Whitepaper

July 2024

Operationalizing Mass Market SatComs

A challenge of both literal and figurative moving parts

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In partnership with

Delivering the Digital Future
Netcracker
An NEC Company

Appledore RESEARCH

Published by Appledore Research LLC • 44 Summer Street Dover, NH. 03820

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Publish date 24 July 2024

Cover image: Bing image creator/Robert Curran

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Introduction

In this whitepaper, we take a succinct look at the challenges posed in automating and operationalizing the rapidly maturing satellite industry. We thank Netcracker for sharing their many learnings, and for the extensive discussions that helped us clarify and crystallize many of these impacts and what is necessary for Network Automation Software (NAS) and Digital Experience Software (DES) to serve this industry.

We will briefly touch on:

- the importance of last mile
- the emergence of LEO satellites and their broader implication on GEO and MEO
- the significant benefits in terms of reach and underserved coverage that can *only* come from satellite
- the transformation of satellite industry economics
- the challenges posed by this very different topology and dynamic environment
- the investment that Netcracker has made in a blueprint (pre-engineering) for operations at scale

The Critical Last Mile: Increasingly a Necessity not a Luxury

The last mile, with the exception of 5G mobile hype, and despite the fact that the last mile consumes the vast majority of capital and resources, is sometimes neglected. An old adage is that “money is in the poles and the holes”. Moreover, due to the capital-intensive nature of last mile access, sparsely populated regions, regions with challenging terrain (or no terrain at all), and regions with lower ability to pay become inconvenient truths. For some use cases this creates coverage gaps, in other use cases it creates digital divides—between urban and rural, between rich and poor. These divides are far more than technological inconveniences; they impact economic well-being, educational parity, and increasingly access to advanced services such as health care. Readers may notice that while it is not Appledore’s core coverage area, Appledore periodically covers any technology that helps in this forgotten, but absolutely critical, space. After all: if a communications system is a chain, the last mile is an absolutely essential chain-link.

Satellite coverage (regardless of the technical details) is uniquely able to serve the most challenging environments such as extreme rural, ships at sea, planes in transit, and forbidding terrain such as jagged mountains. The problem has always been capacity and cost: while technically feasible, satellite was neither cost effective nor did it have the aggregate throughput and latency to be a mass-market solution. Satellite can also provide the missing link in “device to device” services (as opposed to internet access) that are primarily provided by more mainstream terrestrial systems, providing, in effect, mobile roaming into the most remote regions, especially for services that demand “always, everywhere” reachability – whether traditional devices or IoT “things”.

Satellite Market: Undergoing transformation to mass market operations

Satellite can fill a lot of coverage gaps, provide access to underserved areas, and to services that must operate truly everywhere. But this has always been the case – so what's new? Fundamentally, the answer lies in two areas: capacity, and cost. Low-earth orbit (LEO) satellite in particular also improves performance, by decreasing the round-trip distance and therefore delay inherent in a signal.

LEO is the most transformative on both counts. It can support a much larger number of cheaper satellites, which provides both increased capacity and reduced costs. Yet some of the fundamental drivers of change, such as vastly decreased launch costs, software configurability of services, and far more compact and cost-effective RF electronics, impact satellites of all orbital types (LEO, MEO, GEO). Moreover, the success of LEO is causing MEO and GEO operators to rethink what is possible.

Lower costs, along with sufficient capacity and lower latency, are allowing emerging satellite services to be priced such that they can serve a mass market and serve a more primary role in real time and other demanding communications. While still more expensive than terrestrial equivalents, satellites can thrive where terrestrial alternatives struggle – often in both cost and performance. To provide one tangible example, we researched one common use case – rural North America. In mountainous rural Colorado, unreliable 3Mbps DSL (bonded) costs a little under half what Starlink costs; while Starlink provides more than 10x throughput and better overall customer satisfaction. No, it's not at price parity, but one could argue it is at value superiority. Furthermore, the aforementioned DSL service remains unavailable in the most remote parts of this already remote region – at those residences, ONLY satellite is possible.

The potential of success at scale implies that satellite is faced with a truly transformational challenge; how to move from niche, low volume, long duration services to highly efficient mass market services. These providers must, in short order, create what are effectively greenfield software solutions to automate, to lower costs, to ensure a good customer experience, and to deal with myriad business challenges inherent in operating around the globe.

Another dramatic change to the satellite norm is so called “direct-to-device” services in which satellite completes a terrestrial communications service. Conceptually similar to roaming, this demands not only operational understanding of satellite networks, but also understanding of terrestrial networks, as well as the roaming rules, seamless handover, settlements/billing complexities and myriad more complexities that come with the integration of two industries, jointly delivering a combined service, seamlessly. As Arthur C. Clarke wrote: “any sufficiently advanced technology is indistinguishable from magic.” But behind magic is complexity.

Finally, satellite has a further complication, essential to commercial success: they must not only operate efficiently (low-cost, high-scale operations) but they must ensure high customer satisfaction and SLA compliance, all in an environment where technical feasibility and the underlying infrastructure are constantly moving, changing both what service performance may be expected, but also the network configuration (attached points, etc.) that will yield the best solution. These SLAs underpin large contracts and a viable business model.

What's different? What's needed?

This rapidly maturing technology and cost transformation is both a blessing and a curse. It's a blessing in that the opportunity to solve practical and social problems exists, and because a large new revenue stream is within reach. It is a curse in that an entirely new end-to-end solution is needed, and needed quickly. It is similarly a curse in that the challenges faced by satellite often diverge from the underlying assumptions in today's terrestrial networks.

Netcracker elected to step into this environment, work with a "lead user[1]" (in this case **Telesat**), and build first what they call a "blueprint" for Satellite operations, along with the requirements necessary to adapt a modern operations stack to the unique needs faced by satellite service providers. Netcracker theorized that as a "cloud-native full stack" specialist, and also as a specialist in configuring full stacks to clients who preferred not to "DIY", they might have a ready platform that could deliver a significant portion of functionality without radical surgery. This gave them a leg up in delivering end-to-end operations, and allowed Netcracker to focus on the engineering and operational requirements for the portion that does.

By starting with their cloud-native full stack (which contained many required functions and business processes out-of-the-box) Netcracker had a solid pre-built foundation to realistically deliver a top-to-bottom solution, at scale, in a reasonable time frame. Similarly, the cloud-delivered and disaggregated nature of the full stack made it easier to be deployed across the wide geography necessary to support global satellite networks and operations. Given these assets, Netcracker reasoned that the near-greenfield status of satellite operations provided a good canvas to think through engineering and operations as they should be, as opposed to dealing with embedded legacy decisions. Finally, they believed that while every operator would have its own business focus, the most fundamental changes demanded by satellite operations (technology) would have a large degree of commonality across satellite players -- including across the various orbital technology types (LEO, MEO, GEO). In this respect partnering with Telesat as a lead user was a logical choice because no embedded geotechnology or mindset contaminated their "canvas".

For starters, satellite companies need. . . everything. They need to think through and automate everything from service definition, through order negotiation, calculation of an optimal solution and service configuration, provisioning, and through the life cycle to manage the service via a closed "control" loop. At the same time, they needed to be constantly monitoring SLA performance and conformance as well as consider the possibility — or need for — a new service configuration to maintain that SLA. Satellite operators also needed to handle what has historically been one of the

[1] Lead users, to use the term coined by Erik Von Hippel at MIT, are innovators who conspire with tech suppliers to define, refine and take a technology from concept to practical reality.

most complex and labor-intensive parts of telco operations: charging and billing. And in this regard, satellite operations differ dramatically from most telcos.

Traditionally, and unlike telcos, satellite services have historically been simple services with fixed tariffs. Going forward, however, satellite's objectives demand that they adopt more flexible charging, like usage-based, similar to what telcos have been doing for some time. Also unlike telcos, which almost always operate in a specific geography, generally within a specific regulatory and tax jurisdiction, satellite's very value proposition is that they operate *everywhere*. This implies dozens or even hundreds of regulatory and tax environments: and everyone requires different handling in the charging billing and documentation realm.

Table of industry needs and OSS/BSS Impacts

The annotated table below lists the major areas where satellite differs from terrestrial operations, and in doing so summarizes the nature and scope of the blueprint that Netcracker has created for satellite operations.

Table 1: Summary of Unique Satellite Needs and Operational Implications

Need	Operational and Technical implications on NAS and DES[2]
Greenfield at Scale	• Require rapid deployment of complex end-to-end NAS + DES solution • Must operate at scale • Understanding of implications of business model and environment on entire operational system • Must minimize the complexity of integration, testing and rationalization endemic in traditional systems (the "integration tax")
Dynamic Network with constantly changing service configuration possibilities	• The dynamic network ('birds") has myriad, major, implications • Highly dynamic network inventory (physical changes) • Highly dynamic service inventory (as delivered) • Need to constantly recalculate SLA possibilities and alternative delivery options • Complex Root Cause Analysis • Capacity management depends on intersection of moving users & moving network
High dynamic volumes caused by above – 1000s of changes per second.	• Complexity and short reaction times beyond the ability of human actions • Demands automation • Closed loop operation – often hands off closed loops • AI methods highly desirable
Multi-domain (very!)	• Complex service chains • Terrestrial "back haul" from downlink to ROW • Multi-network device-to-device (mobile, interconnect, satellite, …) • Cross-carrier: need to deliver SLA and health data to partners

[2] NAS = Network Automaton Software = Next Generation "OSS". DES = Digital Experience Software = Next Generation BSS. The specifics of each are defined by Appledore in our taxonomy.

Need	Operational and Technical implications on NAS and DES[2]
Global Coverage	• Regulatory regimes • Language and local conventions • Tax regimes • Settlements • Currencies

Source: Appledore Research with input from Netcracker Technologies

It's worth briefly elaborating on the extent of the impacts. Likely the largest is that of multiple moving parts. While fixed Internet access in remote locations will certainly be a use case, a large number of satellite communications use cases involve endpoints that are moving (e.g.: ships, airplanes) combined with the network endpoints which are also moving (the LEO satellites). It should be obvious that the attach point is different at different times of day, and also that the attach points will move continuously throughout the day — possibly even during a session. Unlike a mobile network, where *users* move and handover between fixed network termination points, in many satellite scenarios, either the user is fixed and is handed over among moving LEO satellites, or both are moving, increasing the complexity further. This means that inventory must be extraordinarily dynamic. It means we must track both users and the network endpoints themselves. It also means that calculations must be made as to what endpoint has both the capacity and the ability to satisfy an SLA. Furthermore, SLA's and choices can be impacted by the angle that exists between a user and an endpoint. This might have to do with how far one is from a satellite, whether it is moving toward or away from you, and also your longitude and how that compares to the satellite's orbit. And of course, calculations must be performed considering all of these variables and how they are expected to change over time. Note this implies a strong temporal component to inventory.

While these implications are all captured in the bullets above, the depth of the impact may not be. One takeaway that warrants discussion is that this dynamic complexity, combined with complex calculations on every possible state, demands automation. It also illustrates why not just simple automation, but intent-based closed loops, along with various forms of AI, ML and analytics, performing prediction, will be essential. Yes, these are all concepts that terrestrial networks are playing with, where the dynamic nature of cloud environments and SDN makes them highly desirable if not essential. But the complexity of moving satellites, moving user terminals (planes, ships, . . .) and moving users—and the fact that it is needed *today*, not "when we get it right", poses a different reality.

While the term "digital twins" is often used lightly, Netcracker's approach has many aspects of a digital twin. While they don't model the propagation (that is handled by the satellite industry control plane specialists), the ideal of "inventory" clearly undersells what has been built. At the core of these closed loop and AL/ML driven operations is a representation of the dynamic, end-to-end, environment which includes both the satellite environment, the user devices, and terrestrial components whether interconnection with terrestrial or the complex service chain that is in effect a direct-to-device service. Overlaid on this representation are important sets of data that characterize not only the topology but also the state and important performance metrics. In effect, this *is* a digital twin, providing input data to make decisions and recording the actual state of the network. Such representations are at the core of all advanced and autonomous operations. We see them in what we will loosely refer to as SDN controllers for terrestrial IP networks, and we see what appears to be a more complex representation of them here.

In the Digital Enablement Systems (DES, or new generation BSS) environment, we see a similar complexity driven by SLA compliance, location, differing demands in enterprise contracts (shipping firms, airlines, government agencies), and regulatory and tax environments that differ globally. One size, unfortunately, fits none.

Sample Use Case (Walk-through)

To pull these thoughts together, let's consider an example. Suppose an airline wants to offer upgraded in-flight Internet service, and use the same connection for airplane monitoring, engine monitoring, and other desirable functions for the operation of the airliner. The provider is LEO.

Being an airline, not an individual, we cannot assume a one-to-one relationship between a user (an airplane) and an account (the airline). SLA's may begin with the corporate level SLA but then have multiple tiers based on location and the environment the plane is being operated in. While in flight, airplanes will be moving at roughly 500 miles an hour, and maybe operating at altitudes of anywhere from 25,000 feet (8km) to 40,000 feet. The LEO satellites are travelling somewhat faster: around 7,000 miles per hour. As a consequence, we have the potential for a rapidly changing set of relationships between each of many airliners and its possible attach points. Depending on its altitude, its attach points will also be affected by at least a slightly different angle of reception (the "glancing angle"). And both the distance and angle from the plane to the satellite will be constantly changing for the duration of its connection.

The performance of the service must be constantly monitored. Calculations on alternate connect points must be constantly considered to determine if and when a handover must be made. The handover could be initiated to better meet the SLA, or possibly to free up needed capacity. In the Netcracker blueprint, they predict when the handover will occur by learning from real-time operational data and for this they have requirements for databases that can handle the moving planes, the moving satellites, as well as the implied relationships between them. They furthermore engineer the necessary structure for multi-user enterprise accounts that may have more than one SLA level. A closed loop is used to monitor and make changes as necessary (Netcracker indicates that the actual path computation is already embedded by a specialist in Satellite SDN control/space propagation. In the overall flow, Netcracker informs that PCE and acts on its calculations). This closed loop is informed by extensive predictive analytics and machine learning that understand the many permutations of past performance and can predict both future SLA performance and the best topology for service delivery to achieve that SLA. We can imagine that for any connection, alternate service configurations are routinely being considered in the background.

Customer service operations are similarly complex. There may be reporting regulations that differ from country to country – and many of them may apply to a single account since the airline may fly to many jurisdictions. Similarly, understanding a customer service inquiry demands not only knowing the account but the individual airplane, the time of day, its location, and its constantly changing service configuration.

There are many more complexities that we have overlooked in this simple example, in order to keep this document easily readable. But we have called out some that we think are the most illustrative of this new environment — and the complexities that they cause.

Netcracker's Blueprint and Solution

In brief, Netcracker began with its top-to-bottom Netcracker telco operations stack which encompasses both NAS and DES. Not only is this how they like to do business, but considering the fact that these satellite operators are greenfields, or near-greenfields, it has the advantages of a) providing a complete solution, and b) minimizing the integration cost and complexity due to the fact that Netcracker's various modules are designed to work together. It's a classic best-of-breed versus best-of-suite situation. However, flexible as it may be, it is a rare telco NAS solution that is designed for a network that is flying about the earth. Netcracker, working with its partner and lead user Telesat, essentially performed a differential analysis on their capabilities versus the desired capabilities, after extensive discussion with Telesat.

Some of the key changes were:

- a new breed of service and resource inventory that recognizes a constantly changing topology and serves as a foundation for dynamic performance management.
- a higher level of hands-off closed-loop operation because, unlike telco, it transcended desirable and was necessary.
- real-time assurance with AI / ML/ Analytics at the core; capable of pattern recognition, learning, and therefore effective prediction both to meet dynamic SLA's and to guide attachment points.

The myriad other changes included a regulatory, tax, and account structure necessary for complex enterprise accounts. We should emphasize that these enterprise accounts vary greatly even within the class, some being, for example, airlines or shipping firms, while others are mobile operators that need truly global roaming capability. Without diving into the details, we hope you can imagine the complexity of what is in effect a large wholesale contract that is back to backed by hundreds of thousands of retail or small enterprise contracts managed through a mobile operator.

No doubt this just scratches the surface — but we hope we have achieved Pareto optimality and given you the best insight for the least reading effort.

Real World Deployments

Notwithstanding its recent investment in developing a satellite-specific solution, Netcracker has been running its BSS/OSS as a managed service for **Viasat's** GEO satellite network for over 10 years. Viasat provides communication services to consumers, businesses, governments and military across the world and recently acquired **Inmarsat**.

Telesat is Netcracker's first LEO operator. Telesat decided a greenfield approach was needed for its mission critical communication services focused on enterprise, wholesale and government markets around the world – including the hard-to-reach poles. Telesat has deployed Netcracker's Digital Satellite Solution on distributed cloud platforms for its Lightspeed LEO constellation which it claims is 'the world's most advanced LEO constellation'[3]. The operator has already booked capacity with SpaceX rockets for over 250 LEO satellites for launch in 2026. Consequently, both they and Netcracker are preparing for real-world (out of this world?) scale.

Summary & Practical Considerations

Any top-to-bottom re-systemization is a huge project. One can argue that the hardest of all are "brownfield", because so many practices, learnings, and assumptions are already in place. Yet automating greenfields, which the satellite industry is very close to as it moves to mass market, is an enormous undertaking as well. Moreover, historically, transformation projects have earned a bad name because they have historically taken longer than expected, consumed more money, and in the end not achieved true transformation. Possibly that is because organizations hate to change.

This leads us to the options that the satellite industry has. First, it could assemble and integrate what its own experts believe are the best in breed applications into a top to bottom system. While theoretically ideal, there are several pitfalls here, chief among them the cost of integration and the fact that a single firm is saddled with maintaining that integration for the systems lifetime, which may span decades. It also has the challenge that the firm itself — by definition, new to mass market operations — designs the optimal process. While there are many shades of gray in between, the other end of that spectrum is the pre-designed end-to-end solution.

Netcracker's approach is the latter, and while arguments can be made for many approaches, Netcracker's has several significant characteristics recommending it to any carrier that needs an almost entirely new suite of network automation software and digital experience software, and is not buying from a single vendor that already has a well-regarded NAS/DES solution.

[3] https://www.telesat.com/wp-content/uploads/2021/04/Telesat-Lightspeed-Technology-Infographic.pdf

Netcracker's satellite solution boasts:

1. "Pre-blueprinted" approach for satellite communications' unique challenges
2. Pre-integration – an end-to-end solution that requires minimal custom integration
3. An explicit operating model on which the solution was designed, enabling proven methods and procedures
4. Pre-existing ontology to support intent based operations
5. Expertise in complex inventory (Netcracker, after all, began with inventory and inventory led solutions decades ago)
6. Several proven re-systemizations (outside of satellite) in recent years with customer testimonials

All of these characteristics reduce risk, and speed the risk-adjusted time to success for the solution. Since most of the components come from a single supplier, it ought to reduce the ongoing burden to maintain the integration between capabilities, which is typically a very significant burden for telcos.

Digital connectivity is increasingly a necessity for all businesses, and highly desirable for individuals—regardless of where they are on this planet or how remote they are. No longer is it practical to be unconnected. No longer is it desirable for society to have large numbers that are excluded from an increasingly important source of education, commerce and information. For many practical reasons, satellite communications is the technology best suited to some of the harshest and most remote locations on earth. Consequently, the demand for this capability, as it no doubt increases in quality and decreases in cost, will grow. Therefore, a solution that can accommodate myriad business models, myriad regulatory and tax environments along with the designed in understanding of a network that is diverse in mobile on many axes we'll have and increasing market. Netcracker has made a strong argument that they are among if not the first to thoroughly think through the end-to-end operations for this growing segment.

We also wonder about whether some of the blueprint changes have broader appeal, beyond satellite. A fundamental tenet of this blueprint is that the satellite environment is hugely dynamic, and with that environment, many SLAs and business structures must be met. Might dynamic behavior become more the norm in terrestrial telco networks as well? Will dynamic enterprise WANs and network slices benefit from similar thinking? We shall see.

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