The Communications Satellite Industry's 2nd Quarter Century: Unprecedented Technological Advancement, Exponential On-Orbit Capacity Growth and the Emergence of 'Disruptive Transformation'

Dr. Tom Butash
Principal and Founder
Innovative Aerospace Information Systems
Centreville, Virginia, USA

The second quarter century, 1992-2017, of the Communications Satellite Systems Industry was marked by phenomenal advances in technology and system architectures, together with increased investment to leverage these breakthroughs. Exploitation of higher frequency, wider spectral bands together with great improvements in spectrally efficient modulation and coding, spacecraft payload optimal digital control, onboard digital signal processing, power subsystem efficiencies, multibeam antennas, electric propulsion and launch vehicle technologies, as well as methods for optimizing the capacity of multibeam systems, facilitated quantum leaps in communications satellite capacity per satellite unit Size, Weight and Power and Cost (SWaP$). Consequently, by the quarter century's end, the industry realized an explosion of capacity – both on-orbit and planned for launch – in many markets, with additional investment promising what has become known as the industry's emerging "disruptive transformation."

The first wave of advances was realized in the first decade, 1992-2002, beginning with the rapid development of multibeam narrowband MSS satellites designed to offer unprecedented flexibility in directing signals, bandwidth, power and hence capacity. ACeS (Asia Cellular Satellite) and Thuraya employed Digital Channelizers and Digital Channelizer Beamformers to enable the world's first GSO satellite based cellular services in Asia and the Middle East, respectively. Deployment of these systems was paralleled by the development and deployment of the world's first so called Big LEO and Little LEO systems, Iridium and Globalstar, and Orbcomm, respectively, designed to provide much broader satellite cellular and short messaging communications geographic service coverage.

The development and deployment of GSO and NGSO narrowband systems was closely followed and somewhat overlapped by the development of GSO and NGSO broadband systems, including Astrolink, Canadian Advanced Satcom, Cyberstar, Intelsat Broadband, SkyBridge, Spaceway and Teledesic, most of which were designed with fully regenerative onboard digital signal processing and fast packet switching to effect packet switched data, audio and video communications services. It is instructive to recall that all but one (Spaceway) of these systems were ultimately deemed financially unviable and terminated around the turn of the century due, in large part, to the explosive growth of competitive terrestrial broadband networks and Internet access points during their development. It is also perhaps informative to note that Teledesic, with its originally planned constellation of 840 active LEO satellites, would have been the world's first broadband Megaconstellation had it not been cancelled which, in retrospect, is viewed by some as potentially foreshadowing the fates of broadband Megaconstellations being planned or under development today.

The second epoch, 2003-2017, of the second quarter century began with the landmark breakthroughs of Nakasuga, Nakahira, Sagawa, et al, at NTT DoCoMo and NTT Network Innovation Laboratories, [1-6], and the contemporaneous seminal works of Rinaldo and De Gaudenzi, [7], Lattanzi, et. al, [8], in Europe, which defined a method for maximizing the capacity of multibeam communications satellite systems. The method entails selecting the system's number of beam colors[1], the number and spacing of beams, the frequency reuse pattern across them, as well as the use of advanced ACM (Adaptive Coding and Modulation) schemes to optimize data transmission and reception rates based on the dynamic signal quality measured at each user terminal location, to maximize aggregate system capacity. These breakthroughs facilitated the design and launch of 1st Generation of High Throughput Satellite (HTS) Systems (iPSTAR, WildBlue, KA-SAT, ViaSat-1, Jupiter-1 and NBN Co A & B), all of which employ high frequency reuse in dense multibeam pattern systems and ACM, as prescribed in the aforementioned seminal works, to achieve an order of magnitude increase in each satellite's aggregate throughput capacity over that of earlier broadband communications satellites.

2nd Generation HTS systems, including Jupiter-2, ViaSat-2 and the latest two Intelsat Epic^NG satellites, were launched in late 2016 and 2017, with the latter incorporating flexibility to route the satellite's capacity in response to dynamic changes in geographic demand distribution and the former realizing HTS capacities of 200 to 300Gbps. The 3rd Generation Ultra HTS (UHTS) ViaSat-3 with a capacity of 1Tbps and Ultra High-Density Satellite (UHDS) Jupiter-3/EchoStar XXIV with 500Gbps capacity capable of being concentrated in unprecedentedly dense areas of high demand, are currently under development.

The second epoch also saw SpaceX and Blue Origin initiate a race to develop reusable launch vehicles (RLVs) to dramatically lower space access costs. By year end 2017, SpaceX achieved a vast lead, managing to reduce the cost of a typical Geosynchronous Transfer Orbit launch by 40 to 50%, thus setting the standard for low cost launches. SpaceX promised further cost reductions as it perfects its RLV technology. Moreover, use of electric and hybrid electric/chemical propulsion became increasingly common and is expected to be employed on more than 50% of communications satellites by 2020, facilitating even more cost saving dual-launches and greater satellite capacities.

These advances were accompanied by a period of unprecedented investment and venture funding in other so called "New Space" systems as well. A $1.8 billion venture capital infusion in 2015 – far more than the total invested over the entire prior decade – was followed by $1.7 billion from venture funding rounds led by Japan's SoftBank in 2016 and 2017. This capital is funding the development of more than a half-dozen so-called NGSO HTS Megaconstellations, including New Space LEO Megaconstellations by Boeing, Hongyun, LeoSat, OneWeb (financed by the SoftBank funding rounds), SpaceX's Starlink and Telesat, each with between 108 and 7,500 satellites, and 7 second generation SES/O3b MEO satellites, which collectively promise to add more than 40Tbps of capacity by 2025 according to a June 2017 Euroconsult study.

However, by 2016 the communications satellite industry faced increased over-capacity and pricing pressures in many markets with a consequential deepening of the downturn in service operators' revenue. This, together with the huge additions of HTS GSO and planned HTS GSO and NGSO Megaconstellation capacity, led communications satellite service operators to scale back replacement/enhancement plans until the effects of the ongoing exponential growth in capacity are resolved.

[1] A beam color is a unique combination of a receive or transmit frequency band and polarization.

Faced with these market dynamics and uncertainties, service operators' reticence to commit to additional near term, conventional GSO constellation replenishment programs was quite predictable. Only 14 GSO communications satellite development contract awards were made worldwide in 2016, a 40% decline from the average of slightly over 24 awards during each of the four preceding years.

The 2016 decline was followed by an additional 30% drop, to approximately 10 GSO communications satellite development contract awards worldwide, by year end 2017. Virtually every GSO satellite manufacturer responded to this market by developing flexible satellites with reconfigurable payloads capable of modifying coverage and connectivity in response to demand dynamics, and reducing manufacturing time and costs to minimize operators' cost per revenue bearing bit.

Despite the technological advances in its 2nd quarter century[2], the Communications Satellite Systems Industry remains challenged with identifying new, emerging markets (e.g., 4K/8K UHD OTT Video, IoT/M2M and 5G backhaul) for sustained, higher demand and developing technologies and systems necessary to meet, but not oversupply this increased demand. To borrow Elon Musk's apt description of the difficulty in determining the root cause of the September 2016 Falcon 9 launch pad explosion, this challenge is "crazy hard," although one our industry has repeatedly met in the past.

Afterthoughts

The wave of innovation that characterized the Communications Satellite Industry's 2nd quarter century culminated in what many industry observers see as an emerging disruptive transformation and the precipice of perhaps the most critical juncture in the industry's history. Are we on the verge of being too successful with the launch of HTS GSO systems and NGSO Megaconstellations by providing capacity far greater than projected market demand?

Indeed, the Communications Satellite Industry might be viewed as potentially going through a disruptive transformation analogous to that which the Oil and Natural Gas Exploration and Production Industry experienced over the past decade. The petroleum industry developed and applied innovative new technologies – targeted horizontal drilling and hydraulic fracturing, in addition to other exploration and production advances – to raise worldwide oil production capacity well above current demand levels. U.S. production of petroleum roughly doubled over this period, and the resulting collapse in the price of oil by more than 70% (at the nadir) between 2014 and 2016 bankrupted many small, innovative exploration and production companies and substantially impacted major petroleum producers.

A realistic assessment of the Communications Satellite Systems Industry's expected market conditions as well as the relentless advances in competitive terrestrial broadband access, including fiber-optic and Advanced LTE 4G and 5G wireless systems[3], and plans for UHTS GSO and NGSO systems strongly suggests that new applications and markets need to be identified to ensure the industry's long term economic health and financial ability to continue innovating to provide compelling solutions for society.

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[2] And perhaps, somewhat ironically, as a consequence of them as well.

[3] Indeed, Verizon Wireless recently announced it will initiate 5G service with 1Gbps data rates to homes and other access points in five U.S. markets in 2018.

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