SatCom ground segments in the cloud

CGI

aws PARTNER Advanced Tier Services

Introduction

CGI, a global IT services provider and systems integrator, has been supporting the Space industry for over 40 years with system integration, bespoke software and business process solutions.

Based on our global client interviews, Voice of the Client, we know that these Space operators are urgently looking to deliver on key business priorities of revenue growth and reduced time to market, created by an increasingly competitive and fast-moving commercial environment.

These priorities have led to new investments in ground segments that are increasingly being deployed using public cloud environments. Based on our global experience in migrating critical operational systems to public cloud infrastructure, we have recently supported clients looking to implement satellite and network operations in the cloud. This paper describes the rationale for delivering business and technical priorities using public cloud, lessons learnt, and our cloud adoption framework which helps clients to develop and implement a cloud migration strategy. In this paper we have worked with one of CGI's partners, AWS, to illustrate this approach using Software Defined Satellites (SDS), which have become an important driver for refreshing ground segments.

CGI has developed network optimisation and mission control software for Satellite operators of some of the most complex SatCom systems, we are now helping clients to leverage cloud infrastructure to drive efficiencies and increase flexibility

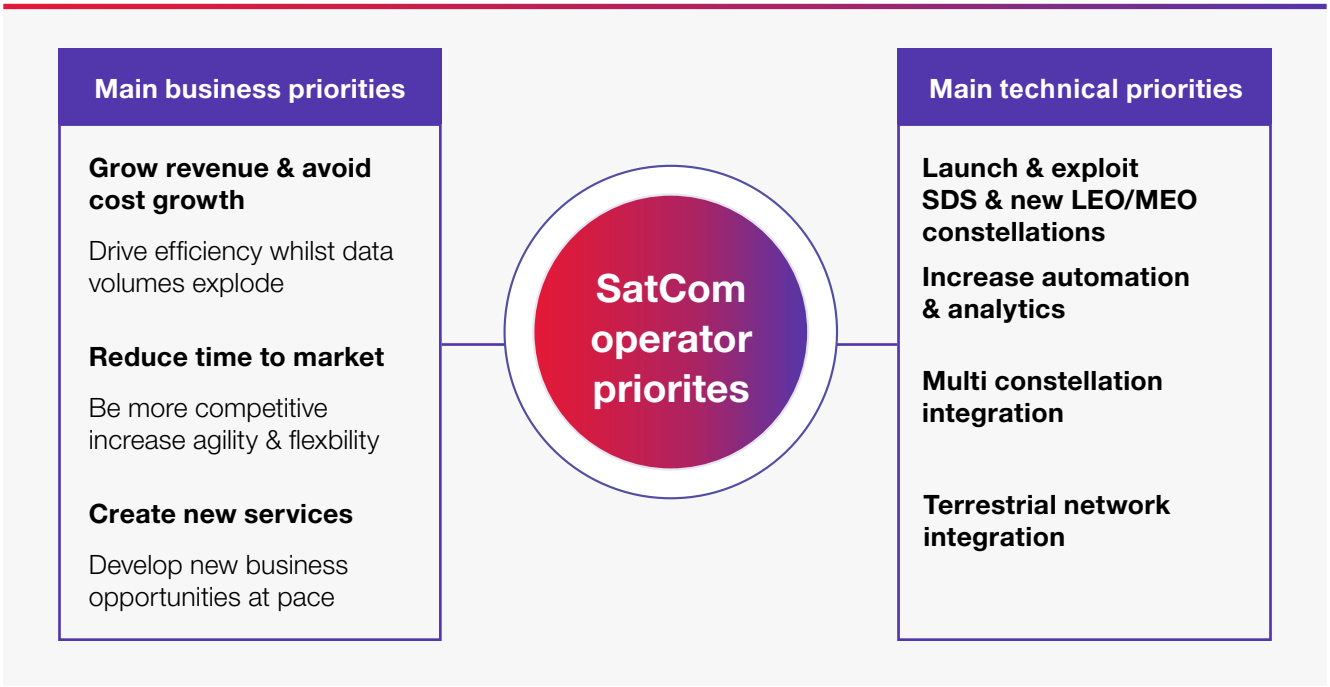


Figure 1. Business and technical priorities identified by SatCom operators and discussed in this paper

Background

SatCom is changing rapidly, operators and service providers must innovate to succeed. Some key industry drivers include:

- The introduction of GEO SDS and LEO/MEO constellations opens up new markets and opportunities, whilst affecting capacity pricing, which has reduced by more than 70% in 5 years due to Starlink according to Euroconsult analysis in February 2024.
- SatCom services must be increasingly adaptable/ dynamic as new use cases are introduced and mobility becomes a driver for revenue growth, generating an increased need for automation and use of data insights in planning.
- The market now demands a deeper integration with terrestrial telco networks. This drives new applications via responsive delivery enabled by Software Defined Networks, Network Function Virtualisation and AI.

These drivers create operational capabilities that ground segments need to provide, as highlighted in Figure 2. In this whitepaper we have chosen to focus on SDS geostationary satellites, but these priorities, capabilities and lessons learnt also apply to LEO/MEO constellations.

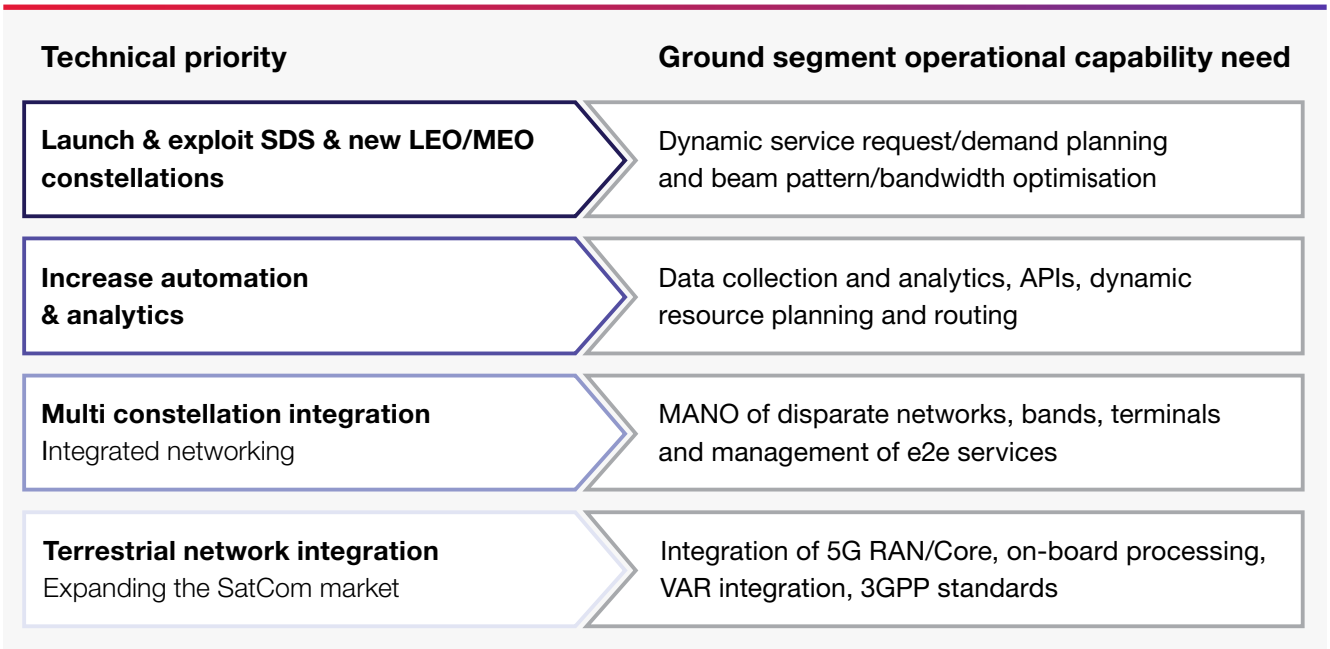


Figure 2. SatCom operator technical priorities are direct drivers for operational Ground Segment capabilities

Software defined satellites, new capabilities

Focussing on geostationary satellites we can identify a clear trend towards SDS. Northern Sky Research (NSR), a leading satellite and space industry research firm, forecasts GEO SDS orders growing from 10 in 2022 to over 200 cumulative by 2032, averaging around 17 per year, with fully flexible satellites accounting for 56% of SDS GEO orders by 2032. Specific advantages include:

- **Flexibility** in coverage area, capacity and frequency with fewer compromises than their predecessors with movable beams.
- **Lower costs and reduced time to market** because volume satellite production can serve multiple needs.
- **Higher targeted throughput and higher fill rates, allowing for lower user pricing** via more responsive airtime provisioning.
- **Access to a wider range of markets** via dynamic service allocation and pricing, more competitive airtime pricing from the lower cost base and improved links with resellers and end customers.
- **Earlier engagement with fundamental market changes** through closer terrestrial and mobile telecoms integration, better cross satellite integration with own and other operators' satellites and potential for outsourcing some standard operational elements.

Allocation of additional SatCom bandwidth to a network must be matched with additional signal processing and packet routing capacity in the supporting ground infrastructure. Similarly, routing customer traffic to an alternative beam with available capacity requires orchestration of ground segment resources towards the destination beam. SatCom service providers must also seek to reduce idle capacity. Modernised ground segment architectures iterate towards this dynamic paradigm by reducing their dependency on specialised hardware, embracing a progressive virtualisation of components that accelerates provisioning. This virtualisation creates the opportunity for public cloud services to be leveraged for cases in which this is technically feasible and commercially compelling.

Flexible deployments also require agile resource management systems (such as built by CGI), to deliver the automation that puts this flexibility at the service of the business.

As the operational mindset evolves from managing multiple independent networks each with static resources to a dynamic model where in-orbit and ground resources are continuously reallocated, speed of adaptation is very important to reduce unused resource bandwidth. Satellite service providers must aggregate the operational and business data that inform resource allocation decisions. This data is consolidated for analysis and decision-making so that advanced analytics and state-of-the-art technologies such as machine learning can be applied to provide the automation that accelerates dynamic adaptation. Modernisation of ground segment architectures is also an opportunity for SatCom service providers to adopt user, control and procurement interfaces that facilitate their integration with terrestrial communication networks. In summary, SDS implementations drive a step change in ground segment software and IT requirements such as shown in Figure 3. Transitioning to this new state as smoothly and efficiently as possible, within a limited budget, remains a challenge.

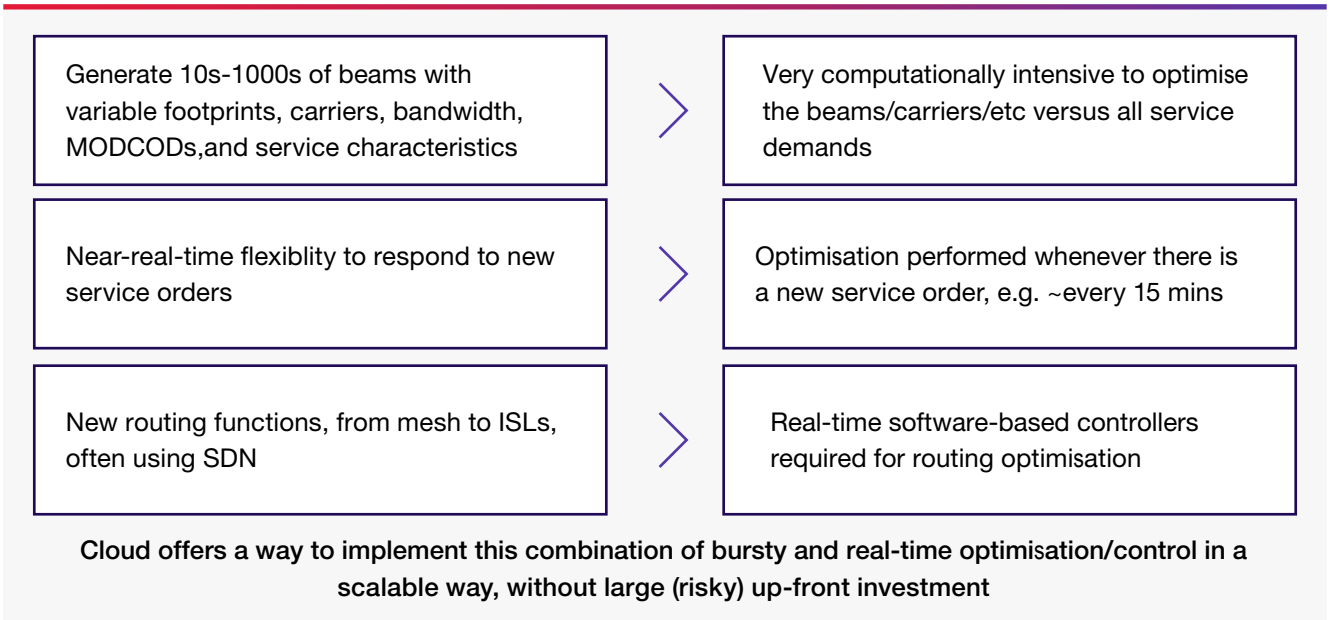


Figure 3. Ground Segment operational capabilities create requirements for new software and IT functionality

Considerations when implementing a ground segment Cloud strategy

Cloud computing offers the ability to lower expenses and optimise operations. As with any significant IT transition, realising these benefits can be difficult without sufficient up-front design and overall project governance.

Cloud advantages

- Ability to scale rapidly and develop globally helps to address 'reduce time to market' and 'create new services' priorities.
- Simplifies enterprise-wide data collection and management, enabling ML/AI and automation to deliver on 'automation and analytics' priorities.
- Coherence with enterprise transformation, supporting the development of end-to-end applications and standardisation of infrastructure.
- Easier implementation of high reliability services and disaster recovery.
- Scalable infrastructure suits an agile and DevOps approach to software implementation, which is also easier to develop with a distributed development team.
- Reduction of CapEx in the ground segment, offsetting the expense until revenue is generated.
- Simplifies integration with end clients and provision of richer solutions, including edge compute.

Potential disadvantages of an IT transition

- Overall complexity of a green-field implementation or integration with existing operations systems.
- Potential disruption to on-going operations through a change to the IT infrastructure.
- Perceived loss of control and ability to offer hosted solutions for clients when switching from SatCom operator-owned datacentre to externally provided IT infrastructure (be it cloud or otherwise)
- Complexity of data sovereignty for some customers and use cases.
- Cyber risks inherent to any change of infrastructure and IT architecture.
- Concerns over cost, particularly egress of user traffic; reimplementation or on-going OpEx, vendor lock-in and security.
- Increase of shadow IT and duplication between teams when the purchasing and management of cloud (or any managed service) is not coordinated and managed across the enterprise.
- Risk of running both new and legacy systems in parallel eliminating cost advantages and creating financial surprises.

Implementing a Cloud strategy and system architecture, coupled with good governance, can avoid these disadvantages, allowing the benefits to be realised. CGI has learnt a number of lessons in how to achieve this which helps our SatCom clients to learn from best practice across multiple industries. Some of the lessons learned include:

Controlling cost and enabling scaling on demand

- Blend/hybridise Cloud with the overall network/ IT architecture and ensure Cloud cost experts are involved in the design.
- Define a holistic architecture early, based on existing frameworks and best practice (e.g. AWS Well Architected Framework), combining public cloud, where it makes sense, with existing and future datacentre capacity.
- Avoid excessive lift and shift: modernise applications where possible, incorporating features like Amazon Elastic Container Service (ECS), Amazon Elastic Kubernetes Service (EKS), and AWS Lambda that provide dynamic compute resources.
- Plan a spot and reserved capacity strategy and VM/processor mix to minimise cost.

Managing compliance

- Consider compliance as early as possible and involve this in all steps.
- Implement national breakouts and enclaves within the architecture definition even if they are not implemented at day one – use AWS Edge Services in such situations.
- Use AWS risk and compliance features (e.g. AWS Audit Manager), policy management (e.g. AWS Control Tower) and automation to improve enterprise compliance and reduce overheads.

Staying secure

- Define the security model (e.g. zero trust) and implement it within the architecture from the start.
- Automate vulnerability scanning, patching and intrusion detection (e.g. using Amazon Guard Duty)
- Involve security as an integral pillar of the roadmap and governance. Implement modern enterprise-wide identify management, such as Multi Factor Authentication.

Maintaining control and avoiding lock-in

- Decide in your roadmap how much control you really need, and of what?
- Consider the cost of switching vs the utility of chosen architecture rather than thinking only of vendor-lock-in.
- Multi-cloud can be a viable option but can also get complex and expensive and is normally best avoided for operations if possible.

Managing latency

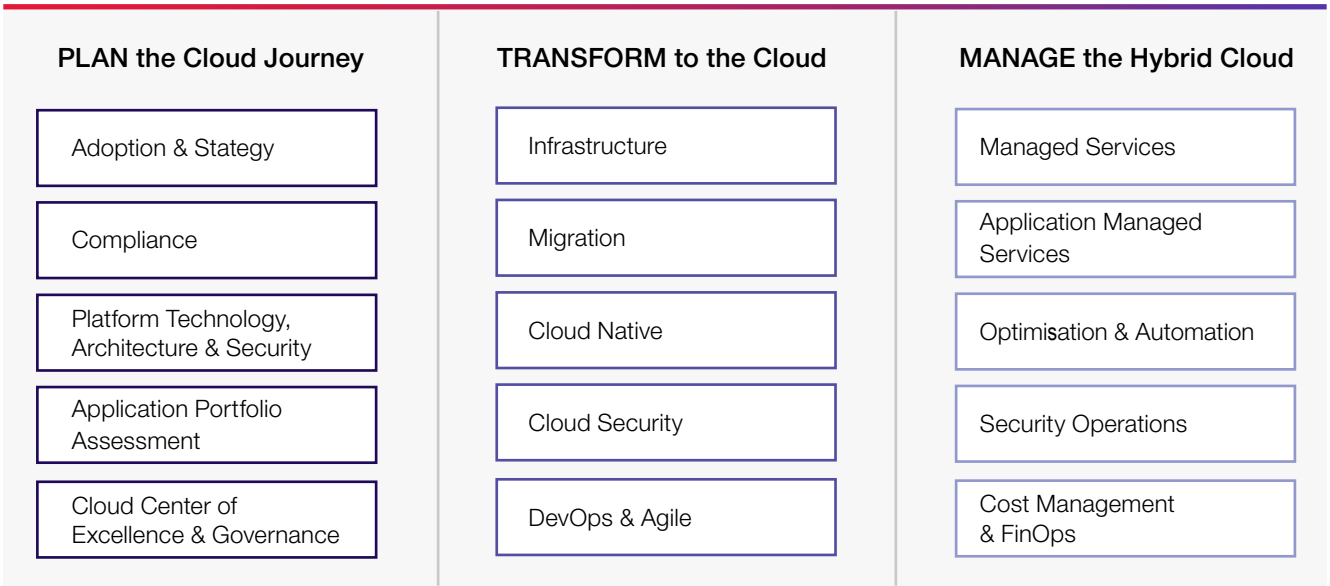
- Use as much of the cloud providers' infrastructure as possible including their WAN and local POPs (e.g. via AWS Local Zones and AWS Wavelength)
- With an adequate design of networking and compute resources, cloud applications can deliver near real-time control, for example of TM/TC or LEO constellation routing.
- Ensure latency in compute and network congestion is considered in scaling approach.

Enabling automation and analytics

- Include data governance alongside Cloud governance.
- Integrate operations data with enterprise data, e.g. using Snowflake.
- Rapidly explore AI/ML using tools like AWS SageMaker, but focus on cases which deliver tangible return-on-investment.

CGI's process for developing a cloud strategy

When developing an effective cloud migration strategy our clients ask us to support them by bringing extensive real-world experience of cloud migrations and specific knowledge of SatCom. CGI's Cloud Adoption Framework has been developed across many industries to bring global best practice to our clients, coupled with our experience of SatCom cloud applications.



The **Plan** stage helps to establish strategy, architecture, and governance. It establishes status and direction of travel for ground segment elements, converges strategies from different parts of the business and prioritises opportunities to modernise. This often includes establishing a 'Cloud Centre of Excellence' to ensure that evolution towards a cloud optimised ground segment continues to be convergent and consistent. In this phase the current architecture is mapped and a target architecture defined, drawing from existing templates and model architectures, such as the ones described in this whitepaper.

Transform helps to implement the transformation through new applications and proof of concepts. It develops an infrastructure deployment based on a reference architecture, including monitoring and reporting. The migration strategy and roadmap are also built, including segregation, architecture dependencies, data migration, application integration and testing. Greenfield cloud native development includes refactoring and modernising legacy applications as well as UX design. Security is built in by design starting with a risk assessment and working through penetration testing and logical segmentation towards a DevOps for security. The overall cloud oriented DevOps is finalised and adopted. This process leads to a secure and robust cloud foundation, a related service catalogue and a migration roadmap for applications.

Manage provides management support services, including managed security and service desks to reduce costs. It includes operation of services including the service desk, monitoring and log management, portals, policy and compliance, service catalogue management, capacity services authentication and operations governance. Processes for optimisation and automation, security operations and cost management and FinOps are also deployed.

CGI's adaptable cloud adoption framework maximises value and reduces the risk of a cloud journey. It is a unique, constantly evolving methodology and toolbox CGI uses to help clients embark on their cloud journey and reach their destination in a safe and efficient manner. CGI transfers experiences gained from client projects back to the framework, thereby enhancing best practices, templates, guidelines, concepts and processes. The framework supports the cloud adoption journey according to specific client needs, no matter how mature they are and where they are on their cloud journey.

Migrating ground segment to the cloud

Based on our cloud adoption framework and experience in migrating SatCom ground segment workloads we have developed a template for ground segment adoption based on AWS, which includes best practice from other industries such as telco. This provides a starting point for a satellite operator, accepting that it must always be heavily adapted for an operator's current network architecture, current state of cloud adoption, security architecture and budget. One template architecture considers a typical geostationary SatCom ground segment as shown in Figure 4.

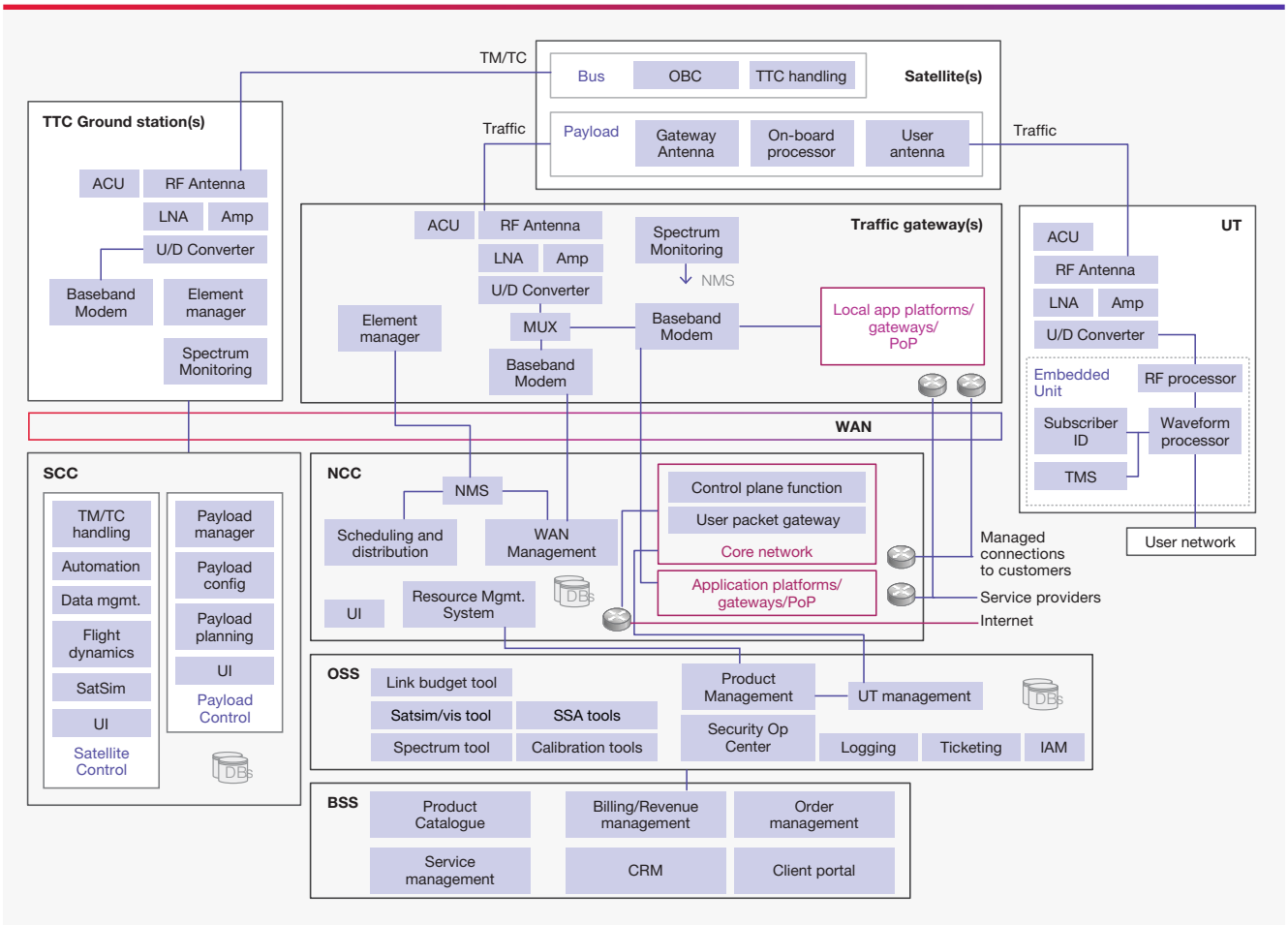


Figure 4. Template typical existing/legacy SatCom operator ground segment used as a model architecture in CGI's cloud adoption framework

This identifies major components of edge data processing within the TT&C and Traffic Gateway such as RF processing, network access, a backbone WAN (typically commercially purchased MPLS) and a network core where services are terminated with a breakout to the Internet. The diagram simplifies for clarity in that the compute/storage architecture is not shown, TT&C and Traffic ground station(s) are shown separately and only single TT&C and traffic ground stations are included. The Satellite and Network Control Centres (SCC and NCC) together form major elements of the Operations Support System (OSS) that manages satellite resources, gateways, user links and terminals and is therefore a key element in maximising gains from SDS.

Edge processing is typically done using on-prem equipment such as modems, VSAT hubs and routers and functionally includes performance monitoring, frequency and interference monitoring. It may also include local data breakout for some services. The core, which may be hosted in multiple locations for redundancy, typically consists of an on-prem data centre to host routing and termination functions for services such as voice, data and messaging. In addition, network control functions such as authentication, subscriber control/billing, monitoring and network management are provided. Some services may be provided remotely or by disaggregated systems, for example by using shared network management or security operations centres.

Software components are now available that can perform many of these ground segment functions in a reliable efficient and flexible way, including those in Gateways and Network Management Systems (NMS). Other elements where advances are needed to support SDS are demand/resource management, data analytics, cyber and terminal management. Integrating these is critical, and many also need full and rapid access to data traffic for their analytic functions, something cloud deployment can readily support. Many clients are also keen to own the IP for core network functions which provide competitive advantages and, historically, this has been where CGI has developed bespoke applications for SatCom clients.

For legacy systems many applications with different objectives and origins will typically have evolved into a complex blend of on-prem and, potentially, some existing cloud-based applications. Progress towards a more comprehensive cloud-based infrastructure must therefore be targeted, structured, guided by experience and based on embedded governance processes to ensure persistent benefits.

Based on our model architecture we have created a migration assessment for individual components as well as considerations based on best practice from a range of industries including telco and SatCom, as shown in Table 1. A good starting point for migration is often comparatively self-contained elements, particularly those in the control/management functions rather than the direct data path. Elements related to the WAN supporting external links and data analytics also yield considerable benefits from early cloud deployment. Moving cloud hosting beyond the internal IT organisation to serve the full operations systems yields potential advantages including:

- Optimised customer and reseller links in a cloud solution based on cloud provider networks.
- Links to terrestrial services/5G can be implemented via links at the Core and potentially also at RAN level.
- The ability for customers to build redundancy more cost-effectively using shared responsibility models. Being able to spin up a redundant/secondary NCC and SCC rapidly if needed can yield significant cost savings since there is no need to provision the compute/storage/network for the secondary systems.

CGI's assessment and template is based on the principle that not all the ground segment elements are best transferred into the cloud, but only those where there is a demonstrable benefit taking into account the business priorities and operational capabilities identified above.

Table 1. Some cloud migration considerations for different elements of SatCom OSS/BSS based on CGI's recent experience

Overall	Integration	• System Integrator to ensure customised design based on open standards, planned transition and effective implementation, including cloud optimisation. • Creating service chain definitions and deployment, using templates. • Overall SLAs and their implementation, linked to the service chains.
TTC Ground Stations	RF equipment Converters/BB modem Spectrum monitoring	• IF converters yield digital IF packets for transport over cloud WAN. • DIFI (Digital IF Interop) standards. Containerised for cloud deployment. • Demodulate/Decode close to antenna via Software Defined Radio using AWS edge/hybrid in preferred region. • Dynamic spectrum management and compliance, interference avoidance.
Satellite Control Centre	Satellite and Payload Control	• Full control and tracking of resources to support dynamic operations. • Redundancy provision and ground station links. • Integration with and reporting to Orchestration and Payload. • Ensuring full dynamic control of beams, frequencies, power and capacity.
WAN	SD-WAN	• Spans across prime/redundant SCC/NCC plus regionally or globally distributed ground stations.
Network Control Centre	Network Management System	• NCC as overall virtualisation and cloud deployment candidate with WAN and Element Manager aspect of Traffic Ground Station. • Provision for AI/ML based traffic analysis and capacity forecasting. • Orchestration/MANO; Software Defined Networking. • Health and status monitoring.
	Resource Manager	• Dynamic prediction & planning – Dynamic Predictive Routing (DPR) • Physical network device management. • Tracking usage for ML analysis and feedback into DPR.
	Core Network	• Control Plane; Connections to BSS/NMS/RMS; External network links.
	WAN Manager	• Orchestration; Network WAN a key part of the system.

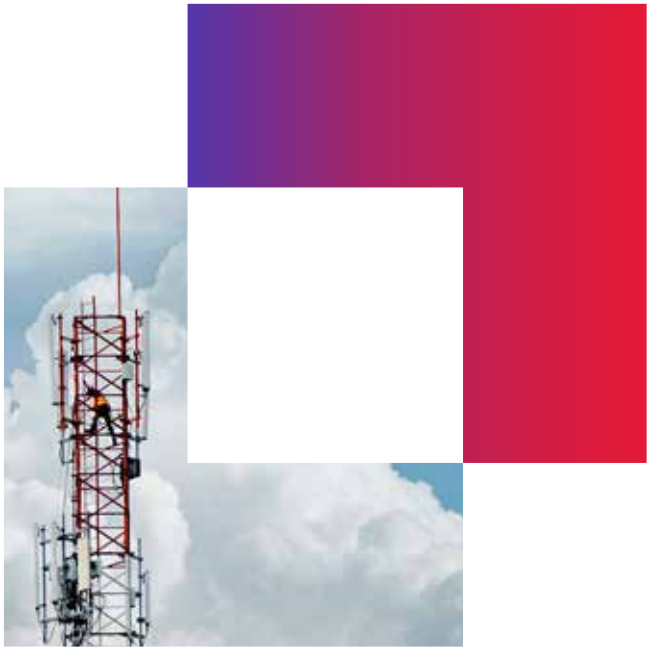
	Security	• Zero trust architecture. Vulnerability management by regular updates/patching. • Enhanced authentication and authorisation.
Business Support Systems (BSS)	Enterprise applications	• Many enterprise applications, such as CRM, are already available as SaaS or deployed in cloud environments. • Migration of bespoke applications may be required. • Managed services and enterprise networks. • Dynamic linkages, including billing impacts of dynamic services. • Tracking commercial aspects of integrated services with other terrestrial and SatCom service providers.
Traffic Ground Station	Element manager	• Direct link to NMS for command and control. • Data volume and latency considerations for traffic ground stations. • Dynamic demand links to orchestration.
	Local Apps / Customer & reseller links	• Client deployment properties. • Charging structures.
Network Control Centre	Core Network Data Centre	• Data Plane; Connections to BSS/NMS/RMS; External network links.
	Local Apps / Customer & reseller links	• Client deployment properties, Charging structures. • Dynamic demand links to orchestration.

Defining a target architecture in the cloud adoption framework

As described above, a cloud migration, which includes the implementation of new capabilities to support new satellites, requires the development of a strategy to realise operational capabilities and benefits without suffering from the disadvantages identified above. CGI's cloud adoption framework, combining strategy and technology, is based on establishing an architectural vision early on, drawing from established templates, enabling rapid proofs-of-concept to derisk key component migrations or implementations as early as possible. For our templates we have worked with AWS to identify key cloud services and native features which can be operationalised to support this de-risking, maximise flexibility and reduce overall cost, based on design patterns created by AWS.

Our cloud adoption framework supports working with our client to develop a target architecture deployed on their chosen cloud provider. We have worked with AWS to create template architectures and Figure 6 shows an example based on the SDS model architecture from Figure 4, highlighting which components are suited to deployment in the public cloud, alongside existing datacentre capacity. This architecture optimises OPEX costs by reducing cloud egress traffic. User and control plane traffic is still routed via the cloud provider's WAN since this is not subject to egress costs and takes advantage of the cloud provider's global WAN infrastructure. Optimising the WAN and simplifying its management is an important part of a holistic solution, something that AWS readily supports.

In this example an AWS Outpost is used within the Traffic Gateway to provide local processing with in-region breakout and low-latency. An alternative



approach is to use RF-Digital conversion (i.e. Digital Intermediate Frequency Interoperability, DIFI), allowing waveform processing to be done remotely to the traffic gateway, i.e. in the cloud.

This architecture is an illustration of how extensive a public cloud migration could be within a single ground segment. Real world deployments would be more complex, especially for legacy systems, and CGI can help SatCom operators create this high level strategy and vision, as well as support it's implementation through our migration services. Critically, we help our clients to develop a roadmap with implementation in carefully controlled phases, to reduce the possibility of running multiple systems in parallel.

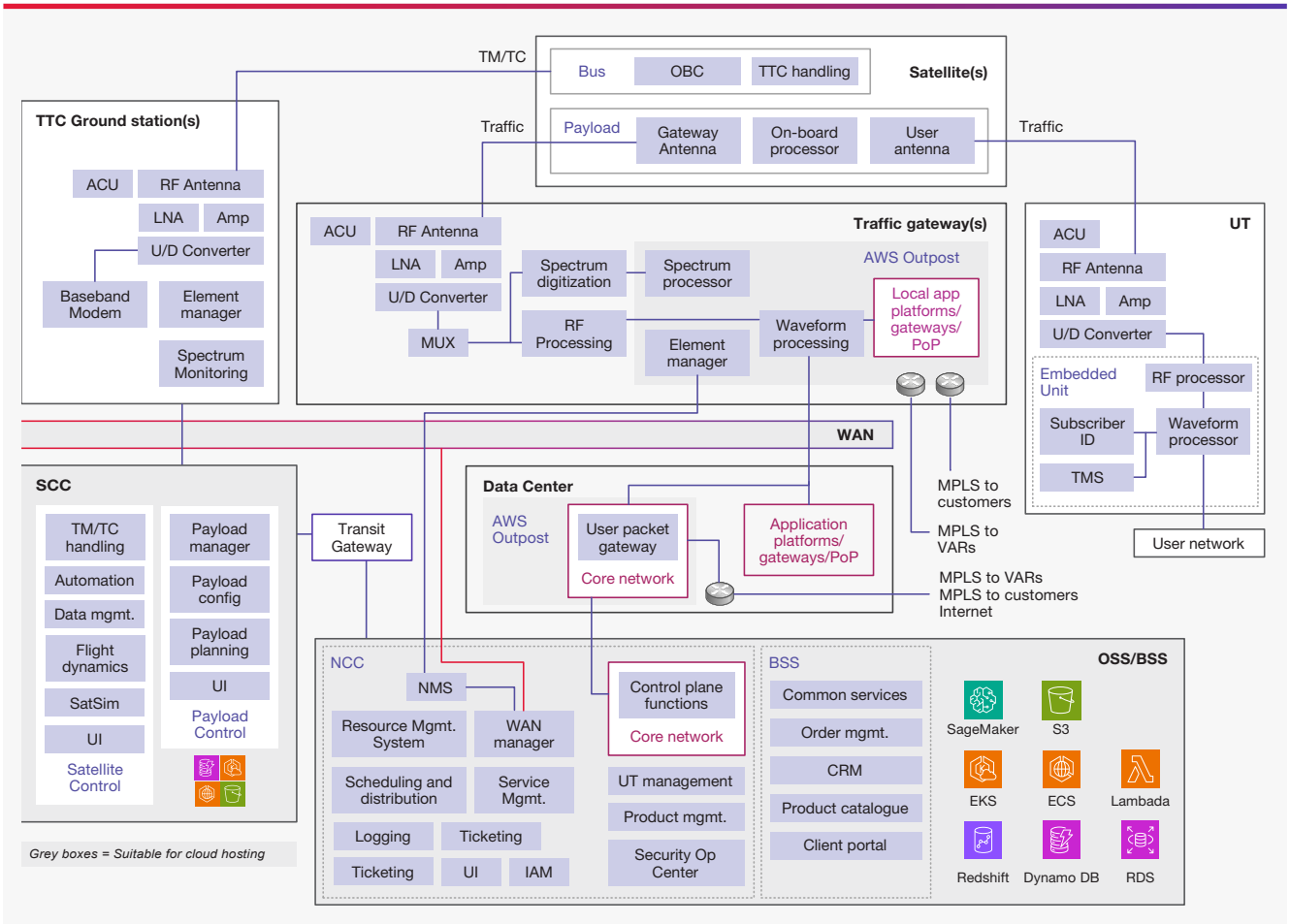


Figure 6. CGI works with clients to develop & implement a target cloud-based ground segment architecture, such as this example, highlighting which components can be migrated to AWS, based on a model geostationary SDS architecture.

Outlook

SatCom's journey towards greater integration and flexibility is enabled by cloud-based software solutions, deployed within an overall cloud strategy combining public cloud and corporate datacentres. CGI's cloud adoption framework, supported by templates for typical ground segment architectures, enables us to help SatCom operators start or accelerate their cloud journeys enabling to deliver business and technical priorities. Our strategic partnership with AWS allows CGI to combine our ability to provide strategic advice and implementation support with first-hand, in-depth knowledge of maximising the benefits of specific cloud functions and services. This support is placed within CGI's suite of services, from systems integration to bespoke software development, covering the full range of IT support required by SatCom operators.

If you are a SatCom operator starting on a cloud journey, or looking for support in delivering an existing migration, then please contact us.

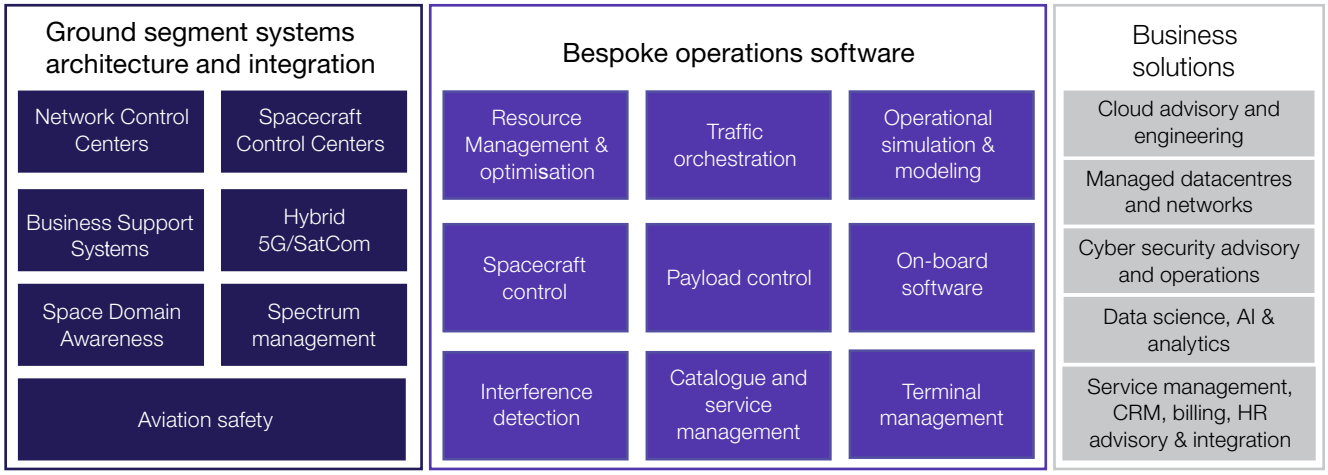
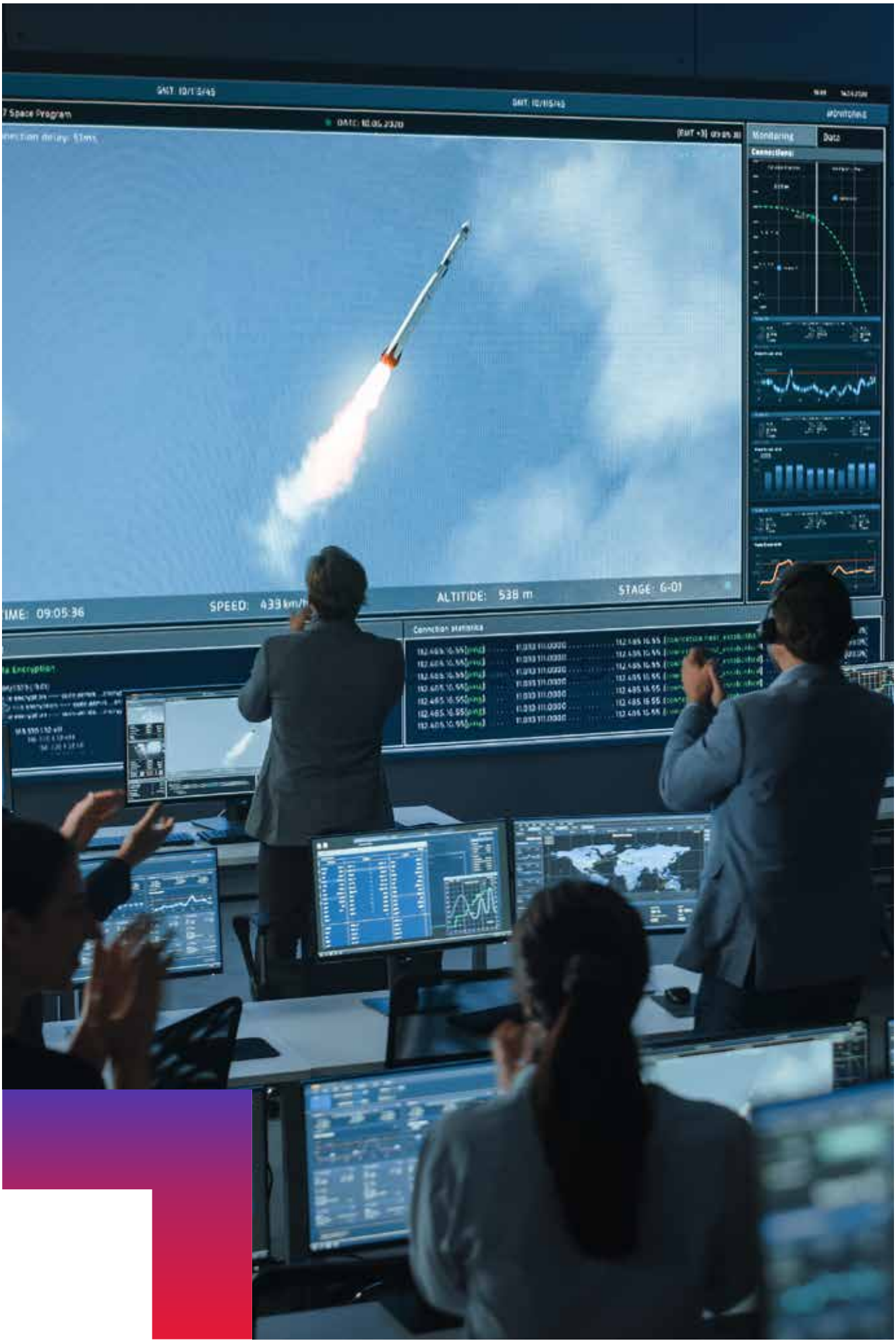


Figure 7. CGI's broad range of advisory and delivery services helps us to support SatCom clients at every stage of their business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We are insights-driven and outcomes-based to help accelerate returns on your investments. Across hundreds of locations worldwide, we provide comprehensive, scalable and sustainable IT and business consulting services that are informed globally and delivered locally.

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