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SPACE “DOMAIN” AND EARTH OBSERVATION, SKILLS AND CASE STUDIES

DOMÍNIO “ESPAÇO” E OBSERVAÇÃO DA TERRA, COMPETÊNCIAS E ESTUDOS DE CASO

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Abstract

The growing awareness and concerns about space, as well as the legal commitments and obligations undertaken by Portugal, and consequently by the Air Force, have created an urgent need to integrate the space domain into aviation operations. By analysing the relationship between space services and products and intelligence and operations, this study aims to identify how satellite-based Earth observing sensors (and the space skills required to employ them) can be used to make the activities of the Portuguese Air Force (PoAF) more efficient and effective. A Case Study methodology was chosen to conduct this work and six case studies were designed and analysed using information obtained from satellites. The findings showed that these products can provide vital information to the planning of aviation missions, improving the PoAF’s situational awareness and contributing to the identification of the organisational competencies required to conduct space-related activities. The findings showed that further integration of space products into aviation operations would improve support to decision making.

Keywords: Portuguese Air Force; Space Operations; Aviation Operations; Space Intelligence; Space Skills.

Resumo

A crescente consciencialização e preocupação com o Espaço, bem como os compromissos e obrigações legais assumidos por Portugal, e consequentemente pela Força Aérea, concorrem simultaneamente para a necessidade premente de implementação do domínio Espaço nas operações aéreas. Considerando a ligação dos serviços e produtos do Espaço com as informações e as operações, esta investigação tem como objetivo identificar

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o potencial da observação da Terra a partir do Espaço (e as competências espaciais necessárias), através de sensores instalados em satélites, para acrescentar eficiência e eficácia às atividades desenvolvidas pela Força Aérea. Para alcançar esse objetivo, foi desenvolvida uma investigação assente na metodologia de Estudos de Caso na pesquisa e no desenho de seis estudos de caso com recurso a informação proveniente dos satélites, em que foi possível observar que a adoção destes produtos pode acrescentar informação essencial ao ciclo de planeamento das missões dos meios aéreos, proporcionando melhor consciência situacional, e contribuir para a identificação das competências organizacionais necessárias associadas ao Espaço. Concluiu-se que existe potencial para aumentar a capacidade de integração de produtos espaciais nas operações aéreas e obter maiores benefícios no apoio à decisão.

Palavras-chave: *Força Aérea; Operações no Espaço; Operações Aéreas; Informações Espaciais; Competências Espaciais.*

1. Introduction

Between 1957 and 2023, 34.595 objects were launched into space (*Our World in Data*, 2024). In 2020, 451 satellites were registered as government satellites, both for military or civilian purposes (Skinner, 2020). Thirty-one years after launching its first satellite, PoSAT 1 (Portuguese Space Agency [PT Space], 2023), Portugal's *Aeros* satellite (which took off aboard a SpaceX rocket) will now provide a new source of ocean observation data (Público, 2024).

With the proliferation of satellites, having situational awareness of space has become essential not only to predict the possibility of a collision, but also to know the position of inactive objects (debris) that could interfere with satellite navigation (Gregersen, 2024).

In 2019, the North Atlantic Treaty Organisation (NATO) recognised Space as a military domain (NATO, 2023) and the European Union (EU) expanded the European Space Agency (ESA) by creating the Space Surveillance and Tracking Support Framework (EU SST), a consortium of several countries, including Portugal, which consists of a network of sensors that provide Space Surveillance and Awareness (SSA) and Space Surveillance and Tracking (SST) to Alliance countries (European Commission [EC], 2020).

Satellites can be used to provide services in five main areas: i) Positioning, Navigation and Timing (PNT); ii) Satellite Communications (SATCOM), which enable command, control, data and monitoring and coordination of space-based activities; iii) SSA/SST; iv) Intelligence, Surveillance and Reconnaissance (ISR); and v) Environmental monitoring (adapted from NATO, 2022, 2023).

The United States of America (US) have been a space power since the late 1940s, thanks to the National Aeronautics and Space Administration (NASA), which conducts a wide range of relevant activities in space.

Portugal has been on its own journey. It has prepared the necessary strategy documents to develop and launch national systems that will allow it to accomplish the objectives it has defined: Council of Ministers Resolution (CMR) No. 30/2018 approved the National Space

Strategy 2030 (ENE2030) (CMR, 2018) and CMR No. 55/2019 approved the establishment of PT-Space (CMR, 2019a).

The National Defence Strategy for Space (EDNE2030) (Ministry of National Defence [MDN], 2020) sets out objectives in the four areas mentioned above and the General Staff of the Armed Forces (EMGFA) has established a Centre for Communications and Information, Cyberspace and Space (EMGFA, 2024). The Portuguese Air Force has developed a space policy (Força Aérea, 2023) and is in the process of building this capability through its new Space Operations Centre (SOC) (at this time, the centre's staff have been selected and are currently being trained).

While the PNT and SATCOM areas are extremely important for countries to ensure independence in the use of their resources, the SSA/SST area is also vital for obtaining situational awareness of the position and movement of satellites in space. ISR (that is, Earth observation for situational awareness and scientific purposes), which in this article includes meteorological observation, is especially important to address important global events such as climate change, the measures mandated by the Paris Agreement (Decision (EU) No. 2016/1841, 2016) in December 2015 and the European Green Deal (EC, 2019, p. 27), or, in the case of Portugal, the Roadmap for Carbon Neutrality 2050[1] (CMR, 2019b) and the National Energy and Climate Plan 2030[2] (CMR; 2020).

It seems clear, then, that satellite observation is essential to assess how these strategies are evolving and if the goals that are set in them are being met. Integrating space services and products into intelligence and operations is crucial because it will add comprehensive multidomain data and information to the process of obtaining air superiority.

This study in the field of military sciences focuses on the area of military operations, and specifically addresses the subareas of decision support and the use of aerospace power.

1.1. Problem identification

The Portuguese Air Force is currently building its space capability. This is a complex process that involves integrating the services and products provided by that domain into the Air Force's operational output, that is, the elements that constitute air power.

The PNT and SATCOM areas ensure precision timing, navigation and communications, while the SSA/SST area provides situational awareness of space and space objects. Despite all three areas being critical for the area of operations, it is the ISR area that should be integrated into operations, not only because it provides additional knowledge about the Earth, but also because it can be used to improve decision making.

This will require more than simply installing spacecraft and training personnel to liaise with space-related European centres and companies.

The question of "How can space be integrated into the ISR the Operations areas to improve

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1 CMR No. 107/2019, 01 July.
2 CMR No. 53/2020, 10 July.

all phases of operations (including planning, execution and analysis), and what skills will this require?" calls for a multi-faceted and multi-domain answer which identifies the elements that support decision making.

The problem is, then, that not only it is still unclear how space-based ISR services and products can be used to improve the services and products that are currently used in the operation of air assets, there is little information on the skills required to use them.

1.2. Objective and Research Question

The research objective (RO) is to determine how to optimise the integration of space based ISR services and products into the operational output, that is, air power, as well as to demonstrate the vital role of Earth observation in improving the aviation operations cycle and identify the skills required to build the Space capability.

The following research question (RQ) was: "How do space-based ISR products and services improve intelligence and air operations and what skills are needed for this to happen?" The following Requirements (R) were defined:

– R.1 Identifying the areas of the operations cycle and space-based ISR services and products that can be used to improve decision making;

– R.2 Identifying the applicable areas and concepts;

– R.3 Identifying the organisational positions (OP) (Páscoa et al., 2011)[3] associated with space activities and describing their roles.

1.3. Methodology

Case studies (CS) explore a practical case (or several cases) in which multiple sources of data are analysed (Creswell, 2014). This methodology can be used to analyse data from each situation and between situations (Yin, 2018), which broadens the scope of the research (Eisenhardt & Graebner, 2007).

Here, a case study is used to identify solutions to improve the integration of the products obtained from Earth observation into the executable that links space operations to information fusion, aviation operations and OP roles.

To meet R.1 and R.2, a review was performed of organisations that use Geographic Information Systems (GIS) and satellite image processing algorithms, such as ESA, NASA, the United Nations and Google. This research was used to design individual CS which address the creation of digital models (CS 1) and their use in risk analysis (CS 2), mission planning and simulation (CS 3), target detection (CS 4), and disaster analysis focusing on rural fires (CS 5) and floods (CS 6).

To meet R.3, descriptions of organisational positions and their respective roles were obtained in the official websites of the armed forces of NATO countries. As more detailed information was available about the US space force, it was the starting point for the research.

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[3] Positions occupied by personnel with specific roles.

In most CS, the analysis was performed by software that collects and processes satellite data and generates useful graphical outputs, which are presented in layers that can be expanded. In the case of floods, the software processes more than 20 operations in the selected area and classifies the signal return of each pixel, for each operation. It analyses 28484x21519 pixels at a resolution of 10x10m per pixel to generate an image that provides information that can be used to support operations.

The study consists of four stages:

– The first stage consisted of identifying the problem, the RQ, the RO and the methodology, describing how the literature review would be performed and defining the research plan;

– The second stage involved collecting information on space skills and digital models, including the algorithms used to process them and information on how to integrate them; the CS were designed at this stage;

– In the third stage, the models were analysed and adapted and conclusions were drawn;

– The fourth stage consisted of reflecting, assessing, drawing conclusions and describing the research findings, assessing if the RO was accomplished and answering the RQ, determining if the problem has been solved, presenting the contributions to scientific knowledge and suggesting future activities.

The assessment will validate the products and services that were identified, used and demonstrated in the CS, and describe how they helped meet the requirements.

1.4. Expected scientific contributions

This work aims to provide the following scientific knowledge: understanding how space services and products can be integrated into the Portuguese Air Force's intelligence analysis and aviation operations cycles, and identifying the positions and roles required to build the "Space" capability.

1.5. Scope and limitations

This study was conducted in 2023, on behalf of the Portuguese Air Force. Some of the data obtained during the research will not be disclosed in this document.

1.6. Structure

This document is divided into four chapters. The first chapter describes the context, the research problem and its relevance. It also identifies the objective, the research question, the methodology, the assessment process and, finally, the scope and limitations of the study.

The second chapter contains a literature review of scientific studies, legislation and expertise on the topic.

The third chapter describes the main areas relevant to space, the services and products provided by each area, gives examples of products and services that can be used to improve the operations cycle and presents the analysis which accomplished the research objective and answered the research question.

Chapter 4 contains the conclusions, describes how the research objective was accomplished, answers the research question, confirms the study's contributions to scientific knowledge and makes suggestions for future studies.

2. Literature Review

The World Economic Forum (World Economic Forum, 2024, p. 8) has conducted a survey of global risks and listed them by order of importance (top four) and time frame:

– In the next two years: misinformation and disinformation, extreme weather events, social polarisation and cyber insecurity;

– In the next ten years: extreme weather events, critical changes to the Earth's systems, loss of biodiversity, ecosystems collapse and shortages of natural resources.

The use of Space and Earth observation (EO) to monitor and track the evolution of climate phenomena represents a substantial effort in the fight against climate change (National Aeronautics and Space Administration [NASA], 2024a; ESA Copernicus, 2024a). In addition to its usefulness as a PNT and SATCOM platform, space has become an essential tool for observing the Earth and its phenomena.

This chapter describes the space strategy of the EU, NATO and Portugal, the importance of space as a multi purpose global platform and how space is used by military organisations, as well as addressing issues related to the organisational aspects of the use of aerospace services and products.

2.1. Space Strategy

The Council of the European Union (CUE) has developed a Space Strategy for Europe (CUE, 2016) and, within the framework of the Strategic Compas[4] (CUE, 2022a, 2022b), Europe has developed its Space Programme, which currently has several components (EU Agency for the Space Programme, 2024):

– Copernicus, which collects EO data and studies: the Atmosphere, the Sea, Land, Climate Change, Security and Emergencies;

– Europe's Global Navigation Satellite System (GNSS), or GALILEO, and the European Geostationary Navigation Overlay Service (EGNOS), which provide PNT services (including search and rescue, in the case of EGNOS);

– Governmental Satellite Communications and Infrastructure for Resilience, Interconnectivity and Security by Satellite (IRIS), which enables communications used in crisis situations, border surveillance and management of critical infrastructures and diplomatic communications;

– Space Situational Awareness (SSA) (in the context of SSA/SST), which includes the surveillance of space objects.

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[4] The Strategic Compass is a joint assessment of the strategic environment in which the EU operates and the threats and challenges it faces, as well as measures to address them. For example, the "Act" component includes the creation of an EU rapid deployment capability of up to 5,000 troops (EC, 2022).

NATO recognises space as a military domain. As such, in 2016, it published a joint doctrine on aviation operations and space operations (NATO, 2016), which confirms that space services and technologies can help maximise the efficiency of military operations.

In Portugal, the ENE2030 describes "space as a fundamental resource for Portugal's collective ambitions" and defines three strategic axes, which include: i) "Stimulating the exploitation of space data and signals (...)"; ii) "Promoting the development, production and operation of space equipment, systems and infrastructures as well as space data production services (...)"; iii) "Continuing to develop national capacity and expertise in the space domain (...)" (CMR, 2018, p. 1258).

PT-Space was created in 2019 (CMR, 2019a) to implement the ENE2030 and the EDNE2030 was approved (MDN, 2020) in 2020. The latter provides an action plan to develop and expand the initial capabilities: PNT; ISR for observation and tracking of surface activities; SATCOM for command, control and data; and SSA/SST.

To build the capabilities / axes defined by the Ministry of National Defence, the Portuguese Air Force developed the Space Concept (Portuguese Air Force, 2023), a document that defines critical elements for building the capability and integrating it into the operational executable.

2.2. The importance of space

Since the 1960s, the community of nations has created a detailed legal framework to regulate activities in outer space (governed by United Nations [UN] treaties) which is set out and enshrined in the applicable legislation (UN, 1966; de Zwart, 2020; European Space Policy Institute [ESPI], 2017).

However, the defence, security and protection of territories and their citizens includes all activities that occur in space, or are enabled by space, and that involve protecting people, interests and values, preventing, deterring and, when necessary, defeating attacks by hostile actors, as well as managing several types of threats (Grest, 2020), risks and dangers (Defence Intelligence Agency, 2022) that could compromise nations' territorial integrity, values and culture.

Military institutions and defence agencies have played a crucial role in developing the space sector, driving investment and innovation in systems that provide significant technological advances for military capabilities, as well as multiple technologies that offer strategic, operational and tactical advantages in the control and use of space as the "ultimate high ground", enabling modern forms of digital and network-centric warfare (Black et al., 2022a; Black et al., 2022b).

The recognition of space as an operational domain has sparked a technological race that led to the emergence and development of a growing range of critical systems that will have an impact on military and civilian capabilities (Banks, 2019):

– Debris management and removal, including techniques for safely repairing, refuelling, moving or de-orbiting space objects, reducing the growing risk of a collision (Wang et al., 2022);

– Industrial construction (Demopoulos, 2023; Factories in Space, 2024a, 2024b;Kulu, 2021; NASA, 2022);

– Long-term secure storage of valuable data and items (for example, to safeguard knowledge for future generations) (Greenblatt & Anzaldua, 2019);

– Monitoring and supporting the resilience of critical infrastructures through the use of EO and PNT data combined with new sensors and technologies, such as the Internet of Things (IoT) and Unmanned Aerial Systems (UAS) (Jung et al., 2023);

– The use of new technologies such as additive manufacturing (3D printing) and quantum algorithms to improve EO (NASA, 2023, p. 6-7; Rainjonneau et al., 2023);

– Gradually expanding the use of EO services, SATCOM and PNT to support emergency services in the prevention of floods and rural fires (RF); communications in remote areas; devices connected to the Internet of Things (IoT); and robotic and autonomous systems (UN, n.d.; ESA, 2017a, 2017b).

2.3. Use of space for military purposes

Among other purposes, military organisations use space to conduct Research, Development and Innovation (RD&I) activities and integrate space sensors into military capabilities.

In 2020, of all satellites registered as military satellites, 135 were used for communications (29%), 110 for navigation (23%), 67 for technology development (14%), 35 for signals intelligence (7%), 85 for optical imaging, radar and EO (18%), and 39 for other uses (9%) (Skinner, 2020).

Given the current number of active satellites (around 10,000 [Celestrak, 2024]) knowing their position is essential to avoid collisions, not only between them but also with space debris. In the short and medium term, these innovations and the technological developments that accompany them will significantly improve:

– the capabilities of radars, terrestrial and space-based optical sensors and data processing to improve situational awareness in the early detection and early warning of near-Earth objects (Lal et al., 2018);

– missile defence early warning systems, including space-based detection of missile launches and trajectories and space-based missile interception (Roberts, 2022);

– space-based cyber security (Bailey, 2020) and advanced space weapons (Harrison, 2020, p. 6);

– conventional prompt global strike capability using hypersonic weapons (Woolf, 2021);

– threat modelling, simulation and analysis by locating objects with high precision, enabling real-time analysis through the creation of augmented virtual reality models (Catapult, 2017; Utilities One, 2023);

– search and rescue operations by providing new technologies that enable location tracking and rapid response (Baird, 2019);

– command and control, communications, computers, intelligence, surveillance, target acquisition and reconnaissance (C4ISTAR) of military forces, facilitating multidomain integration and joint and combined operations (Wald, 2014).

2.4. Capability Development

Militaries all over the world use the Doctrine, Organisation, Training, Material, Leadership, Personnel, Facilities / Infrastructures and Interoperability (DOTMLPFI) methodology (NATO, 2021; United States Air Force, 2021), and the Portuguese Air Force (Portuguese Air Force, 2023) has adopted it for projects aimed at building the Space capability.

As the costs involved in building this capability are high, the Portuguese Air Force, under the framework of strategies ENE2030 (2018), EDNE2030 (2020) and its own strategy (Portuguese Air Force, 2023), is currently developing mechanisms to integrate it into partnerships, such as the ones it has established with CEiiA[5] and GEOSAT for the Atlantic constellation project (Portuguese Air Force, 2024). These agencies are included in the space catalogue (PT-Space, 2024a) and actively participate in the development and use of satellites (PT-Space, 2024b).

With regards to **Doctrine**: the strategic level of the US Space Force (USSF) doctrine (USSF, 2024a) consists of a main document (Space Capstone Publication) (USSF, 2020) that includes the personnel (SDP 1-0) (USSF, 2022), intelligence (SDP 2-0), operations (SDP 3-0), sustainment (SDP 4-0), planning (SDP 5-0) and joint operations (SDP 3-99) doctrines.

NATO has also published military doctrine addressing Space in air operations (NATO, 2016) and the need to establish linkages between three key actors in the process of planning and conducting military air operations.

In practice, an aerospace doctrine should establish linkages between the SOC, the ISR centre and the air operations centre, identifying what should be shared and how it should be used to improve the effectiveness and efficiency of air operations.

These linkages should take into account the threat, the operating context, military capabilities and the need for sharing products and services (in compliance with the existing legislation) that meet the requirements for building the Space capability and integrate it into operations (Chapeaux, 2022; Grest, 2022).

Therefore, the Portuguese Air Force must meet this challenge and take on the responsibility of developing a doctrine that integrates Space into its culture and explains the benefits of space-based products and how they can be integrated into air power using existing military capabilities (such as Air Combat, Air Transport, ISR, Search and Rescue, etc.), as well as its linkages with cyber security, multidomain operations and, at the organisational level, with areas related to sustainability, and specifically to climate change, such as the Portuguese Air Force's Roadmap for Carbon Neutrality 2050 (Portuguese Air Force, 2022; Pinto & Páscoa, 2023) and the initiatives that are currently being developed in this field (Calaixo et al., 2022; Correia et al., 2022).

Organization: the organisational design of the space force (Portuguese Air Force, 2023) includes a set of guidelines and principles that lend consistency to the capability building process and ensure its sustainability by maximising linkages between the new capability and

[5] Centre of Engineering and Product Development (CEiiA).

operations, logistics and personnel. This will include the preparation and initial training for operational roles, logistics, education, qualification and training and RD&I.

Effective integration requires the **Education, Training and Qualification** of personnel with space-related roles. However, this is not all, as conducting and supervising operations requires a common and clear understanding of how space capabilities (military, civilian, commercial, national and multinational) contribute to Air Force operations. Therefore, it is essential to establish the concept of aerospace hygiene[6] in the Portuguese Air Force's areas of operation by generating cross-cutting cultural knowledge that "breathes" Space into the organisation and into air operations.

Given the financial costs involved in the use of Space and the need to share them, a significant part of the skills which the personnel assigned to this area are required to have will be acquired through partnerships, treaties and collaborations with other organisations. Online training is available on various EO-related topics (Saing (2020); NASA, 2024b).

Material: when calculating mission components, the following factors should be accounted for: concept, project management, systems engineering, safety and mission assurance (including aspects associated with flight safety, procedures and quality), science and technology, payloads, spacecraft, space operations, launch vehicle and related services, land-based systems, systems integration and testing, and education, training and communication (NASA, 2010, p. 9).

Bearing in mind Portugal's objectives, the complexity and the high cost of these components, the Portuguese Air Force has formed partnerships with other military and civilian stakeholders (Portuguese Air Force, 2024) to produce, within the organisation, the material required to run the space operations centre and create linkages to other National Defence organisations (MDN, 2018).

Leadership: the new skills should be integrated into C4I networks. It is imperative that the Portuguese Air Force is able to use space services and products in its command and control process, integrating them into the operational product, especially since it will have other military and civilian (and business) organisations as partners.

For this to happen, all DOTMLPFI areas must be prepared, at all levels of command and control, to identify space dependencies and vulnerabilities and to understand how to mitigate the effects of a threat by ensuring situational awareness at all phases of aerospace operations.

Personnel: given the specific nature of this area, in the short and medium term the Space capability will have a limited number of specialised roles (operations, intelligence, engineering, science, acquisition and cyber security / communications, for example), and programmes will be set up for acquiring specific skills, for example, in cyber security (Páscoa et al., 2023).

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[6] Aerospace hygiene implies identifying cross-cutting knowledge about space which all personnel must have, regardless of the area where they develop their activities, as well as establishing the procedures that they must follow on a daily basis (as with personal hygiene or cyber security hygiene).

The doctrinal publication on Personnel SDP 1-0 (USSF, 2022) includes a list of career categories to be developed in the area of operations: astronauts (officers), space operations, intelligence and cyberspace operations.

Table 1 shows the OP that will likely be involved in the Space Capability (USSF, 2024b) in the operational field. Due to their requirements and the rapid pace of technological advancements, it is recommended that some of these specialities be filled by civilian personnel, as they are long-term positions. Space skills have been adapted to the context of the Portuguese Air Force. For example, as the procurement and acquisition OP is usually assigned to the Logistics Command, it was redesigned and removed from the SOC and the roles were adapted to the officer, sergeant and civilian categories.

Table 1 – OP and roles assigned to the Space capability

Position and Category	**Description / Role**
OP 1 Science and Engineering Civilian	Uses a set of technical and scientific skills to develop, operate and implement space systems. Roles include: - Identifying and integrating new engineering systems and technologies; - Monitoring and improving policies, products and technical procedures; - Developing, coordinating, organising and managing engineering studies, projects and processes.
OP2 Intelligence Civilian	Analyses, reports and distributes intelligence to the main mission components, helping to protect the force against expected threats. Roles include: - Assessing vulnerabilities that could be exploited in telecommunications networks and intelligence; - Analysing adversary threat systems; - Disseminating intelligence on economic, political, cultural, social and geographical trends that have an impact on national security; - Providing training on how to collect and communicate intelligence procedures and requirements.
OP3 Space Operations Civilian	Supervises the system to improve communications and capabilities, including space surveillance and command and control. Roles include: - Managing training, planning, mission control and other activities involving spacecraft recovery and launch; - Developing space exploration policies; - Advising on the development, acquisition and operation of space systems.
OP4 Information Technologies Civilian	Keeping intelligence secure and available using specialised software and hardware systems. Roles include: - Developing information technology systems; - Providing technical support for the programme and managing the development of data repositories; - Presenting complex technical intelligence to a variety of stakeholders.
OP5 Cyber security analyst Civilian	Ensures missions are accomplished by ensuring the operability of satellites and missile guidance systems. Roles include: - Ensuring the confidentiality, availability and integrity of cyber systems and networks; - Using software, hardware and firmware; - Improving security programmes, policies and procedures.
OP6 Intelligence Officer	Analyses data and coordinates with other services. Roles include: - Managing and supervising the analysis and fusion of collected intelligence; - Developing intelligence plans and policies; - Producing accurate intelligence analyses and integrating them with combat operations.

[Cont.]

OP7 Cyber Effects Operation Officer	Ensures the effectiveness of operations in cyberspace, from planning to supervising satellite communications. Roles include: - Analysing mission tasks, intelligence, terrain and meteorology; - Advising on risks and mitigating factors; - Deploying cyberspace capabilities.
OP8 Target Analyst Sergeant	Analyses targets and protects them against potential threats. Roles include: - Providing support, examining and validating targets and system analyses; - Managing the list of targets and priorities; - Supporting mission planning; - Conducting vulnerability assessments; - Developing products and intelligence from databases; - Performing Battle Damage Assessments; - Making reattack recommendations.
OP9 Information Sources Analyst Sergeant	Collects and analyses raw data and assesses intelligence from various sources. Roles include: - Producing situation estimates and assessments; - Assessing offensive and defensive capabilities; - Training military personnel on intelligence gathering and communication, reconnaissance and procedures; - Preparing, updating and presenting reports.
OP10 Intelligence Analyst Sergeant	Ensures that intelligence is accurate, efficient and secure. Roles include: - Using global communications to support computer network operations; - Retrieving and correlating technical, geographical and operational intelligence; - Producing technical products and intelligence reports when needed.
OP11 Geospatial Intelligence Analyst Sergeant	Analyses images from satellites and remote driven vehicles to identify unusual activities and potential threats. Roles include: - Exploring, georeferencing and analysing images from sensors and geospatial data; - Analysing terrain and structures and using maps to determine the target's location and distance; - Preparing and presenting geospatial intelligence reports; - Compiling and updating images and destination folders; - Researching and analysing multisensor images, geospatial data and associated products.
PO12 OP12 Signals Analyst (Intelligence) Sergeant	Analyses communications and electromagnetic emissions to detect critical situations. Roles include: - Operating computer equipment and systems to exploit signals; - Manipulating and extracting data from electromagnetic emissions for interpretation and analysis; - Updating the databases with the results; - Performing graphic and electronic analyses to identify communication structures, extract intelligence and determine how they are being used.
OP13 Space systems operator Sergeant	Performs launch monitoring and space flight operations tasks, including the detection of ballistic missiles and tracking satellites. Roles include: - Detecting, identifying and updating orbital parameters in terrestrial vehicles; - Operating defensive and offensive space control systems; - Detecting and tracking missile launches; - Conducting satellite launch and in-orbit operations; - Conducting range operations to support space and ballistic missile launches.
OP14 Space operations operator Sergeant	Supervises space surveillance, space transport, space warning and satellite command and control and assesses the effectiveness of space operations. Roles include: - Preparing space operations policies; - Defining training requirements and performance standards for the systems; - Coordinating space operations activities; - Providing information on the proper use and care of sensitive materials.

Source: USSF (2024b).

Infrastructure: the development and construction of buildings, satellite launch pads and other space-related equipment should be monitored to ensure the involvement of the Portuguese Air Force in the national space community.

Interoperability: given the shared nature of space data, products and services, the requirements defined by Grest (2022) should be met: effectiveness (coherence, credibility, continuity and professionalism), efficiency (development, planning, execution, C2 and analysis and assessment); interoperability (connectivity, standardisation, structure, technology, definitions, security); quality (survival, sustainability, reusability, scalability and flexibility).

Grest (2022, p. 63) provides a list of entities with which an Aerospace Operations Centre liaises (National Defence, Armed Force branches, NATO, partners, universities and RD&I centres, civilian space agencies, industry, government and civilian organisations, etc). Interoperability must be ensured between systems, people, technology, regulation and procedures in terms of semantics, training and qualifications, as well as operating manuals for all levels.

3. Integrating the Space capability into air operations

ENE2030 and EDNE2030 contain Portugal's strategy for servicing its satellites. The strategies provide for Portugal's participation in space programmes and the creation of partnerships with civilian companies to build the Space capability. The following are some space-related statistics (Space Debris User Portal, 2023): there have been approximately 6,500 rocket launches (excluding failures) since the beginning of the space age in 1957; these launches have placed approximately 16,990 satellites in Earth's orbit (about 11,500 of these are still in space and about 9,000 are still active; 35,150 debris objects are regularly tracked by space surveillance networks and more than 640 (estimated number) of break-ups, explosions, collisions or anomalous events have resulted in fragmentation.

This chapter will analyse how space contributes to air operations, discuss the findings and answer the research question.

3.1. Satellite Communications (SATCOM)

Satellite communications enable the transmission of voice, data and other applications via satellite. This technology, which dates back to 1945 (Ostovar, 2010), is considered one of the main factors that helped create a globalised world, and are now vital for military operations and national strategies (about 29% of satellites in orbit in 2020 are registered for military use) (Skinner, 2020).

EU programmes GOVSATCOM and IRIS2 provide satellite communications for crisis management, border and maritime surveillance, and management of key infrastructures and diplomatic communications networks, as well as (in the case of IRIS2) connection of key infrastructures to crisis management.

These services are used in aviation operations and military (and civilian) operations. Therefore, they must be made available by acquiring specific skills that prevent the effects of threats, at all levels, in various areas, such as technology, communications and cyber security.

3.2. Positioning, Navigation and Timing (PNT)

The EU operates the following systems: i) GALILEO consists of 30 satellites, control centres and a network of sensor stations and uplink stations; ii) EGNOS, Europe's regional satellite-based augmentation system, which is used to improve the performance of global navigation satellite systems (GNSSs), such as the Global Positioning System (GPS) and GALILEO, and has been deployed to provide safety-of-life navigation services to aviation, maritime and land-based users in most of Europe.

The GALILEO system allows users to know their exact position with greater precision than other existing systems and provides services used daily by in-vehicle navigation devices, mobile phones and critical emergency response services.

These services are used in aviation operations. Therefore, they must be made available by acquiring specific skills that prevent the effects of threats, at all levels, in various areas, such as technology, communication and cyber security.

3.3. Space Situational Awareness and Satellite Surveillance and Tracking

QAVRE was created by the EU in 2014[7]. It established an SST consortium that currently includes 15 Member States: Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Latvia, Netherlands, Poland, Portugal, Romania, Spain and Sweden.

SST refers to the capacity to detect, catalogue and predict the movements of space objects orbiting the Earth. It consists of three functions: sensor, processing and service provision.

The "sensor" function comprises a network of sensors that survey and track space objects in all orbital regimes. Currently, this network (Figure 1) includes 40 sensors from the SST consortium member states (including radars, telescopes and laser stations) (EC, 2020; EU, 2023; EU SST, 2024)[8].

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[7] Decision 541/2014/EU of the European Parliament and the Council Establishing a Space Surveillance and Tracking Support Framework.

[8] SST Cooperation (2020). EU Space Surveillance and Tracking Service Portfolio.

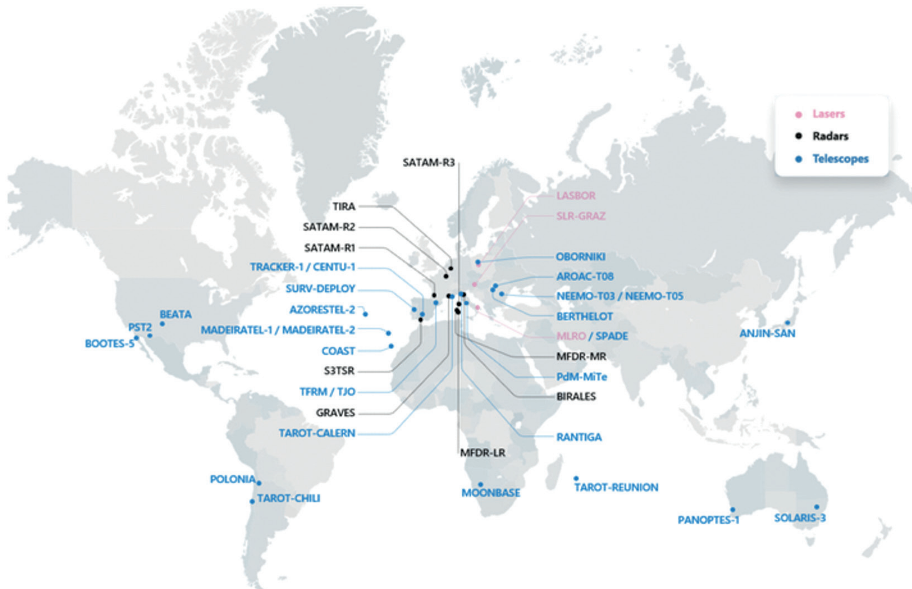

Figure 1 – The EU's SST Sensor Network
Source: SST Cooperation (European Commission, 2020).

The "processing" function coordinates the sharing, processing and analysing of shared data that will be used to generate the future EU SST Catalogue.

The service provision function provides the SST services – Collision Avoidance, Re-entry Analysis and Fragmentation Analysis.

The collision avoidance service assesses the risk of collisions between spacecraft or between spacecraft and space debris, and generates collision avoidance alerts to detect:

– Info Events, which analyse close approaches with a low level of risk;

– Interest Events, which examine close approaches that must be analysed more thoroughly due to the level of risk;

– High-Interest Events, which investigate close approaches with a high level of risk, which may require that the owner / operator perform collision avoidance manoeuvres.

The re-entry analysis service provides risk assessments of uncontrolled re-entry of objects from space into the Earth's atmosphere. The service regularly monitors all objects in space with a mass greater than 2,000kg. When these objects are close to re-entry, the sensors acquire additional data to improve the accuracy of predictions.

The fragmentation analysis service provides detection and characterisation of in orbit fragmentations. The available information (data from sensors that contribute to the EU SST and other fragmentation data from external sources) is subjected to short, medium and long-term analyses, concluding with the provision of different products.

Figure 2 shows extracts from the reports generated by the service (left – re-entry analysis; right – fragmentation analysis).

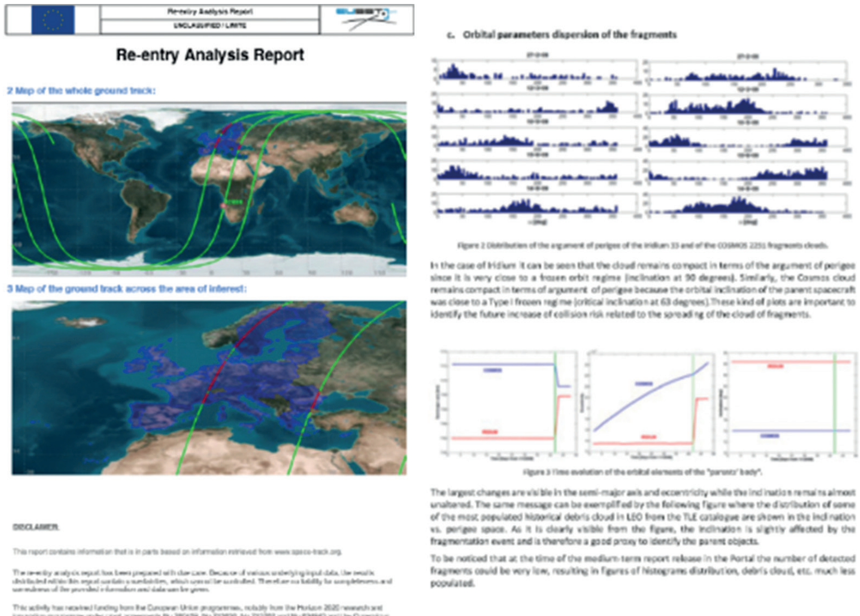

Figure 2 – Examples of Reports.
Source: SST *Cooperation* (*European Commission*, 2020).

Registration on the SST Portal (https://www.eusst.eu/) is required to access these services after the request has been approved.

The services are provided through the SST Portal and are complemented by direct communication between the parties involved. Through the SST Portal, users can: i) download and access products; ii) upload ephemerides and manoeuvre intelligence (or any other type of file); iii) view the evolution of objects in Space; iv) download service configuration documents; v) customise the email notification settings; and vi) access the monthly service statistical report.

3.4. Intelligence Surveillance and Reconnaissance (ISR)

EO products are commonly used to achieve previously impossible goals. For example, images from the Sentinel-1 satellite are used to reduce the risk of bird strikes (ESA, 2017a) and to obtain landscape intelligence (ESA 2017b).

Open source information can be obtained, analysed and integrated into mission planning using several applications. To show how useful this information is, whether captured directly or through the use of GIS, this section will describe the creation of various digital artefacts within the Portuguese Air Force that use or integrate information from satellites and open sources. The examples provided include digital models, risk analysis models, mission planning models, target detection models and models to analyse of the effects of disasters (fires and floods).

These products (which can be created for the Portuguese Air Force or adapted) can be integrated into all phases of aviation operations, from planning to mission analysis, and are examples of connection between Space, Information and Operations.

3.4.1. Creation of Digital Models

Space-based products include open source terrain elevation data captured by satellites. The Terra satellite's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (NASA, 2024c) is available free of charge in 99% of the world. This instrument creates digital elevation models (DEM) at a 30 metre resolution and has two models which are particularly interesting. The Shuttle Radar Topography Mission (SRTM) is another source of DEM (NASA, 2024d).

DEM are used to create digital models of objects of interest and add geographical information to improve decision making, as well as information from the Open Street Map (OSM, 2024). The geographical layers can be uploaded to the Quantum GIS software (QGIS, 2024) to obtain a three-dimensional (3D) view using Qgis2threeJS software (Akagi, 2024).

Figure 3 shows two views of the digital model of an Air Base. The top image is the global view of the Unit. Below is a zoomed-in view that shows buildings, trees, roads, the water network, lighting and the markings on the tarmac.

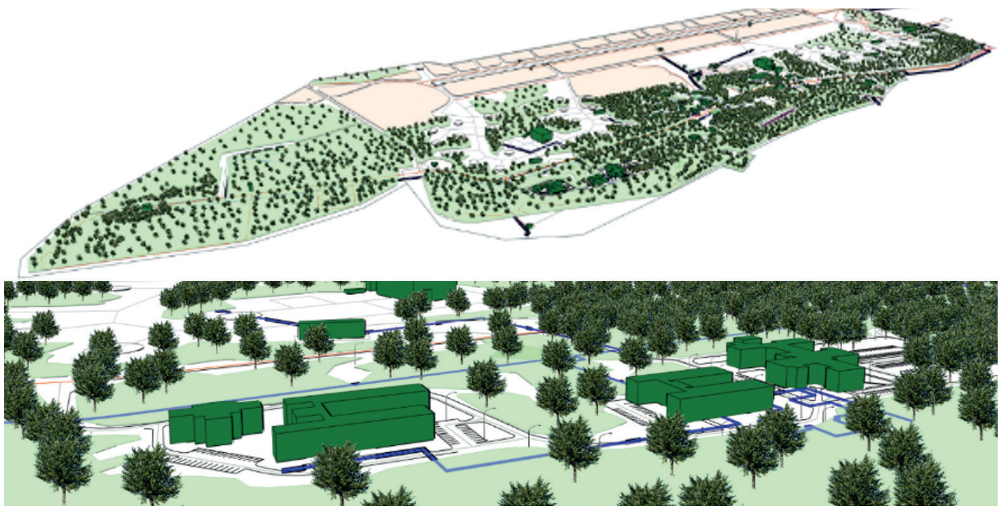

Figure 3 – Views taken from the Digital Model of an Air Base.
Source: prepared using QGIS (2024), Qgis2threeJS (Akagi, 2024) and OSM (2024).

Figure 4 shows three views taken from the digital model of a city. The top image is the global view from the airport, the middle image shows the global view with the elevations, and the image at the bottom is a more detailed zoomed in view in two dimensions (2D).

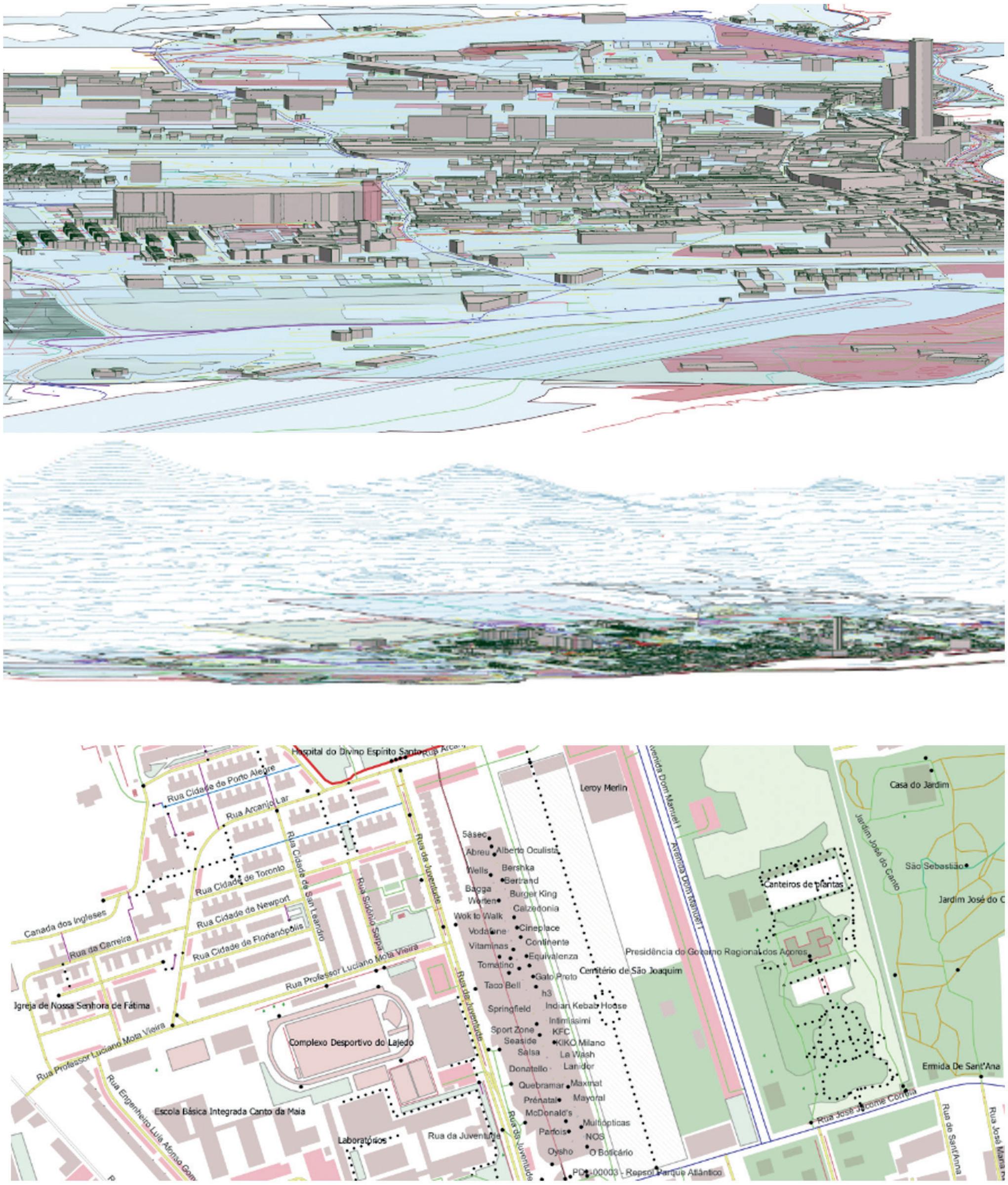

Figure 4 – Views taken from the Digital Model of a city.
Source: prepared using QGIS (2024), Qgis2threeJS (Akagi, 2024), OSM (2024) and SRTM (NASA, 2024d).

Digital models have significant advantages because they make it possible to dematerialise the characteristics of objects of interest by combining different data sources, improving the information used for decision making. They can also be used to calculate geographical information for scenarios used in exercises or real operations.

3.4.2. Risk Analysis

Scientific indexes can be used to monitor soil properties (such as soil moisture) over time through satellite images. The Copernicus Browser (ESA, 2024a) makes it possible to browse images from Copernicus satellites by area of interest, cloud coverage, time range, satellite and index.

In this CS, an area of interest was selected and the Normalised Difference Water Index (NDWI)[9] (Sentinelhub, 2024) was drawn for that area.

In Figure 5, the top image shows the Copernicus Browser interface and the selected parameters. The image is then transferred to the GIS, where the bands can be filtered according to parameters to analyse soil water content (this is usually done after a certain number of days without precipitation) and detect water bodies (after applying the index scale).

Figure 5 – Risk Analysis.
Source: prepared from Copernicus Browser (ESA, 2024a), QGIS (2024), OSM (2024).

[Cloud coverage | Date | Satellite | Index | Area]

9 The normalised difference water index (NWDI) is used to map soil water content.

In this case, the pixels (squares) at the bottom of the image may indicate the presence of water in the soil. While this does not necessarily imply that there are water leaks (the soil may have been watered or rain may have fallen recently), the situation should be assessed through direct observation.

3.4.3. Mission Planning and Simulation

To provide situational awareness of a given area, satellite data uploaded to a GIS application can show several layers of information and even movement.

Figure 6 contains a view of the mission plan of an OGS-42 UAS from the Portuguese Air Force conducting RF surveillance. The image shows the aircraft's planned route (red line), the RF (smoke) and burned areas in different years (yellow and grey areas) (Páscoa & Morgado, 2023).

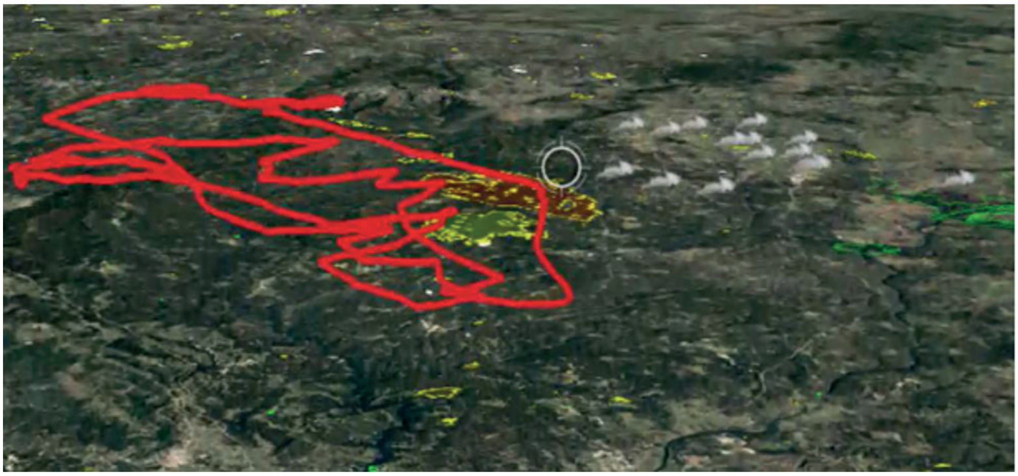

Figure 6 – Planning and simulation of a UAS flight
Source: Páscoa & Morgado (2023) using Google Earth (Google, 2024a).

In this case, an animation can be created showing the flight paths from different angles to simulate, for example, if a position on the ground is visible from the aircraft.

3.4.4. Target Detection

The Sentinel-1 satellite has a sensor that can detect radar signals which are not affected by meteorological conditions, including cloud coverage. The images at the top of Figure 7 show the difference between an optical image from Sentinel-2 (left) and a radar image from Sentinel-1 (right). In this view, the images obtained from each sensor can be compared using Google Earth Engine (GEE) (Google, 2024b).

Radar technology is also able to detect surface targets that would not be visible without ISR capabilities, such as the ships detected in Figure 7 (middle and bottom images).

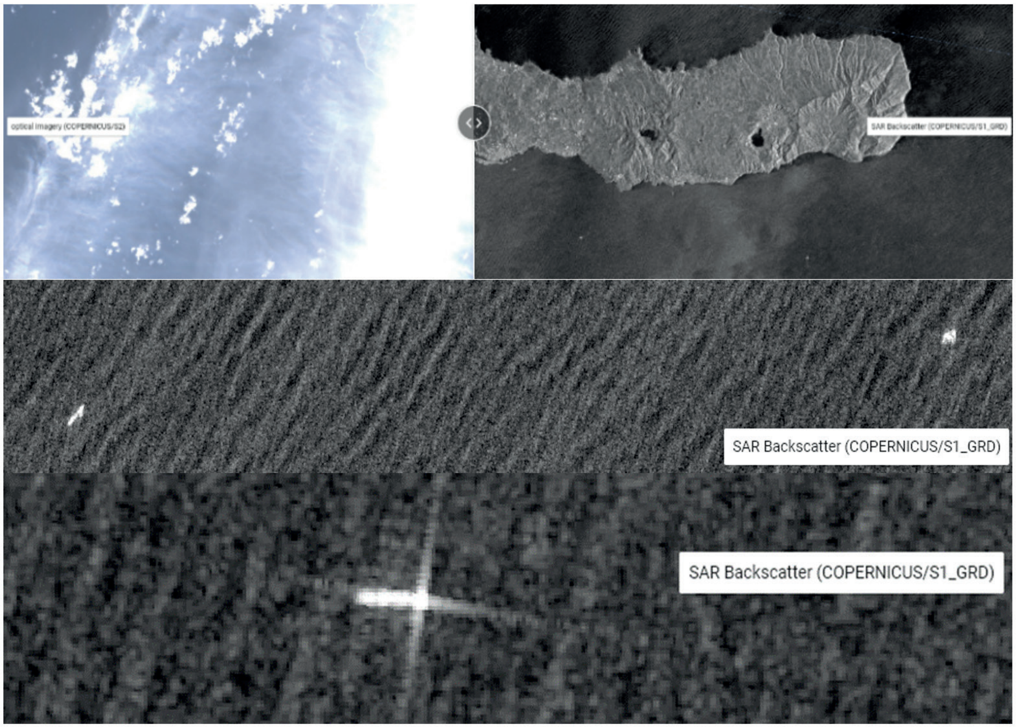

Figure 7 – Target detection using Sentinel-1 SAR backscatter.
Source: prepared from the algorithm run on GEE (Google, 2024b).

3.4.5. Disaster Analysis, RF

When planning territorial surveillance activities to monitor RF, knowing how the fire evolved and how the area was affected is important for designing UAS operations, for example.

This topic contains two examples. The first shows how satellites can be used to obtain information on the burned area and on how the fire evolved, using the Serra da Estrela fire in 2022 as the CS. The CS in the second example is of a fire in Cinfães, in which the UAS collected data on the fire, which are compared with the information obtained from the satellite.

In the first case, Figure 8 shows: (top left image) the area of interest selected for the study; (top centre) the results after applying a JAVA script algorithm (adapted from UN-Spider) (UN, 2024) that runs on GEE (Google, 2024b), using pre- and post-event images from the Sentinel-2 Satellite to draw the Normalised Burn Ratio (NBR) index (UN, n.d.; Keeley, 2009) before and after the event. Next, the difference between the two is calculated to determine the dNBR, which shows the severity of the burned area according to the scale proposed by the United States Geological Survey (USGS) and the colours proposed by UN Spider (UN, n.d.), which can be seen in the centre left of the figure, where the areas that were most affected by the fire are shown in purple.

The top right image is a reconstruction of the fire's evolution (Páscoa & Morgado, 2023) generated using satellite data, showing the total burned area and the date and time the fires were detected by the Suomi NPP and NOAA-20 satellites using the Visible Infrared Imager-Radiometer Suite (VIIRS) (NASA, 2024e) and Moderate Resolution Imaging Spectroradiometer (MODIS) (NASA, 2024f) instruments.

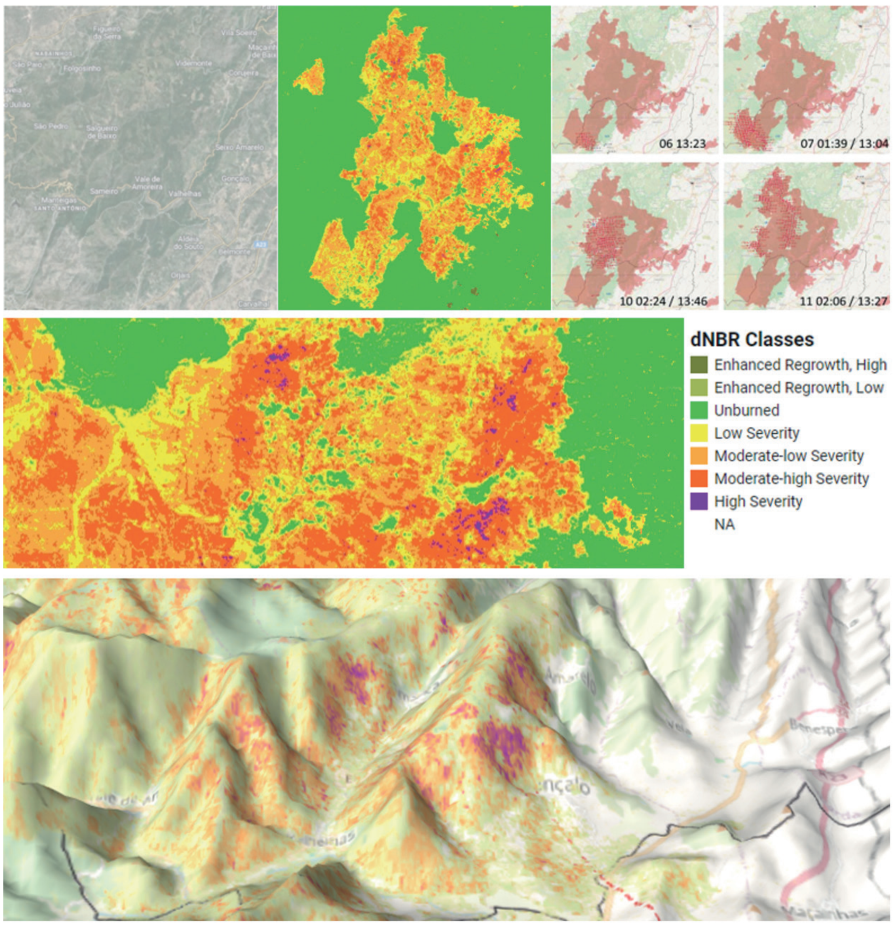

Figure 8 – Analysis of the evolution and effects of RF (example 1).
Source: (top left and centre images and middle image) prepared using the algorithm adapted from UN-Spider (UN, 2024), scripted in GEE (Google, 2024b); (top right image) Páscoa and Morgado (2023); (bottom image) prepared using QGIS (2024), OSM (2024), qgis2threeJS (Akagi, 2024) e SRTM (NASA, 2024d).

The link between this algorithm and the terrain and the GIS features shown in the bottom image of Figure 8 are obtained by exporting the image from the GEE and importing it into QGIS, after which the SRTM elevation model is transferred from OSM (2024) and visualised in 3D using Qgis2threeJS (Akagi, 2024). This way, it is possible to obtain the position of the most severely affected areas on the ground and in 3D.

The second example describes how the Portuguese Air Force captured images of an RF near Cinfães in 2018 using the electro optical and infrared sensors mounted on the OGS 42 UAS.

The top images of Figure 9 show a view of the RF captured by the electro optical sensor (left), the infrared sensor (centre) and the QGIS visualisation (right) (2024) using Qgis2threeJS (Akagi, 2024), the SRTM and the NBR (UN, n.d.; Keeley, 2009). The severity of the effects of the RF on the ground can be determined by comparing the images captured by the UAS OGS 42 and the NBR index calculated from the satellite (the arrow in the right image indicates the NBR colour scale).

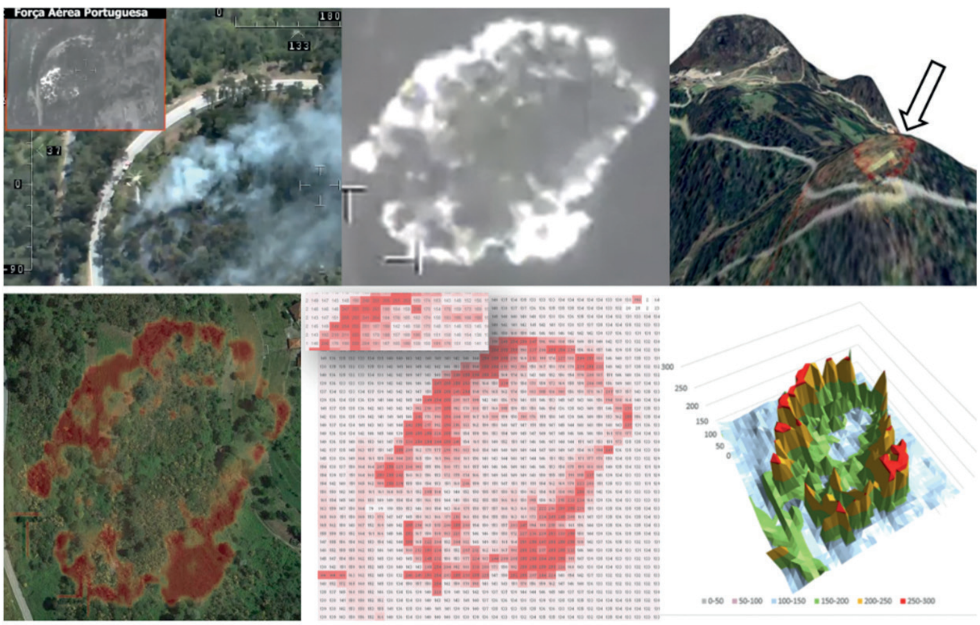

Figure 9 – View of a RF captured by the Portuguese Air Force UAS, with 3D ground position.
Source: Portuguese Air Force (2018), digital models prepared using QGIS (2024), qgis2threeJS (Akagi, 2024) and the SRTM (NASA, 2024d).

Figure 9 contains: (bottom left), the georeferenced image of the RF imported into the GIS, with a resolution of 10 metres (each pixel represents a square of 10 metres); (bottom centre) the intensity of the RF captured by the infrared sensor, digitally represented using the RGB (red, green, blue) colour scale; (bottom right) the 3D digital model in which the colour scale represents the intensity of the RF.

3.4.6. Disaster Analysis, floods

Analysing the impact of floods is essential to predict the effects of climatological phenomena. The following example describes the floods that occurred in São Miguel, Azores, in January 2022. The state of the object of interest before and after the event can be compared using satellite observation. In terms of operations planning, this is useful to assign priorities to the areas where resources will be deployed (for example, according to the population density).

The process begins by creating a chart to determine the periods of above-normal precipitation, using historical data obtained from the Global Precipitation Measurement mission (NASA, 2024g). Other NASA applications, such as GIOVANNI (NASA Earth Data) (NASA, 2024h), can be used to defined the desired area, time frame and type of report.

After selecting the event in January 2022, the average rainfall value in millimetres per hour (mm/hh) is obtained for the desired period. In this case study, the rainfall from 18 to 20 January was analysed, as shown in the top left image of Figure 10.

A comprehensive analysis of the effects of precipitation on the area of interest can be performed. The effects shown in the top (centre and right) and middle images were obtained by adapting a JAVA script adapted from UN-Spider (UN, 2024) and run on GEE (Google, 2024b), using several layers of information taken from the Sentinel-1 satellite (ESA, 2024b).

By analysing the land coverage, it is possible to estimate the flooded area (2,303 hectares, in this example), compare the affected areas with the agricultural areas and estimate the agricultural area affected by the flood (118 hectares, in this example). Global data repositories can be consulted to estimate the number of affected people.

The result of this process can be converted into a georeferenced file, which can then be imported into a GIS application. The image at the bottom of Figure 10 shows the file after it has been imported into Google Earth (Google, 2024a). The application's features can be used to visualise the flooded locations.

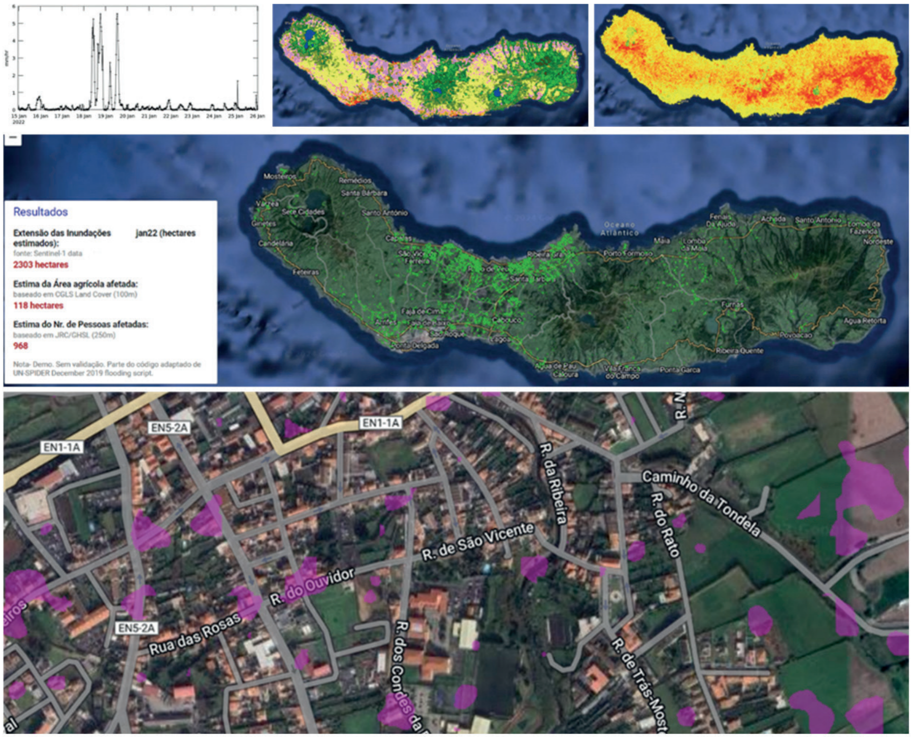

Figure 10 – Analysis of the agricultural area and population affected by the floods of January 2022.

Source: prepared from NASA Giovanni (2024), prepared from the algorithm adapted from UN-Spider (2024) run on GEE (Google, 2024b), Source: algorithm adapted from UN-Spider (2024), result imported into Google Earth (Google, 2024a).

3.5. Answer to the Research Question and Assessment of the Research Objective

The RQ included the following requirements: R.1 Identifying the areas of the operations cycle and space-based ISR services and products that can be used to improve decision making; R.2 Identifying and describing the applicable areas and concepts; and R.3 Identifying the OP associated with space activities and describing their roles.

Table 2 shows, for each space-based service, an analysis of its suitability for operations and intelligence (R.1); the associated concepts (R.2); their relationship with the skill areas and the skills and roles (R.3).

Table 2 – Answer to the Research Question.

Position and Category	Description / Roles
SATCOM (§ 3.1) and PNT (§ 3.2)	Provide a significant contribution to the success of air operations. However, given the threat level that these services face, alternative mechanisms are needed for communication, navigation and to obtain precision timing. This will require skills in the following areas: science and engineering, intelligence, operations, analysis and cyber effects. Analysis of Requirements: R.1 Applicable to intelligence and operations (SATCOM and PNT); R.2 Services provided by satellite communications, in the case of SATCOM, and by precision timing and navigation, in the case of PNT; R.3 **PNT**: PO1, PO3-5; PO7, PO12-14 (see "Position" column in Table 1); **SATCOM**: PO1, PO2, PO4, PO5; PO7, PO12-14.
SSA/SST (§ 3.3)	SST is essential to observe and monitor the movement of satellites in space and to prevent collisions between satellites and drifting objects. It also makes it possible to alert satellite operators about route changes to avoid collisions. As this capability is based on a range of different sensors (radar, laser, telescope), the intelligence area must know the location and path of satellites and the operations area must know what changes will be required to avoid the danger of a collision. Analysis of Requirements: R.1 Applicable to intelligence and operations; R.2 Collision prevention, re-entry analysis, fragmentation analysis, space navigation, satellite operation, space operations, science and engineering; R.3 PO1-14.
Creation of Digital Models (§ 3.4.1)	Digital models can be used to associate layers with a variety of data in a fully controlled model. GIS can also be used to: - interrogate the model and associate different types of areas of interest; - visualise the model in 2D and 3D with rotation; - perform logical operations on layers. Analysis of Requirements: R.1 Applicable to intelligence and operations; R.2 Digital model, Digital elevation model, Information layer, Relationship between layers, Logical operations on layers; R.3 PO1-2, PO4, PO6, PO8-12.
Risk Analysis (§ 3.4.2)	The use of space products and services provides situational awareness of areas of interest for aviation missions. The risk analysis focused on ground observation based on the NWDI index. Other types of analyses are possible, such as simulating flooding in areas of interest to operations. Analysis of Requirements: R.1 Applicable to intelligence and operations; R.2 Digital model, Digital elevation model, Information layer, Relationship between layers, Logical operations on layers, Scientific EO indexes; R.3 PO1-2, PO4, PO6, PO8-12.
Mission Planning and Simulation (§ 3.4.3)	Satellite data can be used during mission planning to obtain geographical data to support decision making, including: the position of assets of interest, range calculations based on distance or speed, the movements of the target of interest by simulating mission parameters and predicting results; visualising 3D coverage radiuses. Analysis of Requirements: R.1 Applicable to intelligence and operations; R.2 Digital model, Digital elevation model, Information layer, Relationship between layers, Logical operations on layers; R.3 PO1-2, PO4, PO6, PO8-12.

[Cont.]

Target Detection (§ 3.4.4)	Tracking and detecting targets is essential for planning operations. Therefore, satellites are useful to assess the status of sites or platforms of interest at all stages of the operations cycle. Analysis of Requirements: R.1 Applicable to intelligence and operations; R.2 Digital model, Digital elevation model, Information layer, Relationship between layers, Target tracking and detection; analysing the effect of aviation activities; R.3 PO1-2, PO4, PO6, PO8-12.
Analysis of disasters, rural fires (§ 3.4.5) and floods (§ 3.4.6)	Two examples of disasters (RF and Floods) were presented, which were used to: - interrogate the model and associate different types of areas of interest; - visualise the model in 2D and 3D with rotation; - use complementary data from different sources (in this case, satellites and UAS); - determine the level of severity of soil damage due to heat exposure; - use scientific indexes to generate useful intelligence for decision support. Analysis of Requirements: R.1 Applicable to intelligence and operations. R.2 Digital model, Digital elevation model, Information layer, Relationship between layers, Target tracking and detection; analysing the effect of aviation activities. R.3 PO1-2, PO4, PO6, PO8-12.

Table 3 summarises the assessment of the RQ requirements and shows the relationship between the requirements and the identified roles.

Table 3 – Relationship between skills and the "Space" capability components.

Position	**Area**	**Category**	**Relationship with intelligence and aviation operations**	**SATCOM**	**PNT**	**SSA+SST**	**ISR**					
							Creation of Digital Models	Risk Analysis	Mission Planning and Simulation	Target Detection	Analysis of the effects of Rural Fires	Analysis of the effects of Floods
					§ 3.2	**§ 3.3**	**§ 3.4.1**	**§ 3.4.2**	**§ 3.4.3**	**§ 3.4.4**	**§ 3.4.5**	**§ 3.4.6**
OP1	Science and Engineering	Civilian	x	x	x	x	x	x	x	x	x	x
OP2	Intelligence	Civilian	x	x		x	x	x	x	x	x	x
OP3	Space Operations	Civilian	x	x	x	x						
OP4	Information Technologies	Civilian	x	x	x	x	x	x	x	x	x	x
OP5	Cyber security analyst	Civilian	x	x	x	x						
OP6	Intelligence	Officer	x			x	x	x	x	x	x	x

[Cont.]

OP7	Cyber Effects Operation	Officer	x	x	x	x						
PO8	Target Analyst	Officer	x			x	x	x	x	x	x	x
PO9	Information Sources Analyst	Sergeant	x			x	x	x	x	x	x	x
PO10	Intelligence Analyst	Sergeant	x			x	x	x	x	x	x	x
PO11	Geospatial Intelligence Analyst	Sergeant	**x**			**x**	**x**	**x**	**x**	**x**	**x**	**x**
PO12	Signals Analyst (Intelligence)	Sergeant	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
PO13	Space systems operator	Sergeant	**x**	**x**	**x**	**x**						
PO14	Space operations operator	Sergeant	**x**	**x**	**x**	**x**						

Source: adapted from USSF (2024b).

Given the information presented in the previous sections and in the assessment of the requirements, the answer to the RQ is that space already provides a vital contribution to aviation intelligence and operations, enabling precision satellite communications, positioning and navigation, which will be further developed in the various areas with the provision of SSA and ISR products and services. This will require the skills and roles identified in Table 2 and described in Table 1.

Therefore, the RO has been accomplished, not only by describing but also by demonstrating the usefulness of current services and products and their relationship to the required skills and roles.

4. Conclusions

This investigation used the Case Study methodology to accomplish the RO and answer the RQ by identifying solutions to obtain Earth observation data from satellites and establishing the relationship between space and aviation operations and OPs.

The most important moments in each stage are described below:

– In the first stage, the concepts used the study were identified, specific requirements were defined and the research plan was outlined;

– In the second stage, a literature review was performed to obtain information on the products captured by the satellites and on space skills. The six CS were designed during this stage;

– The third stage consisted of analysing the information and defining the roles of each OP, and developing / adapting the software to the context of the Portuguese Air Force. The six CS were analysed and prepared, and a demonstration was made of how they can be used in the context of aviation / space operations / intelligence fusion;

– In the fourth stage, the research findings were analysed and assessed in relation to the requirements. This scientific article was elaborate to disseminate the research findings and conclusions, the study's contribution to scientific knowledge and suggestions for future activities.

This article presented the main strategies for space and space-based services and products with regards to the SATCOM, PNT, SSA/SST and ISR components, and identified six CS that provided relevant information for aviation operations, which will require intelligence related skills and skills in other critical areas to be fully integrated and used by the PoAF. The skills associated with the Space capability were identified and their relationship to the roles was established using the CS as a starting point. The study revealed that space can provide a vital contribution to aviation operations. Therefore, it should be integrated with the intelligence cycle.

The answer to the RQ is that space services and products already provide an important contribution to intelligence and aviation operations, enabling communications and precision satellite positioning and navigation, which will be further developed with the provision of SSA and ISR products and services to the relevant areas. This will require the skills identified in Table 3 (the respective roles are described in Table 1).

The study's main contributions to knowledge resulted from the analysis of the CS, in which examples were provided of how space services and products can be integrated into the intelligence analysis and air operations cycles of the Portuguese Air Force, and the positions and roles required to build the "Space" capability were identified.

With regard to future studies that may be carried out to build the Aerospace Force, it would be useful to identify the processes that will have to be developed to integrate the products of Intelligence, Operations and Space, and to provide a more comprehensive analysis of the relevant services and products.

To integrate Space into its operational product, the Portuguese Air Force can collaborate with partners that provide different skills and competencies. Accomplishing this goal is an opportunity to contribute to a future Aerospace Power within the Alliances and partnerships of which Portugal is a member, and would be yet another contribution by the Portuguese Air Force to the transformation of military operations.

"High to the clouds his tow'ring head was rear'd,
New worlds, and nations fierce, and strange, appear'd;"

The Lusiads - Canto IV, Luís de Camões, 1572 [10]

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[10] Open source translation retrieved from: https://www.gutenberg.org/files/32528/32528-h/32528-h.htm

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