THE SPACE INDUSTRY: HIGH TECH AT LAST? A MARKET BASED INTERPRETATION

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ABSTRACT

Despite popular perception of the space industry as *high tech*, many commercial satellites are sent into orbit with years- or even decades-old technology. The significant capital expenditures (CAPEX) involved in building and launching a satellite requires pursuit of a design that will ensure returns and minimize the likelihood of premature satellite loss – a practice that, combined with stable end-user markets, has long meant risk aversion and use of only highly proven technology. Yet, recent ROMs, request for proposals, and firm contracts have highlighted a shift in this rigid *modus operandi* towards greater flexibility in design, manufacturing, and launch approaches. Emerging trends demonstrate a growing dependence on technology during each of these three phases to improve the business case of a new venture; market forces such as heightened competition and rapidly evolving customer demand are obliging operators to forge a closer relationship with the technical aspects of their satellites, adopting new components and processes that best suit the unique business opportunity targeted by each satellite.

This paper analyzes what market trends tell us about satellite operators' changing perceptions of the role of technology in their business, expanding to what this means for the industry at-large. Growing interest in electric propulsion, digital channelizers, ultra-high throughput capabilities, and reusable launch, among other nascent ideas, are driving an evolution in the satellite communications industry and the manufacturers and launch service providers that make them possible. The utilization of newer and more advanced technology to drive market growth and competitive advantage will have a greater role in market dynamics moving forward.

1. INTRODUCTION

The launch of *Early Bird* in 1965 ushered in a new era of communications, and an uncharted market for commercial remote communications and broadcast. Expansion of the commercial satellite communications market in the 1970s and 1980s, especially with the formation of Société Européenne des Satellites in Luxembourg (now SES) in 1985, created a robust industry with growing subscribers counts and revenues. TV broadcast was the cornerstone of this success. TV broadcast markets were not only profitable but predictable over the lifetime of the satellite, even as advances in reliability enabled 15+ year design lives. This strong market in the face of high CAPEX requirements and an inability to service satellites once launched cultivated a risk averse culture amongst commercial satellite operators.[1] Standard processes for implementing '*new*' technology required several years of on-orbit operations to establish space heritage, and operators were hesitant to pay a premium for new solutions. Thus even as manufacturers pursued research and development (R&D) to create new capabilities, it was difficult to monetize this in commercial contracts.

Recent market activity evidences a change in this paradigm. In 2016, Inmarsat established a joint R&D venture with VT iDirect, a manufacturer of ground equipment hardware, on the premise that operators can no longer rely on industry to generate innovative solutions and that a systems thinking approach is required. R&D spending has increased among both manufacturers and operators: for instance, SSL notes a five-fold increase in R&D spending in the last three years[2] and Thales Alenia Space a doubling of R&D spending in the same period[3], while Viasat has shown R&D spending rises of more than 100% since becoming a satellite operator.[4] While Viasat's spending growth in the 2005-2008 period can be linked to the expense of opening a new market in satellite broadband and transitioning into an operator, the ongoing investment increases through 2016 reflect a rising focus on

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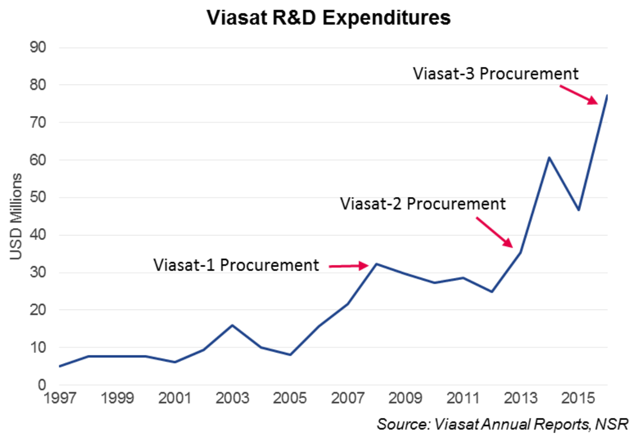

Exhibit 1: Viasat R&D Expenditures

technological innovation at the operator level. In a March 2017 panel, executives from five leading prime manufacturers (Airbus Defence and Space, Orbital ATK, SSL/MDA, Boeing, and Thales Alenia Space) were unanimous in the statement that R&D is more important now than it was 15 years ago.[5]

Stephen Spengler, CEO of Intelsat, recently noted that the market is "in a transitionary phase" in regards to the technological evolution of the satellite ecosystem of manufacturing, launch, and ground segment.[6] An evolving market landscape has steered this change. Given competition from terrestrial solutions and saturation of existing satellite markets, the industry must leverage new technology across the value chain to open opportunities and continue growing – and it has started along this path. While technological innovation has been an undeniable component of the satellite industry since its inception, the pursuit and adoption of advanced technology has intensified to become a driving force of competitive advantage and industry development.

2. BECOMING HIGH TECH

New Market Environment The most fundamental trend driving this shift in the satellite telecommunications industry has been the advent of High Throughput Satellites (HTS). HTS utilizes a technology known as frequency reuse through a spot beam architecture to achieve total throughput of many—oftentimes on the order of magnitude of dozens—of times a traditional satellite for the same allocation of spectrum. The most profound impact of this HTS technology has been, to some extent, a large reduction in scarcity of satellite capacity, and a massive increase in CAPEX efficiency on a dollars per unit of capacity to orbit basis. An example of this is the ViaSat-1 satellite which, at the time of its launch in 2011, had more capacity than all other satellites over North America at the time, combined, while requiring a much lower CAPEX per gigabit per second (Gbps) to orbit than similar satellites: ~$400 million for ~140 Gbps.[7] Comparing this to satellites with a similar mass and payload power profile launched in the same time period, ViaSat-1 achieved $\frac{1}{20}$ the cost per Gbps to orbit. While some operators remain firmly rooted in the traditional FSS world, the majority of satellite operators have started to incorporate some HTS technologies into their business models and future fleet development plans.

The rise of HTS technology has occurred at a time when the greater telecommunications environment has likewise undergone a massive shift. The cost of terrestrial bandwidth has come down dramatically, while bandwidth consumption is soaring. Tangentially, this has impacted the satellite telecommunications industry insofar as drawing consumers from their TV screens to their smart phones, slowly—but steadily—eroding the value of satellite for TV broadcast. Largely absent from the explosion in data growth, and the decline in pricing, has been the satellite telecommunications industry which continues to derive >50% of its revenues from video, and has largely targeted data applications for high-value enterprise or mobility solutions—that is, very small, niche markets to connect airplanes, ships, and vehicles on-the-move. This is beginning to change, however, with tools at the disposal of operators today facilitating new markets and providing elasticity of demand.

Whereas the average global price of a 36 MHz Ku-band transponder serving TV broadcast markets was $2.3M annually in 2010, data markets fetched only $1.6M per transponder.[8] By 2017 this data price has fallen to $1.1M, and is expected to decrease further in the next decade. Given the key role of data demand in future market growth, this pricing decline has a significant impact on revenue generation planning for future satellite procurements.

Today's Operator Drivers These two factors—a massive increase in the CAPEX efficiency of satellites, and a significant decrease in the price of data—have moved the satellite telecommunications industry to the precipice of a new era. While still very much in early stages, satellite operators today are speaking about dramatically expanding addressable markets by actively driving prices down, with this being the crux of the "transitionary phase" referenced earlier by Intelsat's CEO Mr. Spengler. Satellite operators today find themselves in a delicate balancing act, with prices falling quickly, but demand verticals being hard to pinpoint in advance, leading to increasing volatility in metrics such as top-line revenues, as Exhibit 2[9] shows. Compounding this difficulty in the case of some operators (notably Intelsat) are finances that remain tenuous, with Intelsat's debt to EBITDA ratio exceeding 8 in an industry where "investment grade" would be considered anything below 3.3.

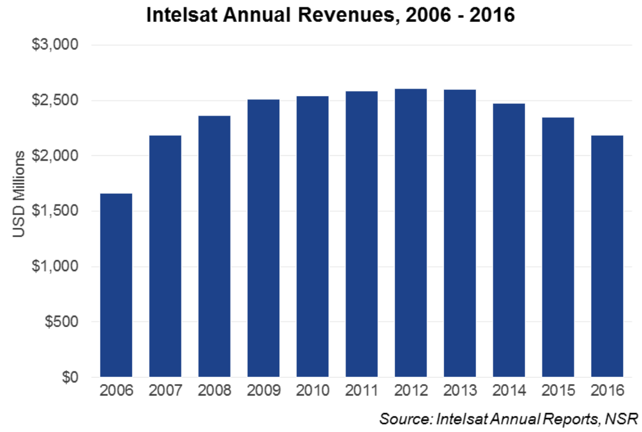

Exhibit 2: Intelsat Annual Revenues, 2006 - 2016

With all of this said, it is apparent that future growth in satellite will need to come from increasing volumes of data being passed through the satellites at a lower cost per bit, rather than from rising, or even flat, prices for services provided. One of the most critical concepts moving forward, therefore, will be elasticity of demand, and a critical driver of success, the extent to which satellite operators can find new verticals with demand that is highly elastic. Likewise, satellite operators have found that in an era of increasingly commoditized capacity, it is becoming essential to maintain margin through vertical integration, partnerships with service providers, and other methods to protect the value of the services being provided.

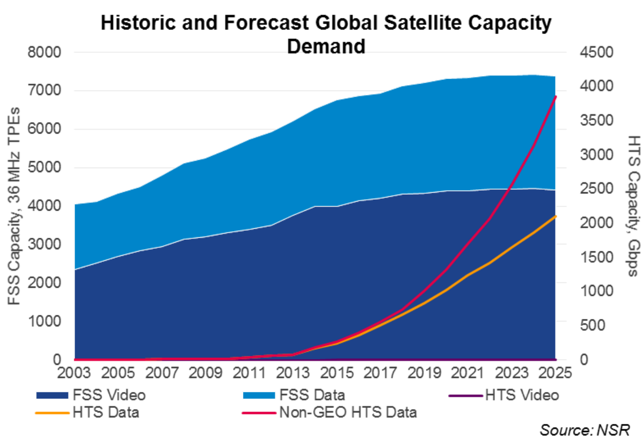

Exhibit 3: Historic and Forecast Global Satellite Capacity Demand

In this new world of elastic demand, falling prices, and orders of magnitude more capacity, the majority of revenue and capacity growth will come from HTS. As Exhibit 3[10] shows, demand for traditional FSS video and data services will, from 2015 to 2025, grow by only around 10% in total, compared to an increase of approximately 75% from 2003 to 2015. Conversely, HTS—both geostationary and non-geostationary—will see growth from a few hundred Gbps today to several thousand by 2025. This will correspond to a revenue increase on the HTS side of approximately $7 billion, with FSS revenues in fact decreasing by around $1.5 billion during that time. Operators aiming to capture new market share

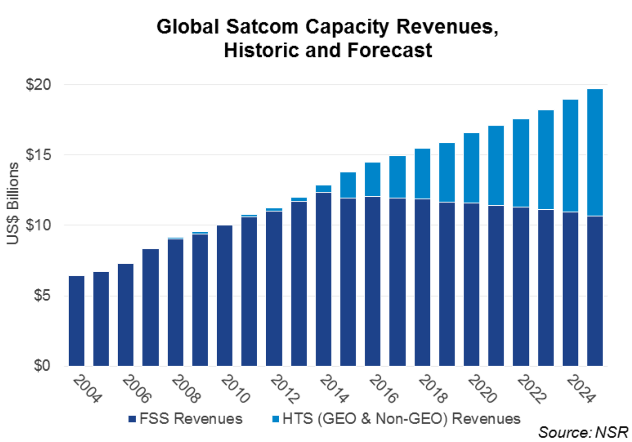

Exhibit 4: Global SATCOM Capacity Revenues

will therefore need to target HTS-type demand verticals, with these including highly elastic applications such as 3G/4G cellular backhaul or in-flight connectivity (IFC). In this context, there are two main drivers behind the business decisions of satellite operators today: optimize CAPEX, and find ways to expand addressable market.

Optimize CAPEX The motivation to optimize CAPEX can manifest itself in a number of ways. The most headline-grabbing has been the strategy of ViaSat, Echostar, and others, that being to simply launch the most capacity for the lowest price, thus achieving the lowest possible CAPEX per Gbps to orbit. However, there are other, equally valid methods that have been employed, such as Eutelsat's "design-to-cost" strategy, which aims to use technologies such as electric propulsion orbit-raising, new (and more cost effective) launchers, and potentially Condosats to minimize CAPEX outlay while maximizing throughput.

Expand Addressable Market Expansion and optimization of addressable market has proven a somewhat less straightforward exercise, given the potential costs and variability involved in attempting to serve more users, serve markets that change during the course of a day, or address changing demand over the course of satellite lifetime. Very high throughput designs, those approaching a Terabit per second (Tbps), increase the amount of available capacity and the number of potential users to be served with a single satellite, though require a significant near term market opportunity to be justified or else can elongate break-even timelines.

Some of today's fastest growing markets, particularly aeronautical connectivity and consumer broadband, exhibit varying demand over the course of a day. For example, as airplanes depart a central hub, demand follows their path and radiates away from the airport. To maximize revenue per bit of capacity allocated, the capacity must follow the aircraft flight paths. Turning to consumer broadband, the demand tends to see significant peaks and valleys in a particular geographic area with time. As usage is traditionally heaviest in the evening hours, there is a fairly well-defined pattern of corresponding Internet use that moves from East to West in a region. Uniform capacity allocation across this region thus would leave some areas oversubscribed while others have spare capacity at a given time.

In addition to these short-term changes in demand, long-term demand evolution is today's reality. Operators have realized that data markets today are less predictable than Direct-to-Home (DTH) satellite markets in the 1990s and early 2000s. Consequently, operators must more critically assess the ability of a satellite to address a market five or ten years post-launch that may be vastly different than that present at the time of satellite design.

New Dynamics The future of these trends is already beginning to play out, with satellite operators speaking about fully flexible and integrated systems, sometimes involving both GEO and Non-GEO satellites, ground equipment partners, and other actors in the value chain. The most noteworthy example of this in the market today is SES, which recently acquired a full 100% ownership of MEO-HTS operator O3b[11], and during a similar timeframe acquired RR Media[12], a video platform services company, to be merged with SES's own video value-add arm, SES Platform Services GmbH. The other significant example would be Intelsat, with the company having recently announced a proposed merger with LEO-HTS startup

Operator Motivation/Goal	Example of Technology Pursued	Example Contract
Reduce CAPEX	Reusable Launch	SES-10 with SpaceX (2016)
Optimize Spectrum Use	HTS	Kacific with Boeing (2017)
Optimize Daily Utilization of Satellite	Beam Hopping	Viasat-3 with Boeing (2016)
Optimize Lifetime Utilization of Satellite	Software Defined Payload	Eutelsat Quantum with Airbus/SSTL (2015)
Broaden Addressable market	Electric Propulsion	Inmarsat 6 with Airbus (2015)
Improve Service to End-users	Regenerative Payload with Active Antenna	Hispasat 36W-1 with OHB (2009)

Exhibit 5: Examples of Technology and Contracts pursued per Operator Goals

OneWeb, backed by funding from Japan's SoftBank[13]. The latter deal is also noteworthy because Intelsat already has existing agreements in place with ground equipment provider Kymeta, and OneWeb has stakeholders that include telcos such as Bharti Airtel and chip maker Qualcomm. The majority of these deals are being driven by a desire to expand addressable market and capture demand from new verticals, with operators acknowledging the challenging pricing environment today as a long-term impediment to growth. In short, in order to remain competitive, and to be attractive to the types of demand that are seeing significant growth today, operators have been forced to use more innovative technologies and more nuanced sales channels. Gone are the days when a satellite operator can expect to launch a satellite fully-leased for the 15-year lifetime, and operators today are finding themselves in a much more fast-moving, fast-changing environment. The uncertainty that this brings about has led to operators to optimize CAPEX spend and take a more cautious approach to new launches, with this oftentimes requiring a new technological breakthrough in order to close a business case.

3. TODAY'S SOLUTIONS

When asked about strategies for overcoming today's market challenges and capitalizing on new opportunities, Intelsat's Spengler commented, "We have to be looking for innovation from all the sources out there – and there are a lot."[14] Four types of technology stand out when reviewing trends in increasing operator reliance on technology to close a business case and increase the bottom line.

HTS The most significant technology-based change in the commercial GEO satcom market has been the emergence of HTS. The multi-spot beam, high frequency reuse payloads were a sufficient departure from traditional FSS satellite capabilities that NSR coined the descriptor *High Throughput Satellite (HTS)* in 2009.[15] Yet implementation of full HTS or hybrid HTS/FSS designs was slow, remaining below 20% of annual launches until 2015.[16] A reflection of operator risk aversion, the high throughput was not seen as a sufficient incentive to procure HTS until it became increasingly difficult to address growing markets and deliver cost competitive solutions within the traditional FSS paradigm. This brought about a significant shift in procurement and launch trends: launch rates of HTS and FSS/HTS hybrid satellites tripled between 2014 and 2015, and are expected to average 41% of launches between 2015 and 2018. This correlates to 36% of all commercial GEO comsats in the 2015-2018 period when including MSS, DARS, & DBS, and will exceed 50% in the coming decade.

Recent system architectures, such as the Tbps-satellite Viasat-3 system, advance the HTS concept to address an even broader market and serve ballooning end-user capacity demand.

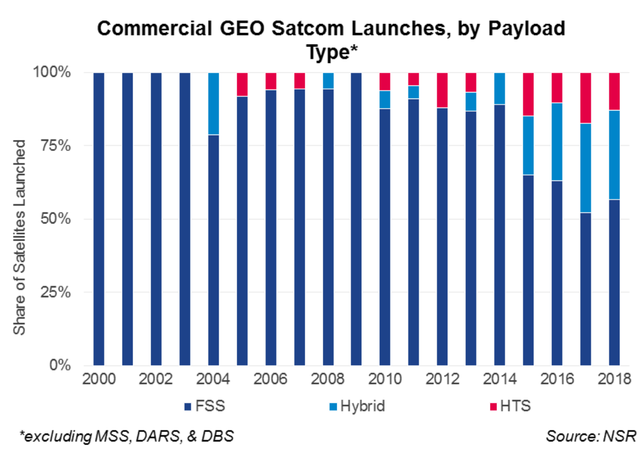

Exhibit 6: Commercial GEO Satcom Launches, by Payload Type*

Flexible Payloads Various forms of flexible payload technology have been available for decades, but aside from MSS systems, adoption rates for payload flexibility have remained low. Commercial operators deemed flexibility too costly for the capabilities gained. As a result of the changing market environment and new operator drivers assessed in Section 2, payload flexibility offers a more compelling value proposition today. Satellites ordered in 2015 and 2016 reflected double the amount of flexible payloads compared to those procured in 2013 and 2014, a market share increase of 30%.[17]

Digital processors have seen a particular rise in popularity. In 2014 Arabsat invested shy of $300M for the construction of SaudiGeoSat-1, planning to leverage Lockheed Martin's flexible processor to counteract jamming and optimize services with frequency hopping.[18] This pricetag exceeds what a comparable non-processed 30 TPE + 24 Gbps HTS payload satellite would cost, but the added capabilities were viewed as critical to delivering a competitive, unencumbered service. The flexible processor for JCSAT 17 was selected to provide capabilities to redirect capacity and power as needed in response to natural disasters or changes in market demand.[19] Both SES-12 and SES-14, scheduled to launch in 2017, house a digital transparent processor that offers partial processing for the HTS payload to customize customer solutions.[20] SES has made pursuit of fully digitized payloads the next step in its technology roadmap.

The Eutelsat Quantum design has taken this a step further, by seeking to software define the satellite. With the ability to reprogram frequency, coverage patterns, and power allocation dynamically in orbit, Quantum will enable Eutelsat to take on a new mission and address a new market at any point in the satellite's design life and without launching new assets. This level of flexibility is ever more attractive as data markets become more uncertain.

Electric Propulsion While Russian satellites have long relied on a combination of direct injection and electric propulsion to place satellites in the designated orbital slot, use of electric propulsion (EP) in western commercial satellites has traditionally been limited to station keeping. New electric thruster designs have extended the applications of electric propulsion to orbit topping or full orbit raising. Since the first fully electric platform (orbit raising and station keeping) was introduced in 2012, both the market share and absolute number of electric propulsion orders has increased. As seen in Exhibit 7, the proportion of satellites ordered with EP exceeded 50% in 2016.[21] EP offers a higher dry:wet mass ratio, meaning an operator can either maintain the original payload parameters and launch a lighter satellite (reduce launch costs) or select a larger payload (increase capabilities). Both options increase payload fraction and hence the capability:cost ratio.

For example, by ordering ABS-3A on a Boeing 702SP platform and dual launching with Eutelsat 115 West B on a SpaceX Falcon 9, ABS was able to place 96 36 MHz TPEs in orbit at a cost of ~$160M*, or ~$1.7M per TPE.[22] Compared to ABS-2, which launched only a year earlier, this contributed to a savings of ~$0.4M per TPE.[23]

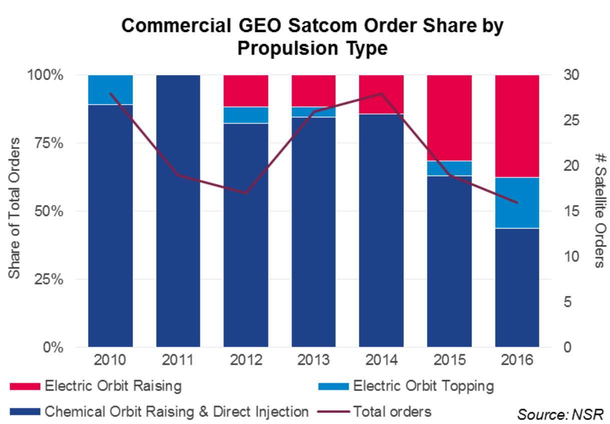

Exhibit 7: Historical Commercial GEO Satcom Order Share by Propulsion Type

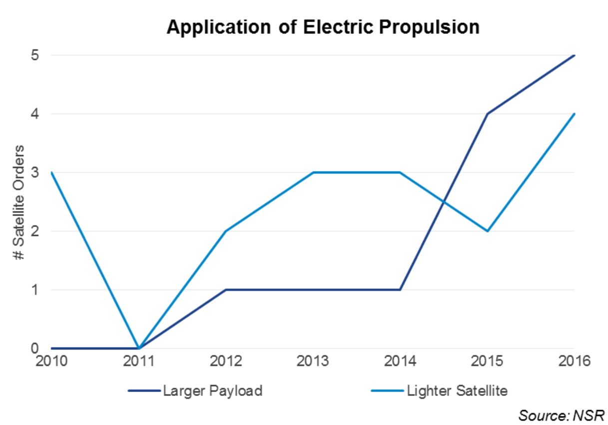

Exhibit 8: Historical Application of Electric Propulsion

* in 2017 dollars

As would be expected, trends in selection of electric versus chemical propulsion closely track launch market dynamics. As noted in Exhibit 8[24], use of EP to reduce satellite mass was pursued at twice the rate of use of EP for larger payloads in the 2011-2014 period, when low pricing for the Falcon 9 and Ariane 5 lower berth made a small satellite more appealing. Since 2014, rising interest in HTS and deployment of global systems has led to the growing employment of EP to add an HTS payload. Inmarsat opted for EP on the Inmarsat-6 series, leveraging the additional mass to place a Ka-band HTS payload alongside the primary L-band payload that will augment the Global Xpress system in high demand regions.[25]

Reusable Launch Incremental improvements in vehicle design and launch operations have achieved some cost reductions with time, but overall launch costs have remained relatively stagnant. SpaceX and Blue Origin are endeavoring to alter this dynamic with reusable first stages, while ULA and Airbus are looking to reusable first stage engines. SpaceX has suggested a 10%-30% price reduction[26] for customers flying with a reused first stage, savings that would directly translate to faster breakeven point for operators. In 2016, SES became the first operator to contract for this capability, saving ~$6-20M on the Falcon 9 launch of SES-10.[27] This position on the first launch of a new vehicle variant indicates a more open risk posture, weighing this tradeoff in favor of the cost savings that will further the bottom line. Five additional reused first stages are planned to be launched in 2017, including additional commercial players leveraging the savings to improve the satellite's business case.

4. TOMORROW'S CAPABILITY TARGETS

Market forces driving this surging adoption of higher tech solutions will continue to evolve and impact operators, requiring ongoing R&D and implementation of new technology to maintain a competitive edge. Inmarsat CEO Rupert Pearce noted in March 2017, "There are massive opportunities out there, but they require us to keep the ball rolling with technology."[28] Daniel Goldberg, CEO of Telesat, confirmed, "It all gets down to bandwidth economics…technology has evolved and will continue to evolve, we need to anticipate the technologies that are coming."[29] Operators' growing interest in leveraging new technologies, particularly those offering payload flexibility, will prompt a positive feedback loop for R&D: as operators implement more capable solutions, their competitors may be forced to adopt similar or more advanced solutions to remain competitive.

Several capability targets have been identified that would mitigate program risk and optimize revenue potential when making new satellite procurements.

More efficient satellite designs are a longstanding target for innovation. Hispasat is under contract with SSL for Hispasat 1F and Amazonas 5, both of which will house a photonic payload to test optical communications.[30] Hispasat sees this technology as a means of reducing mass of future satellites while increasing the available capacity.

Ongoing efforts to enable an operator to change coverage in orbit, including frequency, power, regional coverage, and beam shape, will continue to advance. The Quantum design is a first step towards a software-defined satellite that will offer these attributes. A fully software-defined satellite, including the waveform, remains a goal that would provide a high degree of flexibility on-orbit and on the ground, as well as the ability to adapt to both daily market demand variance and long term market evolution.

Order to launch timelines are on the order of 2-3 years, driven by long-lead components (such as TWTAs) and the level of customization still implemented on standard busses. This constrains both operator cash flow and requires target markets to be defined several year before being served. By launching a satellite sooner after ordering it, such as a year later, an operator would have a better idea of the shape of market demand and could better design the satellite to suit customer needs. Shorter build time satellites may require additional operator willingness to alter *modus operandi*: manufacturers may require a base commitment of annual/biannual orders. Modular designs that enable late decision-making are an avenue of development addressing this goal, as are software defined satellites that leverage software-based specialization rather than hardware-based.

Operator interest in eliminating the fixed 15+ year investment that today's satellites represent has grown alongside market uncertainty. Some operators have proposed shorter lifetimes of 7-8 years, expecting manufacturers to offer a 50% cost reduction on such a redesigned bus. Maintaining a 15+ year satellite bus with the addition of payload flexibility or software definition would offer a reprieve from the long-term fixed asset, given the abilities to alter coverage, but satellite versatility remains limited in scope by satellite hardware such as on-board power. Satellite servicing is an alternate concept, proposed as a means of physically altering a satellite's capabilities while in orbit and thereby offering a different scope of flexibility than software-based solutions. SSL is exploring a satellite platform to which additional payload modules could be attached at any point in the satellite service life, enabling operators to invest in and grow their business in response to market evolution.

In-space manufacturing coupled to satellite servicing seeks to address a launch-based challenge for operators: optimizing deployables within the constraints of a payload fairing. Larger diameter antennas are particularly attractive as HTS designs are pursued and higher frequencies are utilized.

5. CONCLUSION

Falling capacity prices, ballooning supply, and the transition to data driven demand growth have challenged GEO satcom operators to remain profitable and competitive. At the same time, manufacturers continue to offer and develop new technologies that alter the cost:capability dynamics of GEO satcom. This confluence of market pressure and technological availability has brought the value of advanced solutions to the fore, advancing the satellite industry to a point of *high tech.* Operators are turning to technology en masse as a means of improving their business cases. Mark Dankberg, CEO of Viasat, noted in March 2017 that he is, "super interested in new technology of every type."[31]

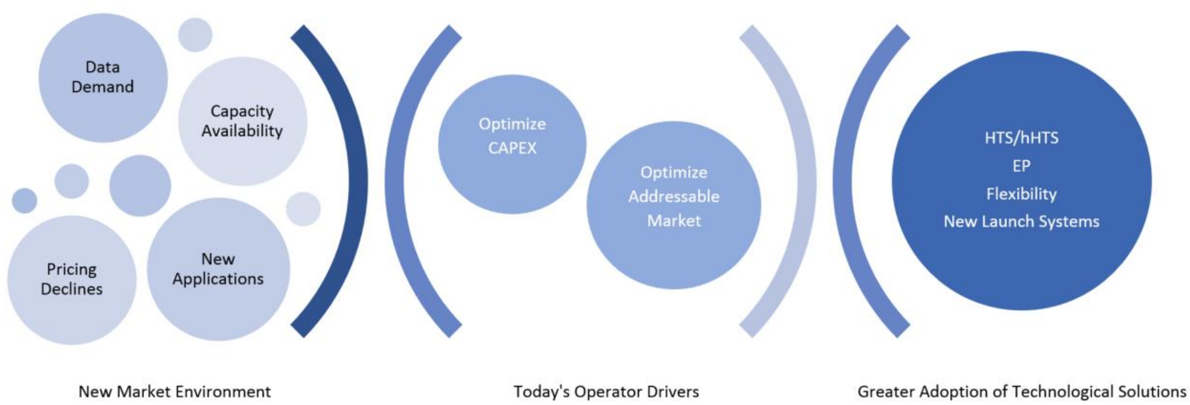

Exhibit 9: Commercial Satcom High Tech Conversion Process

There is no single technological solution to the challenges faced by commercial satcom operators, and the array of technologies developed in response to growing operator interest will address a diversifying market moving forward. Stronger operator support for innovation encourages a faster pace of R&D for the industry as a whole, across the design, manufacturing, and launch segments. Ground segment, while not a focus of the paper, is a critical element to cost efficiency that will also continue to evolve with new practices and technologies.

With a growing diversity in technologies and designs that can be leveraged in a single satellite and across a fleet, competitive factors themselves will diversify. No longer will commercial operators be compared on the basis of fill rates alone, but a combination of revenue per Mbps per month, rate of program ROI, cost per Mbps to orbit, EBITDA margin on data business, and bits per hertz ratio, among other key performance indicators. As this competitive diversification plays out, it is clear that both the long term challenge and the long term opportunity for commercial GEO satcom is the transition in technology that has already begun.

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