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SPACE COMMAND : MANAGE SPACE OPERATIONS IN THE NEW SPACE AGE

Abstract

US Space Command and the Nato Space Center in France incoming demonstrate the will to create a new way to consider Space operations as military field to protect its own space assets, to observe and to support the human activity. Indeed, the ground observation from Space puts the set of assets on orbit as a tool to response at the workflow on Earth. Moreover, the private compagny invest to the Space with a shared capacity to the governemental agencies. This context modifies the Space perception of what would be the requirements to built a Space organization to monitor, manage the operations in the ground or in Space for a civilian or military purpose. The common point is the need to observe, then to interpret data for mapping its environment and to provide business services for people. So, the Space Command principles describre how to observe, collect, interprete, act thanks to a set of data from the connected sensors between the ground and Space. To implemented them, each connected steps is a sensor of what Spacehuman want to identify from the space assets position, the electromagnetic and quantum spectrum, the matter networks named by the matter information theory, the acknowledge of Space meteorology. At last, to protect the set of these manoeuvres, a Space command requires the counter-measures to maintain the operations in harsh context.

Keywords: Commercial, Data, Operations, New Space, Command

I - Understand the New Space features

The human activity gets the possibility to be managed by Space as Services^[1]. The creation of the Space forces in the United States push the others countries to invest in the assets on orbit to monitor and control by networks the data flow available. In the New Space context, the science of observation and the support on the ground are improved by the services thanks to information and communication technologies applied to Space sector. The Space operations include this new context to be taken account with several types of satellites for the workflow management. The geospace, by the observation and telecommunication assets in Space, provide the main sensors used to manage operations.

Following the Earth observation capabilities to the ground, the stakeholders of observation are able to combine conventional information with detection in Space to act for environment protection. The satellite imagery and the Earth observation data are used in the environmental crimes prosecutions in the United States or as evidence in the courts of Singapore.

With the first Gulf war^[2] for identify the targets or to prove legally unexpepected assets in regard to international laws, the link between Earth observation and geo-intelligence methodology^[3] exists.

The Earth's defences applied to environment issue introduce the processing of Earth observation to understand the key parameters showing a danger on the ground : hot temperature, waterflow, risks processing in the complex system like the supply chain management.

The methodology takes account of the Space cyberdefense concept in which the cyber kill chain put a technical organization with a team cycle. Indeed, the Earth's defences mean a data management to provide evidence through multiple sensors.

In addition, some steps shall be followed to produce the imagery with the detection way, plus, the need to authenticate the imagery, to understand the processing on the way on the ground and to explain the matters of the imagery observed.

This processing leans on the Cloud infrastructure in which the storage and the exploitation of data can be exploited with a time to action. Moreover, the data correlation capabilities increase the potential of the imagery thanks to this technology. To support the effects of the observation, the team cycle processing is able to gather information to prove, by evidences, a purpose on the ground, with the unique advantage of observation point in Space as a service.

Even if the governmental agencies lead the Space, the major compagnies propose services to manage Space operations. It changes the Space perception for the human activity and the relationship on duty on Earth. The first Earth image from Deep Space was only taken from 1968 with the Apollo mission to the Moon. The point of view from the observation move higher than before, changing the perspective and the angle to analyse and understand the process on the ground. With this processing, the Space culture^[4] is going to expand outwards the ground. The Emirates Arab United have planned some innovations inspired by Space.

The design of "Mars city" in the desert is in the process of planning. The trend translate that the Space requirements begin to be implemented on the ground following the understanding of Earth mechanisms. To reach this purpose, the data permits the analyses and the conclusions to make decision on the methodology of design. The basis of Space organization use the functionalities of data to design a ground Space command. The data volume available from sensors in Space provide the means to improve the operations in mapping the environment with another perspective.

[1][1] Rod Pyle, "Space 2.0: How Private Spaceflight, a Resurgent NASA, Ben Bella Books, Illustrated, 2019.

[2][2] Anthony Tucker-Jones, "The Gulf war : its origins, history, and consequences, Routledge, 2017.

[3][3] T.P. Singh, Dharmaveer Singh, R.B. Singh, "Geo-intelligence for sustainable development", Springer, 2021. Ray Kurzweil, "The age of spiritual machines, when computers exceed human intelligence", New York, Viking, 1999.

[4][4] Roger Launius, "The history of Space exploration", Thames and Hudson Ltd, 2018.

The framework to observe, to collect, to interpret shall be organized thanks to the sensors according to the ground-to-Space networks. The result of this framework produce a Space command requirements to mitigate the effects of the specificity of ground-to-Space networks to apply fully the services functionalities. The Space work flow has to be considered by the understanding of the tools from geospace combining with the position of sensors.

First, the New Space features determine the Space operation management. For the beginning of Space program in the United States and in the USSR, the Space operation was managed by governmental agencies with the intervention of authorised contractors. It permits the launch of Mercury program and Apollo Mission and the lighting action in Space like Spoutnik in 1957 or in 1961, the first man on orbit with Yuri Gagarin.

With the major private compagny like SpaceX, Amazon, and Apple which have decided to go to Space too, the things are going to change for Space management. Moreover, some start-up or compagny have emerged to fulfill the missions done by the governmental agencies. The assets finding in the low orbit have launched by private compagnies like Orbex launchers. The enlargement of the activity around the Space requirements create several occupations based on the opening of commercial services from Space. It concerns the digitalization of Space system, the revolution of launchers, the new satellites forms called CubeSat, NanoSat, MicroSat.

The features of New Space mean the combining of governmental agencies supported by State with private compagny to realize the means going in Space. Indeed, as Space begins to be no unique domain of astronauts and launchers from governmental agencies, it means people going in Space with the commercial specification. The Space transport apply these principles for the low orbit through the Dragon Crew spacecraft and commercial astronaut.

The commercial assets should maneuver in the safety and security context in regard of the spacecraft cost and the impact. Even if the monitoring and control can be done from the ground station, others parameters should be mitigate by visual avoiding the loss of assets : Space meteorology understanding, the debris effects.

The Space station would be also useful to give support in Space for the technical maintenance of assets in orbit. The mission cycle to go to Space will no change but adapt to the requirements of commercial mission. If the training could be the same, some training on the ground moves to the specific tasks on the assets launched by the compagny. Moreover, the astronauts number would provide a reserve to go to Space in short term to repair or improve the assets. To do it, the international station should be updated by an additional module in which the commercial astronauts would work in Space.

Second, the ground segment infrastructure, with the commercial services available through satellites, produces a data quantity exploitable for specific purpose. And in more the first country in Space, others lands take a place among the Space Nation : Emirates Arab United, India, China, Japan, South Korea and countries in Africa like Ghana, South Africa^[5]. The Space operation are thought in terms of educational program, infrastructure on the ground to open the data flow from the Space to observe, to reflect issues on their territories. The New Space introduces infrastructure, data, new actors in the framework of new requirements in which the command and control features change the operation by Space.

II-Framework of Space command

The framework of the Space operation management can be divided into three four parts. The first topic to understand the networks architecture providing the skeleton of the operation way. The assets need to built Space operation in the New Space require the ground station with a level of data transfer able to be displaying for the monitoring. And the data have to be understood through the matters information theory^[6].

As the Space networks are going to change with more connectivity between the assets, the Space operation are supported by several possibilities to connect them in the different ways. The new

[5][5]Sékou Ouedraogo, "L'Agence Spatiale Africaine : vecteur de développement", l'Harmattan, 2015.

[6][6]Armand Mattelart, "Histoire des théories de la communication", La découverte, 2018.

Space networks use both fiber, copper, ether, laser and above all, the properties of matter to send faster data from the ground and soon to the Moon. It could be described by the matter information theory which explains the way to understand the information, from multiple world of the matter, getting the capabilities to collect and to transmit data and messages through the particles. This theory considers the telecommunication systems as biological in which the potential of the electromagnetism interaction are used both in a physical and biological networks. This information capacity improves the Space assets and disaster management in rising the signals to match the networks connectivity on Earth with those in Space.

This concept explains that every data is the result of the matters properties movement based on the electromagnetic spectrum. It means a signal variation and reception condition changes the data.

The causes are internal and external of the system. Then, the functionalities of the architecture are integrated in the unified communications in which the equipments and the protocols are not standardized in the same support of communication and transmission. The sustainability of the architecture shall be maintained with the performance requirements due to the nature of the system.

The second topic describes the data has to be managed thanks to the architecture.

Thanks to the assets in Space and in the ground, the architecture determines the data volume and its orientation for the conditions of the management for the operations. The concept of Space Domain awareness ^[7] concerns the detection, the tracking, the identification, the characterization, the understanding of any factors associated with the Space domain that could affect the operations. This purpose need data thanks to sensors to manage operations : observation, detection, communication functions. The science of networks is applicable to put the conditions of Space command.

The networks design take account the mobile and fix structure able to be configurable and re-configurable. The fix structure are to be considered by the Space-based telescopes linked with themselves. The mobile structure are the assets in Space or in the atmosphere able to relay any data in the tempo of ground-to-Space.

The three layers of the Space networks is divided by the ground, the atmosphere and the Space. The fix assets find itself in the first layers and the second, the third is the domain of mobile structure. Both of them require integrated sensors supporting the real time in terms on milliseconds, especially when the commercial services depends on the time. The sensors on the networks provide data with different format. The equipments generate data formats. The data volume have to be understood to provide indications, warnings, Space security, and Command and Control.

The third topic is the behaviour of the ground-to-Space combinaison between the assets which compose the networks and the data behaviour. The Earth exploration from data Space combined with the data ground provide a new dimension to understand Earth efficiently.

It depends on the sensors sensibility and the matters properties in the way to simulate Earth functionalities. Thanks to the cyber techniques, the simulation can be a method to catch up the Earth mechanisms. First, the networks should be considered as its own geographic system if we consider, once more, that's the data linked to this network system describes a reality. Then, the model analysis studies the data properties and the networks of digital system between the ground and Space assets. Both of them open some breaches to penetrate the complex process on duty on Earth. And data Space is a key parameter to fill cyber chain from Space to the ground.

This approach reinforces the research from Space for the application of geo-engineering to maintain a favourable climat conditions for business and to anticipate the imbalances incoming for the human specy survival on the ground and the dangers from Deep Space.

The fourth topic is the consequences of New Space mean the increasing of data available for any topics about the Space operations. In regard of the Space industry development through the services delivered to the ground and towards the Deep Space, the operational data needs a method to be correctly collected, organized, and interpreted by the machines and the interface with human. The cybersecurity offers the way to secure the data networks. Nevertheless, the integrity of data shall be checked to secure and protect the brain too.

The Space operation management are based on the machine-to-machine and human-to-machine interfaces. The brains undergo a cognitive burden with the quantity of information incoming from the screen and its environment.

[7][7] John J.Klein, "Understanding Space Strategy", Routledge, 2020.

The cognitive cybersecurity provides the toolbox to design a correct representation of data for any kinds of maneuver in Space or from the ground to the Space. As data is the key control, the understanding of cognitive bias from the brain secures the mission process. Moreover, the brain is faced with the machines errors. The training from data model corrects them through the simulation. Despite of that, the brain undergo the effects of the predictive model in which the no-comprehensive and intelligible data can produce both the wrong decision making, the unexpected maneuvers and the observation errors.

The fifth is the infrastructure on the ground which take account the requirements of Space as a service through the Cloud services. Following the requirements of New Space, the service provider are able to introduce Space functionalities into human life for many services. The networks well known are the major Space company with an ecosystem of start-up providing full services to the ground : Amazon, Starlink, OneWeb, Microsoft. And without to take account from private micro-launchers to get a rocket on orbit, the combination with the Space companies give a support to use Space like high point to the benefit of the land. This step incoming is no more the Earth's Defences with commercial items using the Space assets for the services.

The Earth's defences don't mean only military action, it have to be considered the communication and observation abilities to provide information to the ground to take counter-measure to manage the risks noticed. The available information is now available as a service for large part for observation. The observation, supporting by the communication system, are centered by imagery data. The one-third of the satellites in Space are used for observation used the matters information theory. This theory aims to describe and to understand all biological event by the combination of properties of the matters and the mechanism of electromagnetic spectrum. The Space as service is available through the unified networks.

The private major Cloud compagnies offer Space service thanks to their infrastructures and the data storage availabilities. With mobile station and ground station generally, it follow data in a full network, Space assets and Terrestrial assets for a purpose to observe, a problem to solve, a point to detect. The full networks shall be understood as Space as a service for the mission need : a purpose, a problem, a point.

The Space as services translate the use of Space architecture to deliver a free open access to data through the commercial satellites on orbit. The volume of commercial satellites increase in considering the definition of them out the weight consideration. In New Space any object going to Space to provide a service to the ground shall be viewed as satellites.

It includes CubeSat, NanoSat, MicroSat, PicoSat in the processing of satellites Space management with the satellites weighing 100 kg. On the February 15th 2017, India launched 104 satellites in one launching. The nature of the architecture is composed of LAN and WAN with more integrated communication with many types of receivers.

To support this architecture, the Cloud system is a solution for it considers a resource available as a service used for a purpose. The example of this technology is demonstrated by the AWS ground station or by Azure Orbital. The concept of Cloud services is managed with the satellites in low and middle orbit and the receive satellite data into a virtual private Cloud. Then, the data processing and theirs distribution take place in the Cloud and in the infrastructure.

The reverse engineering of Amazon ground station and the Azure Orbital services complete the means that the traditional agencies own to use Space for their activities. It concerns both the networks with the infrastructure and the data stored thanks to the assets in Space. Indeed, the networks must be able to store a large data volume in the data center and in the same moment the infrastructure has to be available to the user. The data volume increases in the same tempo as noticed on Earth. The case is more accurate with the data Deep Space.

The treatment of data is more complex because it introduces to manage data from telescope on Earth with specific methodology to collect, to analyze, to provide a vizualisation without errors.

The Space data is not only use by the user or customer on the ground. Called by the ground-to-Space concept, it means the capacity to the astronauts to connect the computers on-board in spacecraft to the ground. And thanks to Space as services, the access of scientific database is reliable with the observation in Space. It concerns the experience that the astronauts did in the laboratory in the Space station. The kill chain means a cyber-security methodology to gather and to secure data from the unified networks. The framework concerns one part of the networks from spacecraft in close orbit or in Deep Space.

The data access from and to Space change the operation management for the ground as in Space too. The new technologies change the perception of the things in introducing the words and Space references in the common sense.

The terrestrial networks are combined with those built in Space for user. And the electrical communication through the logic and physical networks modify the perceptions. Outer the need of economy, the Earth's Defences is one of the examples the way to put Space culture to manage the ground. The Space culture comes from the technology available for user. The Space culture is possible thanks to the connectivity which gives the concept of Space as services. It can be define as the use of vocabulary to describe Space communication to be closer to the Space.

The sixth topic is the useful datasets for the missions allowing multiple operational tasks. The geospace missions and the observations illustrate the effects on the missions. The observation missions and the one come from the Deep Space through a methodology to fulfill the missions. The science of data in Space combines the monitoring of spacecrafts, the radiation data on its instruments and mainly the ones coming from the electromagnetic spectrum.

To prepare the Space mission analysis, data is a requirement to provide the operational steps until the Space design. Unlike the Big data on the ground segment, the data incoming from Space is to be considered as huge.

The huge data consists of the data far away from the big data known in the ground. Thanks to the first Black Hole image in 2017^[9], Space mission analysis and design from the ground provide a way to understand how to manage the huge level of data. If new Spacecrafts like CubeSat, NanoSat are able to observe the ground as the classical satellites, the geospace observation in the deep Space gives data for Space mission analysis and design through the specificity of Space geography. The huge data techniques for Space operations can be understood as several ways. Those from the Spacecraft in Space like GAIA telescope, Rosetta probe, and those on the ground to design Space.

The Space data means the need to describe the characteristics of Space geography links with the data lifecycle, the data dimensions, the New Space requirements, the Space territory and the ground segment relationship to manage and design the mission. Then, the conditions of Space geography imply the data volume, the algorithm to deal with data in Space combined with data in the ground segment. Moreover, the Space geographic representation introduces data in the matters information theory with other dimensions.

Otherwise, through this representation, the Space geographic territory can be analyzed to detect, to observe an geographic object in Deep Space. That's the way where this huge data process considers geospace as a territory itself in which the data sets techniques provide the key factors to analyze and design a Space mission thanks to Space as services.

The South Atlantic Anomaly is an electromagnetic perturbation getting Space assets in a temporary shutdown process to avoid the severe damage for their vital features. The Earth electromagnetic field comes from the electric flue produced by the steel external core in the Earth center.

However, the Earth electromagnetic field owns a different value with a loss of intensity from the Africa to South America. Although the Swarn constellation follows the electromagnetic anomaly status, the causes are unknown. Nevertheless, following the Hitomi satellite crash in 2016, the effects on the satellites orbits change the space operations for the service deliveries on the ground and to the Space : for instance Hubble and the different types of satellites incoming from private compagny. The high energy particles resulting of this statement include a way to protect the Space operations : for instance ISS instruments and the data on it. Moreover, the radiation types recorded emphasize the need to think cybersecurity in Space from the particle physic by design thanks to the measurements of SAMPEX spacecraft and that of the International geomagnetic reference field. Both of them are the basic data model to built a Space cybersecurity requirement for Space assets crossing the South Atlantic Anomaly.

The rising of Space mission in low and medium orbit and with that the deep Space exploration increase the data qualification in Space. To make an accurate decision for the mission and the Space program management, data on Space gets its owns features including the networks on the ground and those on Space. Moreover, it concerns the deep Space mission to support the probes technical management with several stakeholders and the network management for long distance as the Mars

[9][9]Santosh Kumar, Deepanwita Datta, Sanjay Kumar Singh, "Black Hole Algorithm and its Applications". Studies in computational intelligence 575:147-170, DOI : 10.1007/978-3-319-11017-2 7, 2015.

missions for the Space operation. The data multipath and its specific qualification in Space need to be understood about its functionalities so that the system can fulfill its mission. To reach on the understanding of this qualification, the data in Space is defined by the three steps : its design, its property, its dimension.

The strategic and tactic decision in Space command depend on these topics in a context where the Space networks are going to be more unified with complex interconnections supporting different parameters, protocols and frequencies. These features are related to the information perception in which the data should be understood and applied in an organization able to guarantee its work flow.