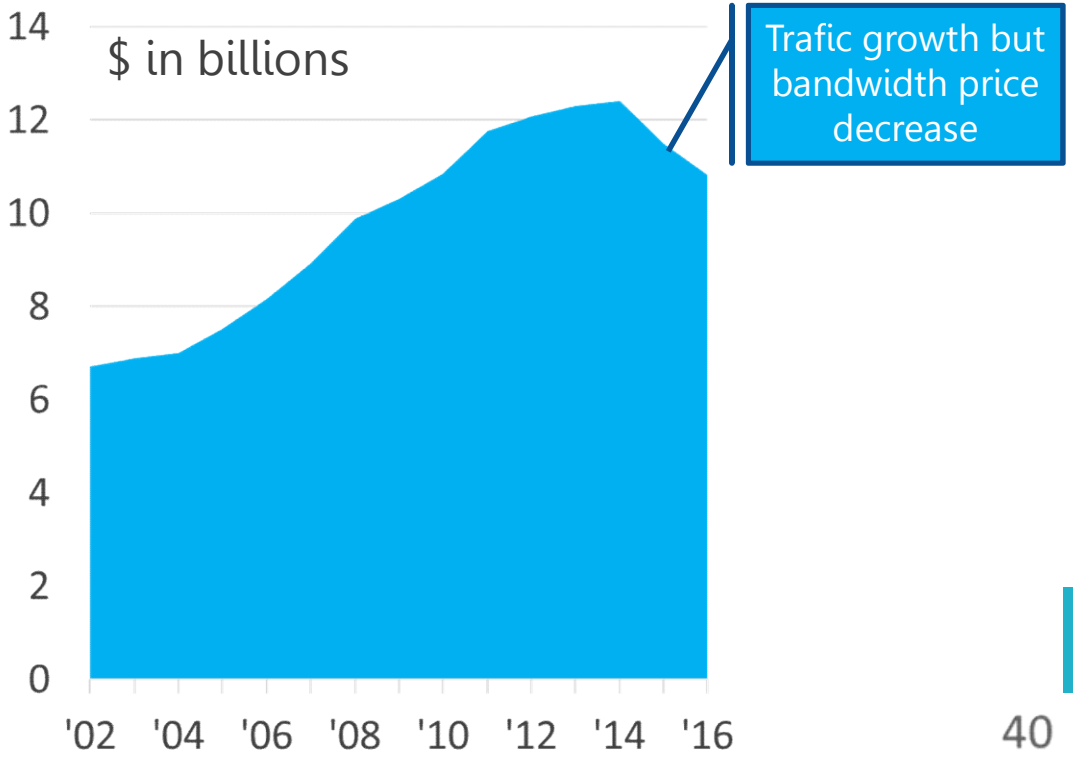
LOT OF PROJECTS :
HOW MANY MATERIALIZE?

LOW DATA RATE COMM. /IoT

- 5-10 projects
- New initiatives expected
- Generalist or highly specialized constellations ?

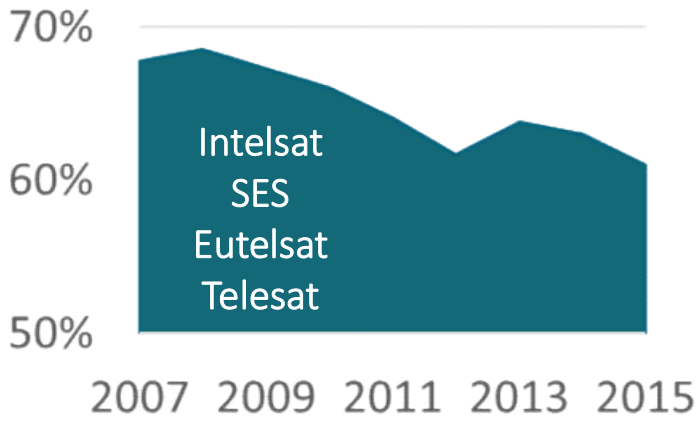
GEO COMSAT OPERATORS: AN INDUSTRY UNDER PRESSURE…

SALE OF 40 FSS OPERATEURS



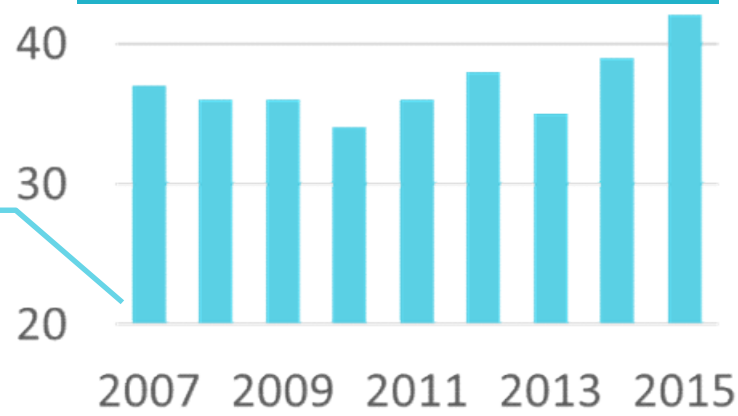
Trafic growth but bandwidth price decrease

MARKET SHARE OF 4 TOP FSS OPERATORS



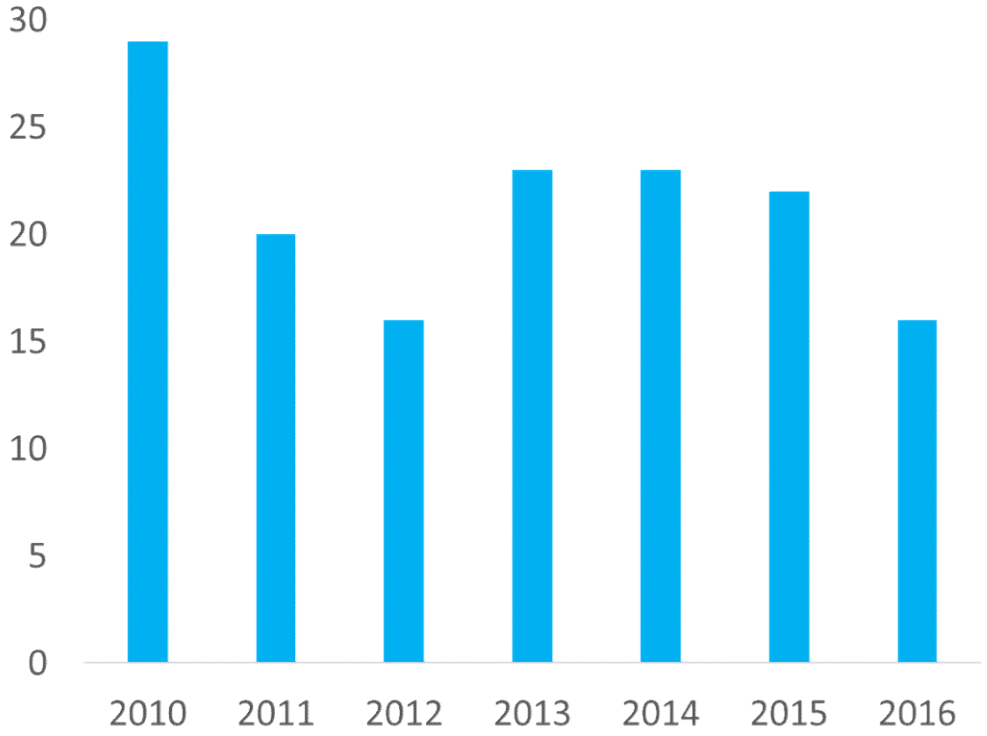
- Existing operators diversifying *(Inmarsat, Viasat, Echostar…),*
- ~5-10 new possible systems (start-ups, domsat)
- M&A difficult (OneWeb + Intelsat ?)
- More strategic partnerships between operators

OF FSS OPERATORS RETAILING BANDWIDTH

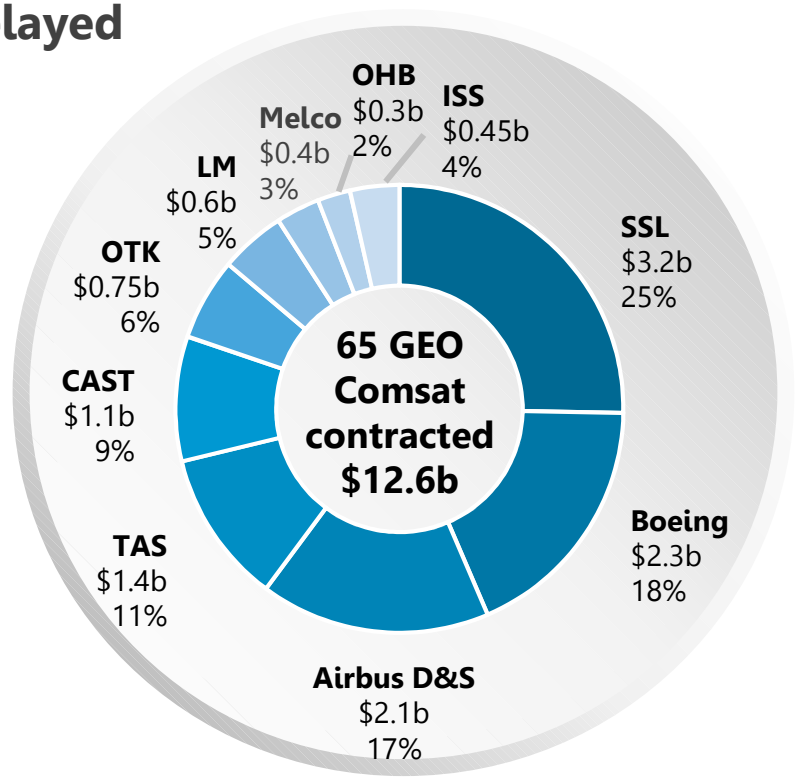


GEO COMSAT ORDERS: COMMERCIAL & CIVILIAN GOVERNMENT OPERATORS

- More **uncertainty** in both demand (operators and their clients) and supply (industry and technology) sides
  - **Technology innovation** and **competitiveness** drive satellite demand
    - Order decision time **delayed**



GEO comsat orders placed annually by operators



Backlog of commercial GEO comsat by supplier

NEW TECHNOLOGIES FOR MORE COST EFFECTIVE COMSAT

3 R&D OBJECTIVES CROSSED WITH TECHNOLOGY THROUGH TRADE-OFFS

- system cost optimization
- throughput increase
- flexibility of resources

NEW TECH CONCEPTS UNDER DEFINITION

- Tbps satellite: at least 2 in orbit by 2020 by Viasat
- Mega-constellation of smallsat for broadband: OneWeb to be the 1rst in 2020
- Flat electronic antenna: critical for mobile datacom (HTS and constellation)
- 20 kW electric engine for GEO injection & deep space missions (now 5 kW)
- IOS & space tug: 3 commercial initiatives for GEO comsat

IN-ORBIT SERVICES (IOS)	MEV	ESS	SIS
HIGH-RES. INSPECTION			
STATION-KEEPING			
REFUELING			
ORBIT/INCL. CORRECTION			
RELOCATION/SLOT TESTING			
PAYLOAD MODIFICATION			
REPAIR SERVICE			
IN-ORBIT ASSEMBLY			
DE-ORBITING			
DEBRIS REMOVAL			

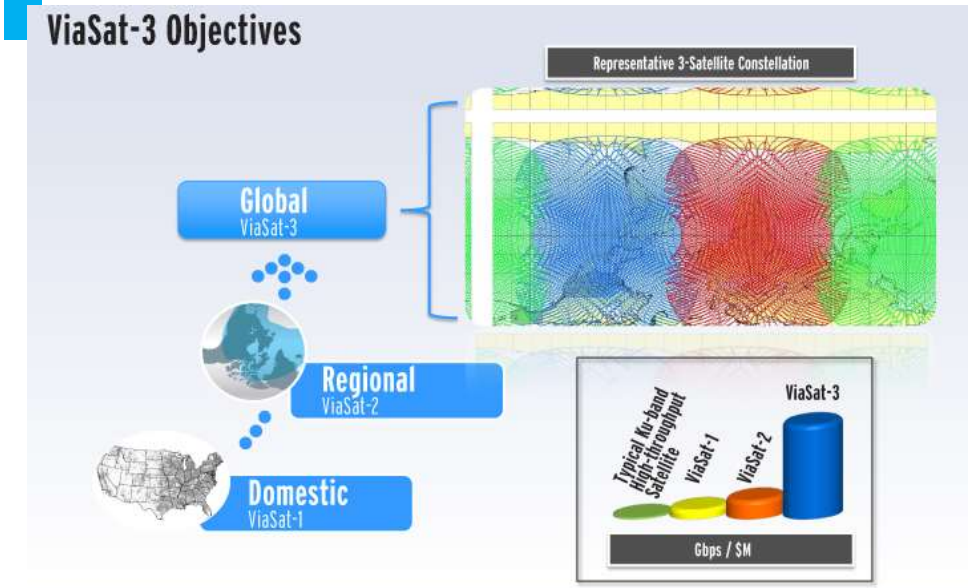
IMPACT OF MAJOR TECHNOLOGY TRENDS

	TECHNOLOGY TRENDS	SYSTEM COST OPTIMIZATION	THROUGHPUT INCREASE	RESOURCES FLEXIBILITY
SPACE	Flex. payloads	High degree	Limited degree	High degree
SPACE	Electric propulsion	High degree	Limited degree	High degree
SPACE	COTS for production	High degree	None	None
SPACE	Q/V Bands	High degree	Limited degree	None
SPACE	Flexible TT&C	High degree	None	High degree
SPACE	SmallSat	None	High degree	None
SPACE	Intersat. links	High degree	None	High degree
SPACE	GaN (SSPA, ..)	High degree	None	None
SPACE	3D printing	High degree	None	None
LAUNCH	Launcher reusability	High degree	None	None
LAUNCH	Dual launch	High degree	None	None
GROUND	High efficiency waveforms	High degree	High degree	Limited degree
GROUND	Access techniques	High degree	High degree	Limited degree

TECHNOLOGY INNOVATIONS BENEFITING TO COMMERCIAL SATELLITES: HTS-related

Technology	Benefit	Maturity
HTS	• **High throughput systems** (HTS) maximize the bandwidth through multiple high-gain spot beams & high frequency reuse • **Four applications**: Trunk/backhaul of IP traffic, mobile broadband datacom (aero, maritime), video transmission (SNG, IPTV), consumer broadband access • **1rst Tbps** satellite of Viasat in 2020 (1 Tbps now on all commercial GEO comsat)	• 50% of GEO comsat in construction are HTS-dedicated or have a HTS payload • Digital processing of incoming signal for spectrum flexibility (but 500 MHz processor availability?) • Steerable beams+ channelizers for partially-processed payloads
Antenna (space)	• Multiple horn feeds to reduce the # of reflectors (up to 7 now) but beam forming required	• Phased-array antennas for reception now competitive • Ka reflectors of 5-7m diam. • Multibeam Earth-face antennas for both emit/ receive
Antenna (ground)	• Phased-array/electronically-steered antenna critical for mobility applications with HTS systems (both GEO and non-GEO) • New tech. in gateway/teleport (beam forming, cloud computing, SW def. modems	• 5 companies develop techno. of which Kymeta is the most advanced commercially (in Ku with metamaterials)

HTS SATELLITE CONSTELLATIONS



Viasat Tbps in GEO

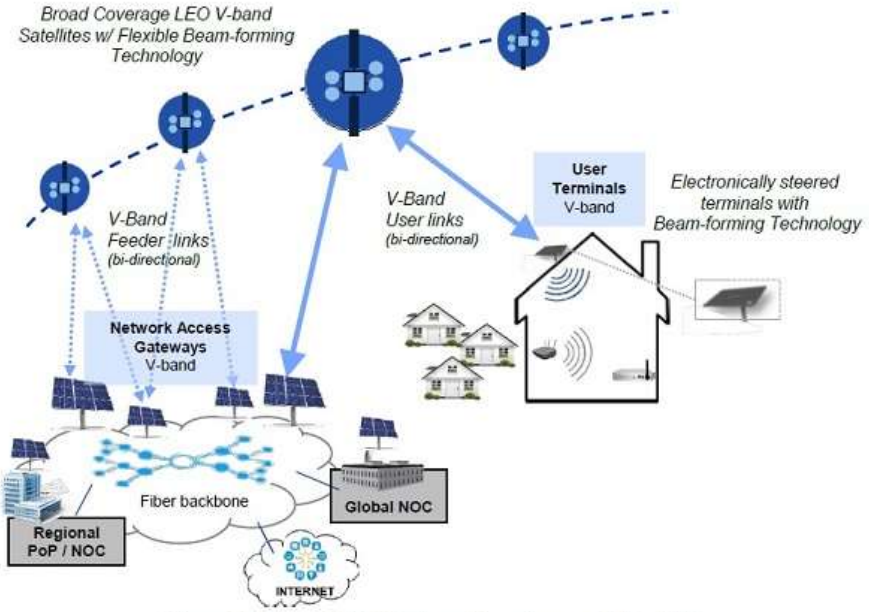
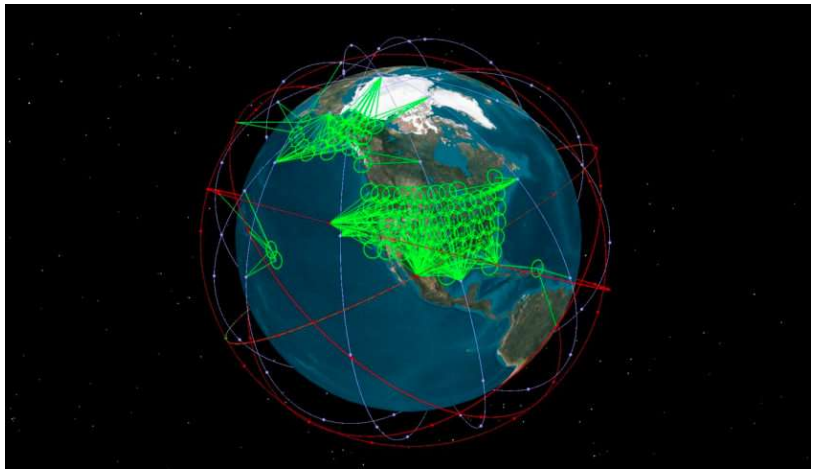


Figure II-17. NGSO System Overview and Facilities

Boeing V-band LEO



CONUS coverage of Telesat Ka LEO

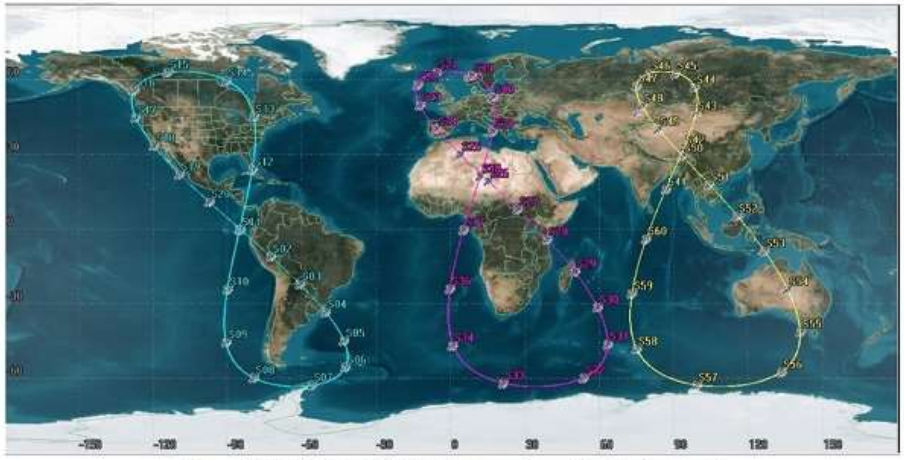


Figure II-3. Ka-Band NGSO System Complete Deployment

Boeing Ka-band HEO

TECHNOLOGY INNOVATIONS TO BENEFIT TO COMMERCIAL SATELLITES

Technology	Benefit	Maturity
Q/V-band	• More spectrum available for downlink • 6 filings at the FCC for V-band constellations	• Medium-term for TT&C • Test for feeder link on GEO
GaN	• Game changer for solid amplification (SSPA) and for transmission phased-array antennas	• SSPA now substitute to TWTA for low freq./low power
FPGA	• Game changer for OBP with signal regeneration	• FPGA availability & industrial processing limit penetration
ISL	• Optical terminals on EOSat and GEO comsat for faster data at higher rate	• Not deployed yet on commercial satellites
SDR	• 1G of software-defined payloads (digital channelization & beam forming)	• Quantum of Eutelsat will be 1rst SDR comsat (PPP with ESA)
Others….	• Smaller and lighter bus structure • Optical fiber connectivity with mass gain • Growing satellite power to run larger payloads	• Deployable radiator in test • 20 kW max today driven by broadcasting

TESTING CONSIDERATIONS

The shift from "analog to digital" in space & ground infrastructure impacts satellite testing at several strategic levels

- New product/service offering: more and new testing needs
- Channel Optimization: compensation for non-linear effects in components
- Channel Quality Assurance: need for real-time monitoring and interferer identification

How to be "faster, better and cheaper" at the same time for the satellite industry ?

- Reduce antenna RF testing time
- Adapt testing process to big payload changes (e.g. electronically-steered antennas)
- Provide modularity (i.e. HW and SW elements adaptable to different testing facilities)

THANK YOU FOR YOUR ATTENTION

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