FROM THE MAN ON THE MOON, TO SPACE FOR THE MANKIND:

A technological innovation system analysis of how the Copernicus earth observation infrastructure leveraged new applications in the Dutch water management sector

Master's Thesis – Innovation Sciences

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Summary

Ever-increasing challenges are pressing our society, which requires drastic solutions. The Copernicus Programme is an earth observation infrastructure developed by the European Space Agency (ESA) and the European Commission (EC) to provide solutions to such global threats through delivering environmental data, while simultaneously contributing to the European economy by opening up downstream business opportunities and job creation. As one of the most significant impacted areas of climate change, the water sector has highly promising potential to leverage on the Copernicus data and its data-derived applications. The Netherlands is one of the most active in applying the technological promises of Copernicus in the water sector. Nevertheless, the program is facing major challenges to exploit the potential of its earth observation infrastructure. This study therefore aims to identify the success factors and blocking mechanisms that stimulate or hamper the diffusion of the Copernicus applications in the Netherlands.

To answer this research question, a qualitative case study has been conducted. Data from desk research and interviews were analyzed through a coding process. Information on the performance of the program and relevant policies were gathered through abductive reasoning, whereby we draw from theoretical insights while allowing for interpretation. In this approach, the Technological Innovation System (TIS) was used, which is a framework to assess the structure and dynamics of a technology, along with insights from innovation policy studies.

The results of this study suggest a strong shift in innovation policies that have led to the current performance of the Copernicus program. Currently, governmental policies are aiming to develop a strong space infrastructure, open up downstream economic opportunities by leveraging on this infrastructure (i.e., the development of space-data derived applications), and addressing user needs in solving societal challenges. These can be characterized as moving towards a type-II Mission-oriented Innovation Policy (MIP) approach. However, the high dependency on governmental involvement and the limited legitimacy on the technology are blocking the diffusion of the Copernicus applications. Furthermore, the study identified several challenges innovation policies are facing in order to address these blocking mechanisms.

Based on the findings, the present study gives recommendations for the relevant mission-oriented innovation policies on the Copernicus and similar programs aiming to address large societal challenges. By combining insights from literature on innovation systems and MIP, the present novel approach was able to identify the challenges the Copernicus program is facing in order to achieve its ambitious goals.

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1 Introduction

Today, we are living in a world that is dealing with great environmental challenges. It is becoming increasingly apparent that climate change is causing pressing problems to our society (Seneviratne et al., 2012). In recent years, climate change has led to much policy attention, and large publicly funded programs are set up across countries to address these environmental challenges. So does the European Union (EU), who have devoted huge investments into the satellite-based earth observation infrastructure, called the Copernicus Programme. Via its infrastructure, the program aims to "… improve the management of the environment, understand and mitigate the effects of climate change, and ensure civil security" (ESA, n.d., p. 1), by collecting, storing and providing a vast amount of environmental data from satellites in space, complemented by sensors placed on the seas, land or in the air. The vast amount of Copernicus data is made publicly available and free-of-charge to all users, which include downstream businesses leveraging on this data to develop ready-to-use applications to public and private end-users. When appropriately applied, it is expected that the accessibility, accuracy, and timely characteristics of the data will drastically enhance our climate monitoring capacity, while stimulating downstream innovations that generate economic and societal value (Copernicus, n.d.-b).

The Copernicus program, despite its ambitious goals, faces major challenges. With total investments estimated at about EUR 8.2 billion from 2008 to 2020 (European Commission, 2019) and the importance of its above-mentioned visions, "it is crucial that it delivers according to the set expectations" (European Commission, 2016a, p. 1). It is anticipated to lead to a return of investments of up to ten times, while simultaneously mitigating the impact of climate change (Onoda & Young, 2017). However, the European Commission (2016b) stated in their Space strategy report that the full potential of Copernicus is far from materialized. This claim is substantiated by the recent market report from the European Commission (2019), indicating that the estimated user base of Copernicus data consists of only about 17% of the total potential users in Europe. Without successful diffusion of the technology in the downstream sector and industries, its potential cannot be utilized to fulfill its environmental and economic objectives. Therefore, this research aims to identify the factors and mechanisms that stimulate or hamper the diffusion of the Copernicus related application services and environmental support products (hereinafter the Copernicus applications). Doing so may help to address climate and societal challenges better while opening opportunities for economic activity.

One of the most prioritized application realms of the Copernicus program is the water management sector. Currently, we are facing the effects of climate change on water-related issues, and the repercussions of a disrupted water ecosystem on our society are immense. For example, in January 2020, Indonesia was experiencing one of the heaviest rainfalls ever witnessed, while Australia was battling one of the worst fire seasons due to extreme droughts (Diela & Widianto, 2020; Parson & Russel, 2020). In the Netherlands, research has shown that there is not only an increase of rainfall of more than 30% in the last 88 years, this rainfall also comes along with longer periods of droughts (Borst & Fonck, 2020). There is a need for proper water management to cope with such an increase in extreme water-related conditions. Copernicus has highly promising potential in this sector by providing key indicators that facilitate decision-makers in their work. The program offers six services (atmosphere, marine, land, climate, security, and emergency) tailored to different users' specific needs. Water-related issues are found in all six categories, making it among the topmost important areas under the Copernicus umbrella (European Commission, 2018).

This study focuses on the experience of downstream businesses in the Netherlands active in leveraging on, and translating the Copernicus data into real practical applications for public and private end-users in the water sector in and outside the Netherlands. The Netherlands, a country that has been dealing with water-related challenges for centuries due to its geographical conditions, has developed a vast amount of water management expertise. Climate change is ever more pressuring these challenges in the Netherlands, making it among the topmost agendas of Dutch policymakers (MER, 2020; Ministerie van Infrastructuur en Waterstaat, 2019). The Netherlands is therefore one of the most active in seeking to deploy the technological promises of Copernicus into the water sector (Simons & Droogers, 2016; Stowa, 2016). Given their considerable efforts, it is central to find out what opportunities and challenges the downstream businesses in the Netherlands face to deploy the Copernicus program in the water management sector. The experience of Dutch downstream businesses in the water management sector will be emblematic of the challenges and opportunities a large publicly funded program like Copernicus faces in a highly institutionalized conventional regime.

Innovation system theories argue that the success and failure of a technology are to a large extent determined by how the innovation system around the technology is shaped and functioning. To assess this for the case of the Copernicus program on the Dutch water management sector, this study adopts the technological innovation systems (TIS) framework, which can be defined as: "A dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology" (Carlsson & Stankiewicz, 1991, p. 93). The TIS framework, initially developed by Hekkert et al. (2007), can be used to define the system's structure and functioning and assess its performance to identify barriers in the industry creation process. This study incorporates the configuration of the actors, networks, institutions, and technologies as the structural elements in the following seven system functions: entrepreneurial activities, knowledge development, knowledge diffusion, guidance of the search, market formation, resource mobilization, and creation of legitimacy (Hekkert et al., 2007; Suurs, 2009). The understanding of the dynamics of this innovation system will thus help gain insights into the factors and mechanisms that stimulate or hamper the diffusion of the Copernicus applications in the water management sector.

In contrast to most conventional TIS studies, Copernicus has a different context. The focus of the program is increasingly shifting towards tackling grand societal challenges through its technology and the stimulation of new business applications and industries. Along with its large public investments, the program can therefore be associated with mission-oriented innovation policy (MIP) characteristics (Mazzucato & Robinson, 2018). It is argued that the TIS framework does not suffice in integrating such a mission-oriented perspective (Hekkert et al., 2020). As an attempt to fill this void, Hekkert et al. (2020) propose the mission-oriented innovation system concept in order to understand system-related dynamics in such goal-driven contexts. However, due to the novelty of this proposed concept, the relation between innovation system processes and the mission-oriented perspective is still underexplored. This study therefore embeds the TIS analysis from a mission-oriented perspective and contextualizes the case of Copernicus as a solution in search of a problem, based on Wanzenböck et al. (2020). This study assesses the effectiveness of the relevant mission-oriented innovation policies on the transformational system failures concept as proposed by Weber and Rohracher (2012).

Therefore, the overarching research aim of this study is to better understand the factors and mechanisms that are most crucial to the diffusion of application services and environmental support products based on the Copernicus infrastructure. This leads to the following general research question (RQ), followed by the sub-questions (SQ) of this study:

RQ: What are the success factors or blocking mechanisms that stimulate or hamper the diffusion of the Copernicus applications?

SQ1: How has the European earth observation program developed since its inception, and how have the relevant policy rationales shifted over time?

SQ2: How has the Copernicus TIS developed in the Dutch water management sector over time, especially in the most recent years?

SQ3: How effective are the current innovation policies on the diffusion of the Copernicus applications?

This study is conducted in collaboration with the dotSPACE foundation, a Dutch intermediary officially appointed by the European Commission to foster the uptake of the Copernicus applications. Answering the above-mentioned research questions gives insights into the current shaping and performance of the identified Copernicus TIS. Furthermore, this research helps to close the gap in innovation system studies concerning to bridge system-level functional analysis towards a mission-oriented perspective. This can be beneficial for businesses like dotSPACE and policymakers aiming to improve the diffusion of the Copernicus or other mission-oriented programs, and will add to the strand of literature on TIS aiming to integrate a mission-oriented perspective. The remainder of this study is structured as followed: First, the theories, their relatedness, and gaps are explained. Second, the methodology of the study is elaborated by explaining its design, case selection, data collection, operationalization, analysis, and quality assurance. Third, the results on the development, structural-functional analysis, and policies are given. Fourth, the answers to the research questions will be given in the conclusions. Finally, the theoretical and policy implications will be discussed, along with the limitations of this study.

2 Theoretical Review

This section will elaborate upon the different theories and concepts to be considered, complemented with their relevance for this study. First, the Technological Innovation Systems (TIS) theory is explained, along with its gaps for this study. To close this gap, literature on mission-oriented innovation policies (MIP) and the concept of transformational system failures will be elaborated upon.

2.1 Technological Innovation Systems

To define the concept of innovation systems, we should first understand the different individual components. In its modern sense, innovation was first mentioned by Schumpeter in the late 1920's, who argued that innovation is 'doing something different'. Over the years, many more definitions of innovation have been adapted and developed on this notion. In a literature study on innovation, Edison et al. (2013) analyzed over 40 different definitions of innovation. They considered the following, based on the definition of the Organisation for Economic Co-operation and Development (OECD), the most comprehensive: "innovation is production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and establishment of new management systems. It is both a process and an outcome" (Crossan & Apaydin, 2010, p. 1155).

A system is defined by Carlsson et al. (2002) as "a set of interrelated components working toward a common objective" (p. 234) and consist of components, relationships, and attributes. Components are the operating parts of a system, such as actors and organizations, formal and informal institutions, and artifacts. The relationships are the links between these components and influence the system as a whole. Finally, the attributes are the component's properties and their relationships, and characterize the system (Carlsson et al., 2002).

Studying innovation in the context of systems has gotten much attention since the concept of innovation systems (IS) was first introduced by Freeman and Lundvall in the 1980's and stems from the notion that innovation does not take place in isolation, but as a part of a broader context (Freeman, 1995; Lundvall, 1988; Nelson & Winter, 1977). Early literature is mainly focused on national innovation systems (NIS), whereby the system's boundaries are delineated within a country (Lundvall, 1988). Later, the literature advanced by successfully applying the theory to regional, local, sectoral and technological level (Carlsson et al., 2002). The latter has become popular among scholars and often used to explain the nature and rate of technological change, without restricting its boundaries on a certain geographical area. Instead, it focuses on a specific technology and its context.

This concept of a technological system was first defined by Carlsson and Stankiewicz (1991) as "a network of agents interacting in a specific economic/industrial area ... and involved in the generation, diffusion, and utilization of technology" (p. 111). In their study, they argue that a technological system differs from other ISs since it is (1) focused on a specific techno-industrial area, (2) not limited to national boundaries, (3) and explicitly focusing on microeconomic aspects. Hekkert et al. (2007) complemented this line of research by stating the importance of system functions to gain insights into the dynamics system's structural elements. This study will use this analytical approach to understand the structure and mechanisms that stimulate or hamper the diffusion of the Copernicus Programme within the water management sector in the Netherlands from a Technological Innovation System (TIS) perspective.

2.1.1 TIS delineation, structure, and functions

Indeed, a TIS is focused around a specific technology and cuts through the geographical and sectoral dimensions (Hekkert et al., 2007). The delineation, and following identification of structural and functional elements, is therefore not always a straightforward process (Bergek et al., 2008). Although a TIS is neither abstract nor objectively identifiable in terms of its delineation (Markard et al., 2015), Bergek et al. (2008) propose three types of choices that need consideration to delineate a TIS. The first is the choice of the technology or knowledge field. Once this decision is made, it is important to choose the depth and breadth of the study. This delineation determines the range of applications the technology or knowledge field is relevant. A broad range of aggregation helps to get a broad picture of the system, while a more specific scope can reveal more details. This scope dictates which actors, networks, and institutions will be analyzed. Finally, the TIS may also have a spatial focus to capture the most relevant aspects in a regional context. A TIS should however not be limited to such a spatial delineation, because a TIS cannot be understood and assessed without a global context (Bergek et al., 2008).

The structure of the TIS consist of the most basic static elements in the system, meaning that these are relatively stable over time. It does, however, not mean these elements are not subject to change. Especially in the formative stage of this innovation system, the structural elements are expected to change, but this is relative slow and guided by the system's non-static functions (Suurs, 2009). Although there is some ambiguity in the literature concerning the different structural elements, their variances are rather semantic than content-wise. Drawing on differences in conceptualizations, we can distinguish three structural elements that form the structure of the technological system; actors and networks, institutions and technology (Bergek et al., 2008, 2015; Hekkert et al., 2007; Jacobsson & Johnson, 2000; Suurs, 2009). Table 1 gives an overview of the structural elements and their definitions.

The actors consist of all actors involved in the innovation process, either direct (e.g., developer or adopter of the technology) or indirect (e.g., enabler, regulator, financer). They generate, diffuse, and utilize the technology through their choices, actions, and networks. Therefore, the build-up of the technological system depends on their presence, skills, and willingness to take action (Suurs, 2009). Based on their role in the process, Wieczorek and Hekkert (2012) defined different categories of actors; *Civil society, companies, knowledge institutes, government, NGO's,* and *other parties*.

The second structural element are institutions and can be defined as 'the rules of the game', or more formally as "the humanly devised constraints that structure political, economic and social interaction" (North, 1991, p. 97). They consist of informal/soft (e.g., customs or traditions) and formal/hard (e.g., laws or copyright) 'rules'. The former are extremely important for the initial development of the system to guide the first steps of the development of the technology. The latter are of crucial importance for intervention in the system through, for example, incentive schemes or subsidy instruments (Suurs, 2009). In the structural analysis, main focus will be on the formal institutions in place, since informal institutions are impossible to map systematically (Hekkert et al., 2011). As argued, informal institutions are of major importance as well. Therefore, attention will be given to this in the functional analysis.

Third, the technology is an often neglected element in TIS literature on the structural elements (Suurs, 2009). Since the TIS approach has emerged from innovation system studies with a geographical focus (i.e., national and regional innovation systems), technological change is often considered as an outcome of the system. The technological artifacts and its workings are, however, of crucial importance of the development to the system. If the technology does not perform well, the system may stop developing (Suurs, 2009). Furthermore, the technological capabilities enable and constrains the actions of the actors in the system. This study will therefore incorporate the technological element in the structural conceptualization.

Structural Dimension	**Definition**
Actors and networks	All involved actors in the development of the technology. Actor categories contain civil society, companies, knowledge institutes, governments, NGO's, and other parties (e.g. legal, financial, consultancy, and broker organizations). Linkages between actors and actor groups may occur. If these are dense enough, we speak of a network. Networks are crucial for the dissemination of knowledge.
Institutions	Humanly devised rules (formal and informal) that structure political, economic and social interactions. • Formal/hard: rules, laws, regulations, instructions • Informal/soft: customs, common habits, routines, established practices, traditions, ways of conduct, norms, expectations
Technology	All technological artefacts and infrastructure that form the focal of the TIS. As well as the techno-economic working of these artefacts, such as reliability, safety, and costs. These are of crucial importance for the understanding of technological change.

Table 1 - Structure of the technological innovation system. Adapted from: (Hekkert et al., 2007; Suurs, 2009)

Although the structural analysis of a TIS will give a comprehensive overview of all the static elements within the system, this is not sufficient to understand the determinants of change (Hekkert et al., 2007). To understand what happens within the system, the activities that take place within the system need to be mapped. Such activities, called 'functions', was first described by Johnson (2001). In recent literature, much work on this potential has been carried out, showing that these theories are still emerging. Today, a consensus seems to have emerged on the seven system functions proposed by Hekkert et al. (2007). These include entrepreneurial activities (F1), knowledge development (F2), knowledge diffusion (F3), guidance of the search (F4), market formation (F5), resource mobilization (F6), and guidance of the search (F7). Table 2 gives an overview of the different functions and its description adopted from Hekkert et al. (2007).

System functions	**Description**
F1. Entrepreneurial activities	At the core of any innovation system are the entrepreneurs. These risk takers perform the innovative commercial experiments, seeing and exploiting business opportunities.
F2. Knowledge development	Technology research and development (R&D) are prerequisites for innovation. R&D activities are often performed by researchers, but contributions from other actors are also possible.
F3. Knowledge diffusion	The typical organizational structure of an emergent innovation system is the knowledge network, primarily facilitating information exchange.
F4. Guidance of the search	This system function represents the selection process that is necessary to facilitate a convergence in development, involving, for example, policy targets, outcomes of technical or economic studies and expectations about technological options.
F5. Market formation	New technologies often cannot outperform established ones. In order to stimulate innovation, it is necessary to facilitate the creation of (niche) markets, where new technologies have a possibility to grow.
F6. Resource mobilization	Financial, material and human factors are necessary inputs for all innovation system developments, e.g., investments by venture capitalists or governmental support programs.
F7. Guidance of the search	The emergence of a new technology often leads to resistance from established actors. In order for an innovation system to develop, actors need to raise a political lobby that counteracts this inertia, and supports the new technology

Table 2 - Functional elements in the technological innovation system. Adopted from: Hekkert et al. (2007)

The interplay between the structures and the functions within the TIS will determine the functioning of the system. As Hekkert et al. (2007) argue, a functional-structural analysis will give quite a good overview of what happens within the system. This will provide a more precise and complete basis for understanding factors that support or hamper the development of a technological system than solely focusing on structural or functional elements.

2.1.2 Cumulative causation and motors of innovation

As described above, the interplay between the structures and functions determine the development of the system. Besides, system functions do not operate in isolation either. Based on Myrdal’s (1957) work on cumulative causations, it is argued that system functions can influence each other and cause cumulative relations reinforcing each other (Suurs, 2009). For the advancement of a TIS development, positive interactions between system functions are considered essential (Jacobsson & Bergek, 2004). An example of such a cumulative causation could be the government allocating many resources in supportive programs to open opportunities for experimentation (F6). This allows for entrepreneurial activities seizing upon the resources and programs by the government (F1). This may lead to a better legitimacy among actors getting more familiar with the technology and willing to adapt it (F7). The improved legitimacy may positively impact the future of governmental resources, because a majority of citizens are optimistic about the technology and agree to allocate even more resources (F6). This simplified example shows how the positive fulfillment of one system function causes other system functions to reinforce and leads to a virtuous cycle. On the contrary, cumulative causation can also negatively influence and reinforce other system functions. In this case, instead of a virtuous cycle, a vicious cycle may occur whereby system function negatively reinforce each other and could lead to a breakdown of the system (Suurs, 2009). It is argued that especially in the formative stage of a TIS, feedback loops may appear that enforce vicious or virtuous cycles (Unruh, 2009).

Understanding how positive or negative feedback loops within an innovation system could occur provides a system-level explanation of why the TIS is developing as it is (Suurs, 2009). Furthermore, it provides insights into the role of different policy rationales on the system's performance and could show essential implications for future intervention strategies (Skott & Auerbach, 1995). In an attempt to generalize findings of above-described cumulative causations within TIS, Suurs (2009) identified several 'motors' of cumulative causation that appear as patterns around a sustainable technology in a formative stage. The following motors are identified: (1) *Science and Technology Push* Motor*,* which is driven by strong knowledge development and diffusion, supported by governmental resources and R&D programs. (2) *Entrepreneurial Motor,* also driven by strong knowledge creation and diffusion, but mainly driven by entrepreneurs and high legitimacy. (3) The *System Building Motor* is similar to the entrepreneurial motor, but instead of strong knowledge creation and diffusion, the entrepreneurs advocate for strong policies and regulations that benefit the technology. (4) *Market Motor* is driven by setting up strong institutional structures (guidance of the search) that directly facilitate a commercial demand for an emerging technology. Most other system functions benefit from these formal regulations and positively reinforce each other.

2.2 Mission-oriented Innovation Policies

The recent emerging grand societal challenges have led to a shift in innovation policy rationales. This shift entails that economic prosperity is no longer solely on the policymakers' agenda. The need to address these challenges is becoming of increasing importance (Boon & Edler, 2018; Mazzucato, 2016, 2018; Robinson & Mazzucato, 2019). These grand societal challenges include, among others, environmental threats, such as global warming and sea level rises, demographic threats, such as overpopulation and aging, or poverty in developing countries. These problems are often considered 'wicked', and defined as "complex, systemic, interconnected, and urgent, requiring insights from many perspectives" (Mazzucato, 2018, p. 803). In order to address these challenges, we can learn a lot from historical mission-oriented policies. Besides economic goals, historic mission-oriented policies were also targeting to achieve specific objectives. Kattel & Mazzucato (2018) define mission-oriented policies as an innovation rationale based on two pillars; (1) setting a purpose for public investments while simultaneously (2) creating conditions for new markets.

The difference between historic mission-oriented policies and more recent innovation policies focusing on addressing grand societal challenges is the degree of wickedness (Boon & Edler, 2018). In the past, missions were mainly related to clearly defined outcomes, such as 'the man on the moon', and mostly required clear technological challenges (i.e., space rocket that brought us to the moon) (Nelson, 1974). Nowadays, problems are much more wicked, because there is no clear outcome and the technological challenges are more complex (Robinson & Mazzucato, 2019). We can distinguish the two differences in the above mission-oriented innovation policy rationales as type-I and type-II, respectively. Besides the wickedness of the challenges and complexity of technological solutions, both innovation policy rationales also differ in their structure, such as vertical or horizontal decision-making and single or multiple financing sources. Table 3 gives a full overview of the differences, based on (Robinson & Mazzucato, 2019).

TYPE-1 Mission-Oriented Innovation Policy (MOIP) *Examples include defence and nuclear*	TYPE-2 Mission-Oriented Innovation Policy (MOIP) *Examples include environmental technologies and societal challenges*
Clear challenges with well-defined goals and specific objectives	Broad challenges with a complex mix of goals and objectives
Single source financing administered by a centralized authority	Multiple sources of financing stemming from a variety of innovation system actors
Centralized control within a government administration in clearly defined value chains.	Decentralized control with a large number of agents involved across many value chains and innovation ecosystems
The goals and the direction of technological development are defined in advance by a small group of experts.	The direction of technical change is influenced by a wide range of actors, including government, private firms and consumer groups.
Participation is limited to a small group of firms due to the emphasis on a small number of radical technologies.	Emphasis on the development of both radical and incremental innovations in order to permit a large number of firms to participate.
Diffusion of the results outside of the core of participants is of minor importance or actively discouraged.	Diffusion of the results is a central goal and is actively encouraged.
The mission is defined in terms of the number of technical achievements, with little regard to their economic feasibility.	The mission is defined in terms of economically feasible technical solutions to particular societal problems.
Self-contained projects with little need for complementary policies and scant attention paid to coherence.	Complementary policies vital for success and close attention paid to coherence with other goals.

Table 3 - Differences in policy rationes between type-I MIP and type-II MIP. From: Mazzucato (2019)

Although type-II policies are less focused on single technological solutions to solve certain clearly defined challenges, scholars and policymakers are still very much focused on the technological solutions to solve wicked societal challenges (Diercks et al., 2019). Therefore, Wanzenböck et al. (2020) criticize the fact that the framing and legitimacy of these challenges are often taken for granted. They state that different societal challenges require different types of solutions. Furthermore, the authors state that academics and policymakers have primarily focused on the range of technical solutions to solve these issues, instead of focusing on the nature of the challenges as well. Both too wicked problems and solutions may affect the effectiveness of mission-oriented policies. The authors defined a problem-solution space with the following four categories to contextualize missions and their related problems and solutions: (1) disorientation, (2) problem in search of a solution, (3) solution in search of a problem, (4) and alignment. Understanding where a case is located in this space can help to categorize the MIP better and align the solutions with the problems (Wanzenböck et al., 2020).

2.2.1 Transformational system failures

Although TIS can help understand the performance of a technology-specific innovation, it has not been contextualized in the challenge of strategic and goal-oriented system transformations (Hekkert et al., 2020; Weber & Rohracher, 2012). More precise, the TIS framework, and most empirical analyses, are centered on specific emerging technologies and do not fully capture the dynamics of transformative change of existing systems, which is an important goal of MIP. To move away from such a firm-level innovation framework and develop a more goal-oriented framework, Weber and Rohracher (2012) propose four transformational system failures to be assessed by policymakers: directionality failure, demand articulation failure, policy coordination failure, and reflexivity failure.

Directionality failure aims to address issues regarding policies that are not just developed to generate innovations as efficient and effective as possible and generate economic returns, but also target a certain direction. To do so, technology-specific policies are necessary that favor the development of the technology in the right direction (Jacobsson & Bergek, 2011). These policies needs to happen on two levels. Externally, by absorbing requirements from outside the innovation system. Internally, by interpreting and negotiating such requirements. In essence, this is done by establishing collective coordination and shared future visions by all actors. Often, matters of power and agency come into play, such as actors or actor groups who are unwilling to adapt to the new technology. To overcome such difficulties and achieve a strong shared vision among actors, a portfolio needs to be implemented, consisting of soft (i.e., coordination and information), hard (i.e., regulations and standards), and funding policies (Weber & Rohracher, 2012).

Demand articulation failure reflects a weakness in the identification of user needs. Novel solutions are commonly too centered on the technologies itself and lack the usability for their practical end-users. This limits the market uptake by users and consumers, which is often crucial after the TIS development phase (Weber & Rohracher, 2012). Close cooperation with end-users is therefore crucial in this process. Makerspaces, whereby end-users have direct access to the experimentation process (Svensson & Hartmann, 2018), or user-led open innovation (Hienerth, 2006) are examples of instruments in which the active role of users is proven successful for the diffusion and end-users' acceptance. Finally, government and public agencies can use procurement policies and act as prime users to stimulate technological advancements from a demand side (Weber & Rohracher, 2012).

The policy coordination failure concept relates to the functioning of the policies on multiple levels and directions. Both vertical and horizontal policy coordination failures may exist. Vertical coordination failure refers to the malfunctioning between agencies varying in different layers of the society, such as European, national, and regional. Horizontal coordination failure entails the coordination between various policy approaches, such as R&D and sectoral policies (OECD, 2005). Misalignment and a lack of coherence between public bodies on different levels and in different directions may hamper the technological development and the guidance of the direction. Additionally, private or public-private institutions may play an important role in developing clear standards and regulations in the field (Weber & Rohracher, 2012). Also, the sequence and timing of various policy approaches may have a strong impact on its success and the technological (Sartorius & Zundel, 2005).

Finally, reflexivity failure means to what extent a system is capable of monitoring its progress towards addressing transformative change and its missions (Weber & Rohracher, 2012). This ability is important for three reasons: (1) Being able to reflect is vital in the long-term discourses and directional change. By understanding the current situation, policies can be adapted or introduced to achieve the desired goals; (2) The ability to take into account the distributed nature of decision-making in order to develop the right policies accordingly; and (3) The ability to act flexibly in the sense that policy options need to be kept open to be able to adapt to most recent knowledge. According to Wanzenböck et al. (2020), high reflexivity is highly relevant in a situation of convergents solutions and divergent challenges. The next section will elaborate on the framing of Copernicus as such a solution in search of a problem from a mission-oriented perspective.

2.2.2 Copernicus from a mission-oriented perspective

Public space agencies, such as the National Aeronautics and Space Agency (NASA) and European Space Agency (ESA), are also challenged to approach relevant mission-oriented innovation policies due to the changing characteristics of the space sector and external influences. Robinson and Mazzucato (2019) identify both internal and external pressures that have led to more targeted innovation policies towards tackling grand challenges and bringing economic value. Internally, the space sector is subject to budgetary limits and faces pressure due to emerging space-faring nations and firms. This changing domain is referred to as 'new space'. Instead of low production activities and a focus on high reliability ('old-space'), new-space has an emphasis on high production rates and lower costs per unit. Externally, space is becoming more interconnected with different sectors and has to bring value outside the space domain. No longer space is solely meant for science and space exploration, it is getting more and more connected with different domains along the whole value chain (similar to industry 4.0, this is referred to as Space 4.0 (ESA, 2016)). This has led to an increased focus on downstream value-creation outside the space sector. Finally, there is greater pressure on space agencies to show its socio-economic value by responding to grand societal challenges.
In order to respond to these pressures and changing policy debate, one of the consequent flagship approaches under the ESA is the Copernicus Programme. "Copernicus is the European Union's revolutionary Earth Observation and Monitoring programme, looking at our planet and its environment for the ultimate benefit of all European citizens. Thanks to a variety of

technologies, from satellites in space to measurement systems on the ground, in the sea, and in the air, Copernicus delivers operational data and information services openly and freely in a wide range of application areas (European Commission, 2015c).” Doing so, it aims to provide solutions to various global threats, while simultaneously contributing to the European economy by opening up downstream business opportunities and job creation.

The societal challenges Copernicus aims to address are very broadly defined. The Copernicus program, through its earth observation infrastructure, promises to help address three main challenges: (1) Improve the management of earth natural resources and protect the environment. (2) Improve the safety, security, and quality of life from the European citizens, due to societal challenges. (3) Understand, mitigate, and adapt to the effects of climate change. Meanwhile, the six thematic application domains of the Copernicus are set up to specifically address essential information needed in the following areas: marine, land, atmosphere, climate change, security, and emergency. Although these areas are of major interest to the program, the challenges Copernicus aims to address are not limited to these application services and are widespread outside the space and earth observation domain (European Commission, 2015c).

Furthermore, besides the societal and economic impacts, Copernicus contributes to the excellence of the European industry in space, which is considered a highly strategic sector with strong growth potential. Instead of performing activities as single Member States, its collaborative efforts fully exploit the opportunities. This is also deemed important to act as a strong space actor and world leader. Copernicus has the capabilities to deliver independent and autonomous information to European decision-makers, which supports and strengthens the EU’s position in international negotiations. It also serves the European participation in global initiatives, such as the Global Earth Observation System of Systems.

The Copernicus infrastructure is based on many years of national and European research and development on earth observation. Once it became clear that earth observation had many more possibilities besides monitoring the earth, Copernicus was developed to address many societal issues. These societal problems are very wicked in their nature and Copernicus therefore does not have a single specific objective to begin with, besides developing the six thematic areas. The highly developed technological earth observation infrastructure, combined with the concrete expectations and long-term agreements, has much potential to address societal challenges. These challenges, however, remain highly wicked and broadly framed. This frames the program as a solution in search of a problem, as proposed by Wanzenböck et al. (2020).

To study the development of the Copernicus program from a mission-oriented perspective, this research adopts the notion of Mission-oriented Innovation Systems (MIS) as proposed by Hekkert et al. (2020) . The authors define MIS as "the network of agents and set of institutions that contribute to the development and diffusion of innovative solutions with the aim to define, pursue and complete a societal mission. While the development of the MIS framework is still underway, we could draw insights from the above described TIS and MIP literature. In order to overcome the limitations of the TIS, this study draws on the transformational system failures concept to assess the implications of the innovation policies in place.

3 Methodology

This section will elaborate on the methodology used in this study. First, the design of the research is explained. Followed by the case selection, the data collection, operationalization, and data analysis. Finally, the quality of the research is justified.

3.1 Research design

To study the development of the Copernicus program from a mission-oriented perspective using the above described theories, a qualitative case study has been conducted. This both serves to analytically assess the TIS and complementary frameworks and allows for more in-depth knowledge. This approach may reveal theoretical and empirical insights which would not appear from quantitative analysis otherwise. Abductive reasoning based on a case study is applied to find the best explanations from the observations (Bell et al., 2018). The next section will elaborate upon the selected case.

To answer the research questions, the research design follows several analytical steps. First, the development of the Copernicus Programme is studied in several phases from the perspective of mission-oriented policies. Second, the structure of the current system is analyzed (i.e. actors and networks, institutions, and technology). Then, a functional analysis is conducted looking at the different system functions. Finally, the study assessed the implications of the innovation policies in place and draws conclusions from it.

3.2 Case selection

Focusing on all aspects and all applications domains of the Copernicus Programme is not considered realistic to trace specific stimulating or blocking mechanisms. Therefore, this study focuses on a single sector to which Copernicus has high potential and prioritizes its development. One of the areas that is being impacted most by climate change is the water sector (United Nations, 2010). More specifically, the European Commission Head of Climate Adaption stated in the 'Copernicus For Water Management Workshop' that all elements with regard to the quality and quantity of water are potentially impacted by climate change (European Commission, 2018). For example, temperature rises intensify the global hydrological cycle, causing extreme variation in precipitation. This leads to both flooding hazards and risks of long periods of drought (EEA, 2007). Copernicus is therefore collecting data on various elements that give critical insights into the changing water ecosystem. These insights support decision-makers and water managers in their daily practices. More importantly, water-related indicators are included in all six thematic areas of Copernicus. This case will therefore not limit our view to a particular segmented service. It rather provides us the opportunity to understand the program in a comprehensive way, but still focusing on a specific application domain.

The Netherlands has been dealing with water-related issues for decades. Due to their geographical location, they are encountered to various challenges towards managing their water. About a third of its country is below sea level, while simultaneously they are at the deltas of two the major river systems, the Rhine and Meuse. These challenges have helped the Netherlands develop a vast amount of expertise in the management of water for centuries. Not only to protect themselves against flooding of rivers and sea, dealing with groundwater levels for agriculture, water quality, and water scarcity are also amongst the Dutch expertise (Lintsen, 2002). Climate change affects all these water-related topics, and the Netherlands is and increasingly will experience issues due to this, such as rising sea level, extreme rainfall or droughts and changes in water quality. This led to the fact that managing these water-related challenges is evermore among the topmost critical agendas of Dutch policymakers (MER, 2020; Ministerie van Infrastructuur en Waterstaat, 2019).

Copernicus can bring an enormous added value to decision-makers who need to understand and adapt to these changing environments. Furthermore, the Dutch expertise in water management can maximize the benefits of Copernicus by leveraging on its data and develop applications on it. Subsequently, water managers all around the globe dealing with these issues can use these applications. Finally, decades of experience and expertise has led to many existing institutional settings in the Netherlands, both formal and informal. It has developed regulations, standards, and many organizations to optimally manage the Dutch waters, such as the Dutch Water Framework Directive or the Water Act framework. Furthermore, the many years of experience have led to institutionalized ways of working among water managers and policymakers (Lintsen, 2002). The case of the water sector in the Netherlands therefore provides excellent context conditions to examine how a highly institutionalized conventional regime of public water management can stay as core resistance or be overcome by the Copernicus innovation.

Still, the Dutch water sector is very large, and Copernicus has limitless opportunities to provide relevant information in this sector. Therefore, to get more concrete in-depth insights, three specific focus areas are chosen to focus on. This focus does not limit the scope of the research, but rather provides a comprehensive understanding of the field. The following focus areas are considered the most relevant for this study given the differences but also the interrelation between them due to their very nature, the potential of the segment in deploying the Copernicus technology, and availability of data: (1) water-related risk mitigation, (2) agriculture and (3) water quality. Despite their differences in nature, which is mostly related to their practical purposes, they form strong linkages between them due to shared characteristics. They share similar resources, actors, networks, and technological capabilities from Copernicus. This makes it a comprehensive system to study.

Water-related risk mitigation is relevant considering the increases in extreme weather due to climate change, which causes urban flooding or extensive droughts. Copernicus has the potential in mitigating these risks, through better mapping and monitoring the earth’s water bodies (Services Copernicus Emergency, 2019). Agriculture can benefit from better water management using Copernicus data for irrigation and water resource management (Copernicus, n.d.-a). For example, it can serve farmers with the ability to measure soil moisture and groundwater levels to support managing their crops. Finally, Copernicus has shown its potential for water quality management due to its capabilities of measuring several variables helping to determine its quality, such as temperature, salinity, and oxygen (Copernicus Marine Service, n.d.). This potential can for example be relevant for assessing the quality of drinking water, bathing, or fishing.

In a geographical sense, the value-adding businesses for this case who are active in the three selected segments, are based and located in the Netherlands. Value-adding businesses refer to those downstream companies leveraging on the Copernicus data to develop ready-to-use applications for public and private end-users. These application services, along with their users, are deployed onto these segments in other regions of the world as well.

3.3 Data collection

To gain relevant insights into the research area, data was collected from multiple sources. Through extensive desk research, scientific literature, policy documents, market, and company reports were collected. This gives an understanding of the field's background, development of the program, policy rationales, and structural formation of the TIS. Several search engines were used to assess the literature, such as 'Google', Google Scholar', and 'Scopus'. Here, different search strings were used based on a set of the following keywords: *'Copernicus', 'Programme', Sentinel', 'GMES', 'ESA', 'European Commission', 'Earth observation', 'Satellite', 'Water', 'Management', 'quality', 'flooding', 'risk', 'agriculture', 'Netherlands', 'Market', 'End-users', 'Preferences', 'Behavior', 'Policy'* . In addition, synonyms, related words, and translations in Dutch were used.

Primary data was collected through seventeen interviews divided over policymakers, value-adding companies, end-users, and experts in the fields and segments. These interviews took the form of semi-structured interviews (Bryman, 2016). Interview guides with open-ended questions were prepared beforehand, which take into account the information the study seeks to collect based on the different relevant concepts . The open-ended structure allows to ask more in-depth questions based on relevant findings or interesting indications. The interview guides were tailored to specific actor categories and are prepared both in English (Appendix A) and in Dutch (Appendix B), based on the interviewee's native language. Along the way, the interview guides were further revisited when deemed necessary based upon new knowledge and the latest insights (Bryman, 2016).

Through the research visit at dotSPACE, the initial contacts for interviewees were found. As an innovation broker with a strong knowledge base of the water management sector, it has a comprehensive overview of the activities concerning the Copernicus program in the Netherlands. Additionally, snowball sampling was used to find other relevant actors. This was done until all actor groups were substantially represented, and data saturation had been reached. Table 4 gives an overview of all interviewees, their actor groups, and details about their expertise or company. Interviews were held online, using applications such as Zoom, Skype, and Microsoft Teams. Face-to-case interviews were not possible or discouraged due to the Covid-19 pandemic. Table 5 gives an overview of the collection methods related to the different concepts. The indicators defined in this table will be elaborated upon in the next section.

Interviewee Number	Interviewee category	Interviewee/company details
PM1	Policymaker	Working for an ESA initiative to stimulate the uptake of satellite-based environmental information in regional and global programs.
PM2	Policymaker	Head of user engagement within one of the Copernicus core services.
PM3	Policymaker	Two employees of the national space authority. One who is a delegate of Copernicus national user uptake initiatives. Second is a senior advisor on satellite applications.
VA4	Value-adding company	Dutch value-adding company focusing on drought in the Netherlands and Africa and mainly adding value through the development of models and algorithms on space data.
VA5	Value-adding company	Dutch company giving consultancy on water security (i.e., flooding, river management, climate change). Mostly active in the Netherlands, but also international.
VA6	Value-adding company	Dutch company creating user-driven products and giving consultancy in agriculture and water risk management. Mostly international customers.
VA7	Value-adding company	Dutch research and consultancy firm, combining scientific research with practical applications to address water issues, such as water for agriculture, water risk management, and water quality. Active on a global and national scale.
VA8	Value-adding company	Dutch company expert in the processing of space data for water management in agriculture. Pioneer in developing algorithm and models as a solution for complex water management issues on a national and global scale.
VA9	Value-adding company	Dutch company focusing on drought issues mainly within the Netherlands. Using their own ICT solution to add value to space data, but also developing products and offering consultancy directly to the end-user.
ES10	End-user	Pioneer in the usage of earth observation data in the Dutch water management. Founder of a consortium that promotes the use of space data in the sector. Also working for a Dutch water authority board.
ES11	End-user	End-user at one of the Dutch water authority boards. Working on monitoring various water-related issues (such as drought, flooding, and water levels)
ES12	End-user	Implementation specialist of space-based data at one of the Dutch water authority boards.
ES13	End-user	User of earth observation data at a large international engineer and project management company. The interviewee focusses on the usage of earth observation data to map out water-related issues at various projects.
EX14	Expert	Expert in remote sensing and the applications for end-users. Head of ESA BIC in the Netherlands for several years, currently mainly active in networking and increasing awareness of space data opportunities within end-users.
EX15	Expert	Expert in the application of remote sensing in water applications. Working at Dutch ministry, focusing on innovation issues. Currently performing a study towards institutional barriers for earth observation data in the water sector.
EX16	Expert	Professor in the field of spatial application for water management. Active in various projects and programs from ESA and EU in developing applications for soil- and water management.
EX17	Expert	Expert active at an international non-profit company mainly active in brokering between (potential) end-users, business and policymakers.

Table 4 - Overview of the interviewees and role and company details

3.4 Operationalization

In terms of operationalization, Table 5 serves as a guide to link the collected data to relevant theoretical concepts. Various indicators were defined based upon insights from the theoretical review presented in this study. This was done for each element in the design of this research, along with the relevant theoretical concepts: (1) the overall development of the Copernicus program and policy shifts, (2) structural analysis, (3) functional analysis and (4) transformational system failures. The presented indicators help identify theoretical concepts in the data from the desk study and interviews. This study is, however, not limited by the defined concepts and indicators. The abductive reasoning approach allows to draw our own conceptual indicators from the data as well. The next section will elaborate upon this analysis process.

3.5 Data analysis

All interviews were recorded upon consensus from the interviewees and the data was fully transcribed verbatim. Interviews were mostly held in Dutch. To allow non-Dutch people to read the transcripts and ensure triangulation, the transcripts were translated into English. To ensure consistency in the translation, a translation dictionary was set up to keep track of the most important concepts and terms and their English/Dutch translations. Furthermore, it served as a guide to keep the translating process as consistent as possible. Due to the extensiveness of the transcripts, they are not added to this document, but can be retrieved upon request. Interviewee names, company names, and other detailed personal information have been anonymized to ensure the privacy of the interviewees.

After transcribing the interviews, the data was analyzed in Nvivo using the coding process as described by Bryman (2016), in an abductive manner (Bell et al., 2018). That means that the data was analyzed in both an inductive and deductive way. Deductively, theoretical insights and indicators as shown in table 5 were used to guide the coding process. Inductively, grounded theory was applied by generating new codes with an open-minded view and analyzed to identify new relationships and indications that have not been laid out in the literature.

This process was systematically done using the following steps. First, as soon as possible after the transcription, marginal notes were made based on significant remarks and observations in the script. Second, based on the deductively defined code list, the conceptual labels (i.e., codes) were assigned accordingly to characterize relevant statements made in the interviews. The code list was extended along the way based on the predefined codes, but also any new ones identified bottom-up. The extended code list was continuously revised, refined and aggregated to arrive at a more consolidated code list. Third, we referred back to the theories to see how new codes, which emerged inductively from the analyzed data, related to the more deductively defined codes. The results were triangulated with the secondary data to validate the outcomes. This process helped to answer the sub-, and therefore also, the main research question(s).

Concepts		Indicators	Data collection method
Overall development of the Copernicus program and policy shifts		Events, challenges, objectives, decision-making, (complementary) policies, regulations, reports, radical/incremental innovation, range of actors, sources of financing	- Desk research
Structural analysis	- Actors and networks	Types of end-users in water management, value-adding service providers, consultants, policymakers, interaction of actors between segments	- Desk research - Interviews
	- Institutions	Formal rules (e.g., laws, regulations) Informal rules (e.g., habits, routines)	
	- Technology	Physical artifacts relating to Copernicus (e.g., sensors, satellites), intangible technological infrastructure (e.g., services, expertise)	
Functional analysis	F1. Entrepreneurial activities	Room for experimentation, presence of entrepreneurship, quality of entrepreneurship	- Interviews
	F2. Knowledge development	Availability of knowledge, knowledge sources, knowledge types	
	F3. Knowledge diffusion	Presence of knowledge diffusion, diffusion networks, leading networks	
	F4. Guidance of the search	Vision of the system (of different actor groups), supportive policies/programs, regulations	
	F5. Market formation	Market size, niche markets, institutional barriers/incentives, demand articulation	
	F6. Resource mobilization	Availability of resources, accessibility of resources, resource purposes (e.g. infrastructural investments, subsidies)	
	F7. Creation of legitimacy	Awareness of technological potential, resistance to change, legitimacy of investments, lobbying actors and coalition forming, trust in quality	
Transform-ational system failure	- Directionality failure	The shared visions of all involved actors, collective action and coordination, long-term agreements	- Interviews
	- Demand articulation failure	Cooperation with end-users, active actor involvement in governance processes, procurement policies, acting as (initial) end-user	
	- Policy coordination failure	Horizontal (e.g., between different policy approaches) and vertical (e.g., national, regional) policy coordination, private policymaking (e.g., setting of standards by businesses), sequence and timing of policies	
	- Reflexivity failure	Ability to monitor the performance on achieving transformational goals	

Table 5 - The concepts and indicators used in this study, along with the different data collection methods

3.6 Quality of the research

Although there is a lot of ambiguity about different criteria for assessing the quality of qualitative research, validity and reliability are often used to do so (Bryman, 2016). We will draw on this notion and use the work from Lecompte and Goetz (1982), who defined four criteria: (1) internal reliability, (2), external reliability, (3) internal validity, and (4) external validity.

Reliability is concerned with the degree to which research can be replicated (external) and the degree to which members of the research team agree on the observations and outcomes (internal). The replicability is assured by reporting on the research process in detail, especially on the data collection, coding, and analysis. This highlights the steps required that have led to the results and findings. Furthermore, the thesis is guided by the supervisor and evaluated by a second reader. This supports the process of the research and ensures the internal reliability by evaluating the observations and outcomes of the study.

Internal validity relates to whether the results of the study are consistent. This is depending on how credible the sources of literature are and the responses from interviewees. By mostly using first-order literature, such as papers published in credible journals and official policy documents, the quality of the desk study is assured. Furthermore, by assuring the interviewees' anonymity, there is minimal conflict of interest as interviewees expressed their views and explained their strategies. Finally, interviewees were selected upon their representative role in the system, their expertise, and independence on the outcomes of this study.

Finally, external validity refers to the generalizability of the findings to other social settings. Since this research particularly focuses on the water management in the Netherlands, it cannot be assumed that the results are easily generalizable to other settings as well. However, as argued earlier, water is a comprehensive sector of Copernicus since it is included in all thematic areas of the program and therefore represents the program very well. More specifically, it can also draw lessons or policy implications to other sectors and potential applications under the umbrella of Copernicus. Furthermore, Copernicus can be considered a very representative case to study other large and new publicly funded programs aiming to address grand challenges, due to its role as a flagship program in the modern mission-oriented policy approached from the European Union, European Commission, and ESA. Lastly, to contribute to external validity, the results were validated by both experts in the field and dotSPACE. Their insights gave an understanding of the findings' generalizability in other segments and sectors the Copernicus Programme has potential in.

4 Results

This chapter presents the results of the study. First, the development of how the Copernicus program came to existence and the underlying shift in policy rationales is elaborated upon. Second, the findings of the structural and functional analysis of the program are given. Third, implications on the relevant mission-oriented innovation policies on Copernicus are explained through the transformation system failures concept.

4.1 Development of the European earth observation program and the shifts in policy rationales

4.1.1 Founding phase (1975 – 1996): Building a strong European space sector and earth observation competence

When the 10 European states signed a convention in May 1975, it meant the establishment of the European Space Agency (ESA). This agency develops and implements a joint space program defined by all its 22 member states today. All member states participate in the mandatory program, which is mainly scientific research activities, but can also participate in optional programs, such as earth observation and navigation. Initially, the mandatory part represented the largest share of the program but is now limited to around 15% of the total budget.

In the following years, ESA achieved various successes in the field of space activities, such as the launch of the meteorological satellite Meteosat in 1977. Furthermore, ESA started to work on a European space policy in the 1980's and came up with 'a coherent, complete and balanced long-term European space plan' in 1985 to steer the European space program (ESA, 1985). Important aspects of this space program are to enable the European scientific community via the expansion of the scientific program, develop the further potential of space in the areas of telecommunication and meteorology, invest in earth observation science and applications via space and ground techniques and improve the competitiveness of the European industry in application areas by means of advanced developments of space systems and technology. So, the main goal of ESA was to improve the European space industry by advancing in technological development.

The European Community, forerunner of the European Union (EU) and eventually replaced in 1997, saw the need to play a more important role in the European space policies due to (1) the rise of the impact of space outside the sector; 'it will affect more and more the whole economic, industrial and cultural life of European society. (2) Europe had reached the state of commercial applications in a number of sectors, such as launch vehicles and telecommunication. (3) With the adoption of the single act in 1986, the Commission had acquired a wide range of competencies in research and technological development.

Furthermore, they argue that there have been great successes in the development of space technology, but 'there is still a need for a matching effort to encourage exploitation of the potential offered by these techniques' and for which ESA does not have the necessary resources (European Commission, 1988).

One of the main areas on which the European Community focuses is earth observation (European Commission, 1988). Although it was still in its infancy, they argue that it has great potential for economic, social, and strategic importance. Through the advancements made in the development of the earth observation technologies, such as Meteosat, SPOT (Satellite pour l'Observation de la Terre) and later ERS (European Remote Sensing), space-based applications are within Europe's grasp. However, these satellites' data supply was not matched by applications that were extensive enough for such systems to operate. While there had been some progress in weather forecasting, little use had been made of its practical potential. The European Community identified three factors that delayed and hampered the development of the application market. First, potential users were often unaware or poorly informed about possible applications and benefits of satellite data, except for certain major institutional and private end-users. Second, the methods, techniques, and equipment for data processing and interpretation were underdeveloped. The European initiatives to improve these were scattered, and the techniques were developed without concern for 'ruggedness, portability or cost-saving'. Therefore, there was a need for public support and better coordination of effort. Furthermore, the role of the value-adding sector, which offers processed and interpreted data in response to the needs of the end-users, is marked as important for the development of applications. However, the sector was relatively underdeveloped due to competition with public institutions and universities, doing exactly the same job. Third, the Community acknowledged the importance of guaranteed continuity of space data (in-orbit and in-situ) and stated the importance of technological advancements in sensor performance, acquisition times, and data frequency. In addition to these three factors, they acknowledged the importance of legislation, standardization, pricing policy, and international cooperation.

The Community realized that there was a need to address those factors affecting the development of application markets while simultaneously advancing the European space technologies. They tried to do so by establishing a stable application market via the following set of actions: (1) promoting European R&D on methods and techniques for processing and interpreting satellite data; (2) stepping up demonstrational applications (pilot projects), promoting feasibility studies and implementing operational systems in Europe; (3) training the end-users; (4) setting up European experimental facilities to prepare for the use of satellite data; (5) contributing to future space mission, based on the needs and requirements of users; (6) identify the necessary measures to support the emergence of a commercial value-adding sector; (7) and promoting common positions in international negotiations on problems relevant to the legal and economic environment for remote sensing.

In the late 80's and early 90's, Europe was mainly active in better coordinating the European space policy between different actors. In 1993 the European Commission (EC) set up the space advisory group, which involved officials from the Member states, ESA, and the Western EU (European Commission, 1993). Later, in 1996, the European Parliament requested the Commission to reinforce their coordination and cooperation with ESA and other relevant European organizations 'through the definition of a EU space industry policy' (European Commission, 1996a). Such a policy should be aimed at the promotion of applications and markets for European space technologies, particularly via the use of such technologies by national and European governments and in implementing common policies. These clear challenges and centralized control and financing therefore characterize the policy approaches in this phase as type-I mission-oriented innovation.

4.1.2 Initial phase (1996 – 2013): Exploring the downstream space market

In 1996, the Commission adopted a policy on the EU and space: *fostering applications, markets and industrial competitiveness* (European Commission, 1996b). It can be considered a shift in space policy from just R&D to a broader policy objective along the value-chain of upstream space technologies towards downstream applications. After the European space forum in 1995, there was a growing consensus about the importance of downstream space activities. While the Commission acknowledged the importance of the upstream space infrastructure and related activities, such as R&D, they stated that it was necessary to avoid a narrow concept of space industry by just looking at these elements (European Commission, 1996b). It is important to look beyond these technological capabilities and further down into the value-chain, because 'the services and user segment may make up more than ten times the value of the spacecrafts and launchers'. Furthermore, they stated that besides economic benefits, space applications could impact policy fields such as environment, agriculture and development aid. They stated that the EU can place space techniques in the right policy framework and may play a key role as a pioneer customer. In this communication, the Commission was also clear about the roles the different actors should have. Together with national space agencies, ESA should remain the most important actor in the development of the European technological base. The European Community needs to support the development of the market, pilot and demonstration projects, and methodological research. Finally, the downstream sector should be 'free to elaborate its strategy and choose a path'.

Although the investments and expected revenues of earth observation were only a margin of the total of space applications, the Commission recognized the potential of satellite data for earth observation and stated that there was a need for major European efforts to make it grow (European Commission, 1996b). They stated that the market was highly underdeveloped and that the EU plays a fundamental role developing these, since they were amongst the largest purchasers of data services to map and gather data from large and inaccessible areas of the earth. A 'two-step approach' was introduced to establish a self-sustaining market: first, the EU government developed applications based upon earth observation data, and acted as pioneer users of these applications. Then, once the market was consolidated, it would be the role of the private downstream sector to deliver the data services to the end-users on a commercial basis.

In the late 1990's, the EU began to develop and implement its two flagship programs: satellite navigation and earth observation. The latter, which we now refer to as Copernicus, was originally founded in 1998 when the EC, ESA, EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites), and national space agencies signed a manifesto for the development of a space-based environmental monitoring system. The then called Global Monitoring for Environment and Security (GMES) was endorsed by the EU and ESA in 2001 to gather, interpret, and use data and information to support sustainable development policies. In the decade to come, significant resources had been allocated to ensure guaranteed access to the relevant data for its goal to support sustainable development policies. This was mainly done via the long-term agreements on the continuity in EUTMESAT, ESA, and national space missions, as well as the agreements on the development of the Sentinel missions.

In the meantime, the space policy kept evolving and the first-ever Commission-ESA collaborative long-term space policy was set up in 2000 (European Commission, 2000). In this document, they were fully aware of the role space-based information can play for the economy, society, and politics. Furthermore, they acknowledge the fact that satellite systems and services create opportunities for revenues in these markets. It was stated that these revenues are generated through a complex interplay between the industry developing these space systems, the user equipment and service providers (which we now call value-adding services), and the policymakers who need these space tools for political purposes. They stated that such revenues should suggest that it is time for public authorities to reduce their role in the market. However, due to the 'strategic dimensions' and 'dual-use aspect of space', technology is not developed in a free market. This refers to the earlier mentioned approach, whereby space applications are both developed and used by public organizations, mainly for strategic reasons. Therefore, the role of the government was deemed essential and had to be continued. Nevertheless, it was stated that the industry and private sector should be stimulated to enhance the possibilities of a return on investment through public-private partnerships. To do so, and open up new markets, 'Europe must develop a way for the different actors to work together and seize opportunities'.

In 2003, however, when the Commission adopted a whitepaper on an action plan to implement European space policy, it was still argued that the potential benefits of space technologies could not be fully secured under the current institutional and budgetary arrangements (European Commission, 2003). The arrangements were still too much focused on R&D and not appropriate for an optimal exploitation of space assets. This led to the first

European space policy in 2007. Key strategies included the creation of standards by public authorities and increased participation by SMEs since they are crucial to innovation. (European Commission, 2007). When reviewing the current implementation of the European Space Policy in 2008, the Commission noted the need for an appropriate regulatory framework to develop innovative and competitive downstream services (European Commission, 2008).

The Copernicus infrastructure was rolled out in three stages. In the first two stages, the pre-operational (2008 - 2010) and initial operations stages (2011-2013), they launched the land monitoring, marine monitoring, and emergency response services. The latter was the first to become fully operational in 2012. These services used data from the contributing mission, because the first Sentinel would not be launched before 2014. In 2012, the name was changed from GMES to Copernicus, to pay homage to European astronomer who revolutionized the understanding of the earth. In this period of time, the space component was seen as 'the principal determinant of the EU to deliver its ambitions', because the space assets determine for a large part the services that may be delivered and account for the significant share of the costs of the system (European Commission, 2009). Nevertheless, the potential of downstream space applications was being acknowledged, and the development of a commercial market was stimulated via the two step-approach and better coordination of actors. This indicates the type-I MIP on achieving a successful earth observation infrastructure, together with strong policies on creating a market.

4.1.3 Bridging Phase (2013 – 2016): Envisioning space as a strategic driver for economic growth, innovation, and societal challenges

It was not before 2013 that the Commission adopted its first EU space industrial policy. The report, named *releasing the potential for economic growth in the space sector*, must ensure a central European political policy (European Commission, 2013). Space was mentioned as 'a driver for growth and innovation, and contributes directly to the objectives of the European 2020 strategy', the European long-term (2010-2020) strategy for smart, sustainable, and inclusive economic growth. More specifically, they stressed the role of space in; (1) addressing grand challenges, such as climate change; (2) provide the EU with strategic important knowledge; (3) stimulate innovation and competitiveness in and outside the space sector, and contribute to economic growth in almost all economic areas. The latter was mainly driven by the financial crisis of 2008 to 2012, and the fact that European space industry had to face increasing competition from emerging space powers such as China and India.

In the policy realm, earth observation was seen as an emerging market with high potential for growth and job creation and was highly important for the EU. The benefits of the fully operational Copernicus Programme through 2030 were estimated at 34.7 € billion, comparable to 0.2 % of the EU GDP. However, several barriers were mentioned that slow down the development of innovative applications and market development. These include the uncertainty regarding the availability of services and legal framework; lack of awareness of the possibilities among the possible users; lack of cooperation among the space and non-space sector; lack of cooperation among the value-chain of data provider; service developers and end-users; and the lack of support to the creation of start-ups and development of high-growth companies.

Based on this background, the Commission proposed five objectives and measures accordingly. First, the framework conditions needed to be improved via legislations, standards, the availability of skills, and access to the global market. Also, the should consider a free and open data access policy for the public. Second, the need to support R&D was stressed. The European space competitiveness needed to be improved via innovation policies, such as favoring space applications in policies, awareness-raising campaigns, and supporting SMEs in the downstream sector. Also, the importance of R&D in the advances of space technologies, and the need for a more extensive use of space data in the commercial, scientific and public domain were mentioned. Third, access to financial resources was stressed as important. Mainly the importance of the use of structural funds and innovative financial instruments to promote the development of innovative satellite-based services by SMEs was argued upon. Fourth, the need for a better use of a procurement policy was stated. To do so, they stressed the need for a long-term and clear planning of the institutional market, analyze the role of public procurement on the market, and, for the transition of the development phase and operational phase of Copernicus, early coordination was necessary. Fifth, a 'real European launcher policy is necessary', to become independent from other space-faring nations. Sixth, the Commission stressed the need for a space surveillance and tracking system to support national security interests.

When the Sentinel-1A was launched on 3 April 2014, the Copernicus Programme was fully operational. Sentinels 2A, 3A, and 1B were launched in 2016. In these years, the importance of space applications was acknowledged by the new President of the European Commission, and policy priorities were more and more shifted towards the two flagship programs Galileo and Copernicus (European Commission, 2014, 2015b). In order to release the full potential of Copernicus and Galileo for the European economy and citizens, the Commission presented a roadmap for the implementation of the (renewed) space strategy for Europe in 2015 (European Commission, 2015a). It stated that the Union will invest over 12 € billion in the years 2014-2020 and is expected to create a substantial return on investments through economic activities. Furthermore, the following strategies were stressed in the roadmap: First, the market implementation and uptake of the programs. While the developments of both programs were full-on track, with full capacity scheduled for around 2020, it was expected that both will have significant market opportunities in the downstream sector. However, to maximize the economic and societal benefits, 'it is necessary to ensure a robust market and user uptake of the two programs'. Furthermore, due to profound changes in the space sector (i.e. space 4.0), new opportunities for the private sector were arising. It was important that Europe is not missing out on these opportunities and encourages stronger participation of the private sector. To do so, they stated that 'it is important to identify and address existing obstacles to the functioning of the internal market in the area of space-based applications'. This phase marks the bridging between type-I and type-II MIP, whereby the potential of space on grand societal challenges was being acknowledge, but not yet fully acted upon.

4.1.4 Take-off phase (2016 – Now): Exploiting the opportunities of space based applications and services for the EU economy and towards addressing grand societal challenges.

In May 2016, the Council expressed their worries about the pace of the initiatives on the use of space data (Council of the European Union, 2016). It was stated that the wide potential of space data, services, and applications is technically proven, but not yet well-integrated in other policy domains besides space. Both the user and the market uptake are much smaller than expected based on the availability of resources. They concluded that 'the mere availability of data is not enough to unleash the envisaged socio-economic impact. Various barriers and challenges were identified, including legislative, technical, policy, organizational culture, security, and privacy and liability. The Council agreed that in addition to investments made in upstream space infrastructure, there also investments needed in downstream developments. This discussion's results have been a valuable input for the newest European Space policy, adopted in October 2016 (European Commission, 2016b).

Furthermore, a resolution from the European Parliament on the user uptake of the two flagship programs, adopted in June 2016, also emphasized the disappointing uptake of downstream applications and services (European Parliament, 2016). They stated that both public and private demand need to be stimulated and that obstacles to the optimal functioning of the market need to be overcome. Additionally, it stated that future developments should be user-oriented and driven by public, private, and scientific users' needs. It also acknowledged the fact that there are many actors involved, and underlines the need for better coordination and a simplified institutional landscape. Finally, the necessity of regional dimensions was mentioned, such as the increased involvement of regional and local authorities in implementing space policy.

The results of both the discussion and resolution can be seen in the space strategy for Europe, which had been adopted in October 2016 (European Commission, 2016b). It stated that due to the changing context of the global space sector (space 4.0), Europe needs to maximize its efforts to promote its position as a leader in space. To do so, one of the key strategic goals is to maximize the benefits of space for the society and the EU economy. It is argued that space technologies, data, and services are already indispensable in the daily lives of European citizens, but the potential has not yet been fully exploited. The space strategy adopts the objectives as proposed in the resolution on the user uptake and encourages the uptake of space services. Besides stimulating the uptake, the Commission also confirms its commitment to the program's stability and advancements in the technology, such as new services. These advancements should be user-driven and aim to promote the user uptake.

A year later, in October 2017, the Commission published its mid-term evaluation of the Copernicus Programme (European Commission, 2017). The data acquisition was seen as one of the most advanced elements of the system at that time. At the end of the first quarter of 2017, the Sentinel constellations already had five satellites orbiting the earth, complemented by contributing mission and in-situ observations. All the satellite data is being controlled, calibrated by in-situ data, and validated before publishing. Many users consider the space assets as one of the key aspects of the program. The six core services that are based on this high-quality data are also considered good by users. Next, the dissemination of Copernicus data was still seen as a weakness of the program. To respond to these issues, the Commission took action by launching the Data and Information Access Service (DIAS) in early 2018, which was expected to bring the user closer to the data. Finally, the user uptake had strongly increased due to the full, free and open data policy and numerous user-uptake initiatives, such as the Copericus Academy, Copernicus Masters and the Copernicus Accelerator. However, the mid-term review also showed the full potential was still not met. Especially sectors outside earth observation were not yet reached using current policies and need to be target more directly.

The above findings mark the shift in the innovation policies on the European earth program to, in short, focus on (1) serving the users who need information in order to improve the quality of life for the citizens of Europe, (2) simultaneously opening up possibilities for a downstream market to generate economic returns. Table 6 below presents an overview of the shift in the innovation policies over time. The development in recent years is considered very beneficial for monitoring and understanding the earth and address societal challenges. A recent report shows that Copernicus significantly contributes to addressing thirteen out of the seventeen sustainable development goals (United Nations Office for Outer Space Affairs, 2018). The above findings on the take-off from the technology also correspond with insights from the interviews. Due to developments in space technologies, such as advancements in sensors and imaging, "there is more and more access to data that we did not have before, which has a huge value for monitoring the earth" (PM2). Not only the technological superiority, also the free and open data policy is considered extremely valuable. One of the interviewees summarizes: "The specifications we get is so much better than it was before; the frequency is much higher, we have systematic radar, and on a global level. The fact that Copernicus has all this, with a free and open data policy, is a total game changer. Really opening up a whole range of avenues" (PM1).

Phase	Mission-oriented policies	Policy approaches
Founding phase (1975 – 1996)	Type-I mission-oriented innovation policies	• Collaborative scientific and technological advancement between member states • Investments in scientific and technological knowledge in, among others, earth observation • Improve European competitiveness • Need of public support and better coordination to create a market
Initial Phase (1996 – 2013)	Type-I mission-oriented innovation policies and market creation	• Upstream space investments are still of major importance • Acknowledges the downstream market opportunities and for societal benefits • Two-way step approach to create market: develop applications and act as pioneer user, then market should take over • Stimulate industry and private market through public-private partnerships
Bridging phase (2013 – 2016)	Type-I towards type-II mission-oriented innovation policies	• Space applications are seen as an important driver for the European long-term objectives (smart, sustainable and inclusive economic growth) • Focus on the two flagship program (Galileo and Copernicus), which aim to address grand societal challenges • Acknowledgement of the need for complementary policies such as legislation, standards and procurement policies • The need for a better integration with large policy programs such as Horizon2020
Take-off phase (2016 – Now)	Type-II mission-oriented innovation policies	• Measures to support and direct downstream space applications for the benefit of European citizens • Create and improve linkages between the downstream sector and end-users and exploit opportunities outside the space sector • Coordinate long-term space infrastructure based on a free and open data policy • Developments of the program are user-oriented and focused towards addressing grand societal challenges • Better coordination of broad range of actors involved; ESA, EC, Member States, Entrusted Entities

Table 6 – Shift in European innovation policies on earth observation

4.2 TIS structure of the take-off phase

As can be seen in the results of the development of the Copernicus program, the most dramatic shift towards type-II Mission-oriented Innovation Policy (MIP) is happening in the take-off phase (2016-now). In this period of time, it is Europe's key strategic priority to maximize the benefits of space of the economy and society. This shift is leading to many dynamics in the innovation system. This section will therefore focus on analyzing the TIS on the take-off phase. First, the system delineation and structural elements will be elaborated upon. Next, the functional performance of the TIS in the take-off phase will be assessed in section 4.3.

4.2.1 System delineation

Before we identify the structural elements that form the TIS, it is important to draw its boundaries. The focal of this study will be on the Copernicus program with a focus on Dutch downstream applications for water management (hereinafter the Copernicus TIS). Furthermore, three segments were identified to concentrate on specifically: (1) water-related risk-mitigation, (2) agriculture, and (3) water quality. This means that the boundary of the Copernicus TIS in this study focuses on the whole range of actors and networks, institutions, technologies, and system dynamics related to these three segments. More specifically, it focuses on Copernicus technologies used by actors in the Netherlands active in adding value to Copernicus data for applications and services in the three market segments of the water sector. It does, however, not limit our view on end-users inside the Netherlands, because many Dutch value-adding businesses specialize in developing application for end-users in high-potential foreign countries and regions. Especially large spread areas and regions with fewer local sensors for water management are targeted by the Dutch value-adding sector, such as Africa and South America. Furthermore, it includes policymakers on all levels of analysis (i.e., along the value-chain), international end-users active in the three water management segments, and other actors involved, such as intermediaries, research institutes, and experts. Lastly, it includes formal and informal institutions that concern all structural and functional elements related to this, ranging from the development of the technology to the application of products and services by end-users.

Although the three segments may serve different purposes and end-users, they share many characteristics. Value-adding businesses active in the field often do not specialize in one of the market segments. Instead, they have expertise in two or more work fields. This is due to many overlaps in the system. For example, Copernicus’ technology that is used to address issues in these segments is very homogenous (i.e., Sentinel 1 and 2), actors share expertise in often more than one of the segments, and end-users are often concerned with multiple objectives simultaneously (e.g. water managers need to be aware of the water quality to serve farmers with their agricultural needs). This has led to a high cross-segment dependence and interaction. Specifically, networks that have emerged go across the three segments, actors are involved in multiple segments, institutions relate to more than one segment, and the applications often serve more than one purpose. These findings showed the need to, instead of separating the segments into multiple sub-elements of the system (i.e., sub-TIS), incorporate all three segments into one TIS to capture all its interrelatedness and dynamics among them.

4.2.2 Actors and networks

This section gives an overview of the different actors involved within the Copernicus TIS, along with their networks. These can either be direct, such as businesses developing applications and services or end-users incorporating these in their processes. Alternatively the actors can be involved indirectly, whereby they merely serve as facilitators or enablers, such as policymakers or financial institutes. Overall, the take-off phase is showing a sharp increase of involved actors and networks. Each subsection below will elaborate on the actor category group, its networks, and their relation to the Copernicus technology.

4.2.2.1 Policymakers

Regarding the structure of the innovation system, the governance of Copernicus is clearly defined. The program's coordination and management are done by the European Commission, accompanied by the Copernicus Committee and Copernicus User Forum. The European Commission is responsible for all activities that concern the coordination and management of the technology and the downstream development. The Copernicus Committee and Copernicus User Forum meet several times a year to deliver input on the European Commission's agenda, upon which its directorate will make decisions.

The development of the space and in-situ component are governed by ESA, EUMETSAT, and the Member States. ESA and EUMETSAT are mainly responsible for the development of the

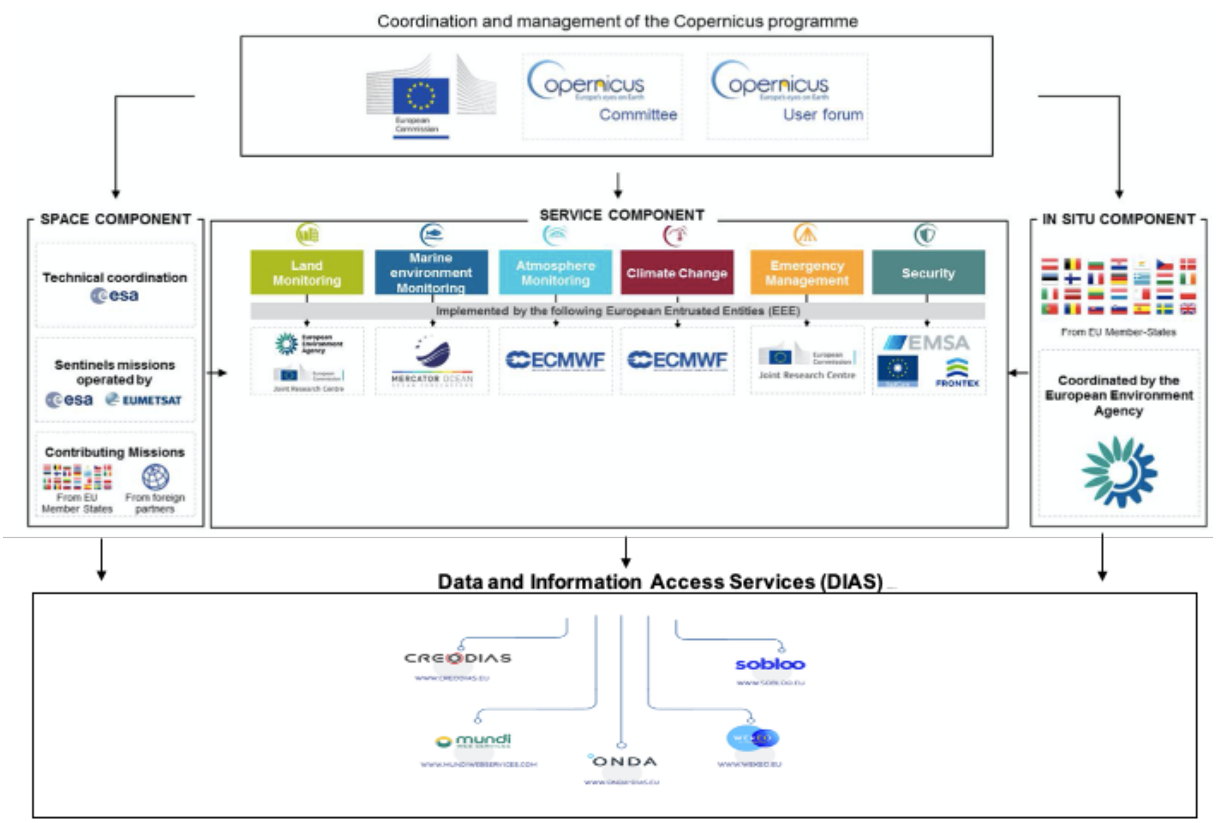

Figure 1 - Copernicus governance and infrastructure

Sentinels. Besides their national space programs, the member states are responsible for the development and maintenance of the in-situ sensors. These components lead to the data generation from the 6 Sentinels, contributing missions from the Member States and in-situ sensors on land, on sea and in the air. The contributing missions are the missions apart from the Sentinels that make their data available for Copernicus. All this data combined (i.e., Sentinels, contributing missions, and in-situ) is made available via the Copernicus Core Services and Data and Information Access Services (DIAS). The so-called Entrusted Entities govern the Copernicus Core Services. These consist of the European Environment Agency, Mercator, ECMWF, European Commission, and EMSA. The DIAS consists of five competing private cloud-based platforms that allow access to the Sentinel data the Core Services. The following five platforms make up the DIAS: Creodias, Mundi, ONDA, WEkEO, and Sobloo. Each platform is again a consortium formed by different businesses from different European companies. Figure 1 gives an overview of the governing infrastructure of all the Copernicus components.

4.2.2.2 Value-adding services sector

Copernicus and related actors' governing role on the collected data ends after the gathering, processing and disseminating this data. Here, the role of the private value-adding companies come into play. Besides providing relevant information in the 6 thematic services, the strategy of Copernicus is to leave opportunities open for the downstream market. One of the policymakers elaborates: "we are really careful to see if we can do something specific, or we leave it up to the market. It is not our intention to be cannibals of the market" (PM2). It is argued that this is partly decided by the mandate of the European Commission, stating to which degree the entrusted entities are allowed to develop applications, and partly by the number of requests in a user requirements database. Only if there is a growing body of requests for a certain development and this is deemed highly relevant, the entrusted entities will try to fill this void.

In the shaping phase (2016-now), there has been an exponential growth in the commercial downstream sector in Europe and outside. More and more companies are focusing on adding value to space data and delivering applications further down the value-chain. Such companies can be focused on developing models and algorithms on raw or pre-processed space data, or can be positioned even more downstream the value-chain and serve the end-users' needs via consultancy or ready-to-use products. Only a few companies have the capacity to perform all the steps necessary to develop ready-to-use end-products. Therefore, many value-adding companies form alliances and consortia with others along the value chain to develop high-quality applications, with each company specializing in a specific part of the process.

4.2.2.3 End-users

Potential end-users can be divided into public and private. Public authorities active in water management vary from international organizations that use Copernicus to understand and mitigate water-related issues due to climate, such as IPCC, to local and regional water authority boards needing information on water levels or quality. Private parties, such as beverage companies or project planners, use Copernicus information to gather knowledge on, for example, the availability and quality of water. Historically, mainly public institutes and bodies, such as water authority boards, were targeted as users of earth observation. In recent developments, more focus is being paid towards private use. “The private sector is an element where we need to work on. Until now it is very much dominated by the researcher. I think 70% of our users are researchers, our intention is to bring this down” (PM2).

Here, we also see networks between different end-users. Since the technology and applications are still emerging, end-users tend to form alliances to maximize the opportunities. For example, instead of acting individually, regional water bodies collectively purchase products that give insights into their water management. Although the private user base is underdeveloped, the potential demand is abundant. The interviewees agree that there are many opportunities for space-based applications, especially in large spread regions with fewer sensors. Furthermore, it is stated that the demand will increase due to the increased effects of climate change.

4.2.2.4 Others

Besides the abovementioned main actors, a few other relevant actors play a role in the structural formation of the TIS. Researchers and research institutes play a major role in the development of the program. In the early years of European earth observation, the sector was heavily dominated by R&D. Not only do they help develop satellites and sensors to gather data, they are also critical in the processing, modeling, and interpretation of the data. Furthermore, it serves researchers and research institutes valuable information on understanding the earth, which still makes them one of the program’s major end-users today. Other actors of significance are national and international financial institutes willing to invest in Copernicus and its applications. This is necessary to fulfill projects whereby Copernicus is mentioned as a requirement for its fulfillment. Finally, experts and expert groups also shape the development of the program. For example, intermediates are of major importance in network formations whereby they act as brokers between different actor and actor groups, such as end-users and value-adding services. Table 7 gives an overview of the different actors and their (sub)categories.

4.2.3 Institutions

Informal institutes consist of common habits, routines, etc., which is hard to capture structurally. This will therefore be discussed in the dynamic functional analysis of the study. Functional institutions around Copernicus consist of formal ‘rules’ that are formed that influence the development of the technology in any way.

Actor category group (section)	Subcategory	Actors
Policymakers (4.2.2.1)	Authorities	ESA
		European Commission
		EU Member States
		EUMETSAT
	Contractors	Entrusted Entities
		DIAS Providers
Value-adding sector (4.2.2.2)	Value-adding companies	Processing and modelling
		Application development
	Consultancies	Consultancy companies
End-users (4.2.2.3)	Public	International water/agriculture organizations
		National water authority
		Local/regional water authority boards
	Private	Private companies relying on water resources (e.g. drinking water, beverages)
		Private companies involving water management (e.g. project planning)
Others (4.2.2.4)	Research	Researchers and research institutes (often also end-users of Copernicus data and applications)
	Experts	Intermediates, advocacies, etc.
	Financial institutes	World Bank, national investors, etc.

Table 7 - Structural elements in the Copernicus innovation system

One of the most important regulations is the open and free data policy. A European regulation drafted in 2014, still valid today, states: "the data and information produced in the framework of Copernicus should be made available on a full, open and free-of-charge basis subject to appropriate conditions and limitations, in order to promote their use and sharing, and to strengthen European Earth observation markets, in particular the downstream sector, thereby enabling growth and job creation" (*Copernicus Regulation (N° 377/2014)*, 2014, p. 48). This decision indeed fosters the use of Copernicus data by downstream businesses by leveraging on, adding value to, and develop products on its data.

Other formal institutes that favor the development of the Copernicus applications are national and internal programs that stimulate research and development to solve societal problems. Programs from the World Bank, the European Horizon2020, or more locally the SBIR (Small Business Innovation Research) favor the use of Copernicus to stimulate its technological development, while addressing societal challenges and stimulate market formation.

Relating to water management, the EU has adopted its water framework directive. This directive commits all member states to achieve good quality and quantity of their water resources. It states certain requirements to which the water bodies need to fulfill to commit to the targets of the directive. Furthermore, it states how these indicators need to be measured (e.g., method to assess the oxygenation of water bodies). Also, member states have their own local water directives that have an influence on the use and adoption of Copernicus data. For example, The Netherlands has developed a ‘flood risk management plan’, which entails all national and regional rules on the management of flood prevention.

4.2.4 Technology

The Copernicus space assets and the data acquisition are considered of very high quality by its users. This can already be seen by the fact that the constellation of Sentinels, the contributing missions, and in-situ data delivers tens of terabytes of data every day, which is widely accepted by the value-adding sector. This sector has already come up with various applications based on the Sentinels and contributing data. Examples of information to which Copernicus data give insights consist of detecting surface water as small as puddles, measuring evaporation or soil moisture, water management for agriculture, and monitoring and mitigating water risks such as flooding.

However, the water sector also acknowledges some limitations and challenges upon which the technology of Copernicus can still be improved. One of the main issues that is considered problematic is the resolution. One value-adding company mentions that “seen from the technical point of view, the Sentinels are a beautiful start, but there is a need for higher resolution data” (VA6). The minimum resolution of 10 by 10 meters in Sentinel-2, which is one of the major Sentinels used by applications for the water sector, is for many value-adding businesses considered too low. Secondly, there is a a high-resolution heat sensor. Such a sensor can be very beneficial for measuring evaporation. One value-adding business explains: “Sentinel-3 has a does have a heat sensor, but it has a 300-meter resolution and that is not useful” (VA5).

Such technical opportunities and challenges also differ per regional characteristics. The immediate added value of the core services is mostly visible at regions or countries with large spread areas in which data is much scarcer, or developing countries who do not have the same capacity as most western-European countries to operate large in-situ monitoring. Additionally, there is often less need of a very high-resolution data in widespread areas due to the large sizes of its land and waters. This way, Copernicus can accelerate sustainable development in developing countries by providing valuable information. That does not mean, however, that Copernicus does not bring value to countries with a high sensor density. An example given by one of the interviewees is that “by the high in-situ sensor density you have a method to validate the Copernicus data and models and are able to develop applications and services accordingly” (PM3). Also, compared to the core services, the raw data from the Sentinels and other data sources can contain much information when appropriately assessed.

Actors in the field, however, agree that space data is seldomly used as a single source of information. It always needs to be combined with other data sources, such as in-situ, and processed via modeling. As one of the interviewees mentioned “satellite data is no magical tool, you’ll need to combine and validate it with data on earth. And if you do so, it can be a very powerful tool" (PM2). This indicates that people working with satellite data can seldomly use Copernicus data alone. They will always need to interact with other actors, technologies and institutions besides the ones relating to Copernicus data.

The Copernicus mid-term review (European Commission, 2017), on which has been elaborated earlier, mentions the weakness of the data's accessibility. These findings are confirmed by value-adding businesses stating that the ESA infrastructure could not handle the data they were collecting in the early years of the program. This would lead to slow processing and downloading times. Additionally, it was not considered user-friendly at all, the users needed to go through all kinds of administrative processes, such as filling in forms, and it needed to be for research purposes to download the data. Data sources from competitors such as NASA and Japanese satellites were considered steps ahead in the accessibility. Although this might have led to an image problem, the interviewees agree that this is getting better. The European Commission had noticed this problem and devoted quite some efforts in setting up the Data and Information Access Services (DIAS), which has been operational since early 2018.

4.3 TIS functions of the take-off phase

4.3.1 Entrepreneurial activities

Compared to four years ago, much progress has been made on the room for experimentation and entrepreneurial activities (PM2). Many start-ups are entering the fields due to the abundance of possibilities, high demand, and the free and open data policy. However, companies and experts already in the field do not necessarily experience much competition and argue that there is still a lot of room for entrepreneurs to enter the field. "There is still much potential in there and only limited applications, while the demand is quite big. So there are many opportunities for entrepreneurs and I think that this will only grow in the future" (VA4). These possibilities are acknowledged by ESA and Copernicus, which encourage entrepreneurship via various programs, such as the ESA business incubators and Horizon2020. The incubators are developed to stimulate space-related entrepreneurial activities, while Horizon2020 is mainly focusing on opening up possibilities for experimentation and entrepreneurial technological development towards addressing certain societal needs. This has helped businesses to set up their companies and give room for internal R&D (VA9).

Although such programs are in place and give incentives to engage in entrepreneurial activities, smaller companies are not able to do as much experimentation as they would like due to smaller budgets. This leads to the fact that many companies form alliances with other companies or research institutes to engage in experimental activities. Furthermore, the high risk is also an issue for entrepreneurs. A value-adding employee states: "There is so much potential, you can have five ideas every day, and on the long term it can become good products with large profits. But, again, nobody does this, because people think it is too uncertain" (VA4). This results from the fact that it requires high investments, while it may take many years before these investments are repaid. Additionally, there is uncertainty in the willingness of end-users to pay for the applications. Although the demand to space-based products is high, indeed, interviewees agree that it is hard to convince end-users of the product as a small company. The role of the government as prime users is therefore still seen as crucial, due to de-risking the market.

Experts in the field doubt the quality and effectiveness of entrepreneurial activities and incentive programs. Many companies developing applications are very focused on solving single cases, such as assessing the groundwater levels in a particular region and reporting on this. These companies are often supported via different funding programs or other incentive instruments. However, such single-case business models are not very sustainable and often does not lead to a scale-up, which accounts for the fact that the sector is still very immature with a high number of small companies (EX14). Therefore, funding many single-case companies does not lead to sustained entrepreneurial innovation hence the long-term technological change. A better approach would be to only invest in businesses that have the real potential to scale-up and bring sustainable solutions. Therefore, experts in the fields state that "It is time to pick winners (EX14)". This also indicates a lack of guidance of search, which is elaborated upon in section 4.3.3.

4.3.2 Knowledge development and diffusion

There is a high degree of specialized and a broad range of knowledge required in order to work with satellite data. Along the value-chain various knowledge types are needed to assess, process, and interpret satellite data. The different knowledge fields needed in businesses working with satellite data include IT, remote sensing, mathematical, agriculture and water, and local expertise (about the location to which the application serves). Policymakers in the field state that "there is enough knowledge available in the Netherlands to fill this whole chain" (PM3). Furthermore, they are aware of the fact that value-adding businesses cannot excel in all aspects and that they need to specialize in certain domains. The expertise in the Netherlands in water management, and using remote sensing for this, is very high. This is also due to the fact that the Netherlands has been battling water-related issues for centuries. More and more educational institutes are arising, and satellite data and earth observation are also becoming an integral part of higher education and universities.. However, other countries are catching up in knowledge relating to water management, "which is an indication that you need to keep stimulating the sector to keep on innovating (PM3)".

Although it is argued that there should be enough expertise to fill the whole value-chain, companies see it as a challenge to incorporate this broad range of knowledge into their organization. Only few people have all the knowledge needed to work with satellite data in the field. To gather knowledge on all these different aspects is difficult and expensive, especially for smaller companies. On the other hand, the development of the infrastructure, services and applications, lowers the entrance barrier to enter the field (PM3). Although this is indeed happening, more should be done to even lower this bar. An expert, who studied the availability of training and education on satellite data, states that there should be way more educational modules and in a more user-friendly manner. Most educational programs are currently focusing on experts and academics, while the private sector needs to be targeted better. Furthermore, there is a huge need for more downstream skills and knowledge, such as IT, but the current supply is mainly focusing on upstream technological skills, such as details of space components or climate details (EX16).

Since it is shown hard to acquire all skills required on a large part of the value-chain, especially for smaller businesses, knowledge networks are vital in this process. By forming alliances and collaborating with other parties, high-quality applications can be developed. This is apparent in our empirics, whereby VA8 is responsible for processing and modeling of the satellite data, and VA9 uses this processed data to develop applications with it, which can be used by the end-users. This product is used by ES11 and ES12, who consider the product of high quality. "For a satellite company it is already a big step if you deliver a daily or weekly grid. But in order to get that to the end-user, it requires another step. And you need a party for that as well" (VA9). So, when businesses are unable to acquire all the necessary skills, a strong knowledge network along the value-chain can lead to high-quality applications. While the strategy of Copernicus is to leave many of these processes on the value-chain up to the market, a better involvement of public institutes is also advocated. Leaving the processing of raw data (i.e. Copernicus data that has not been pre-processed yet) open to the private sector comes with the risk of relatively lower quality products. Therefore, public-private partnerships are favored to ensure high-quality data, because the public would be responsible for delivering initially processed data that is approved and verified.

Not only the value-adding companies, but also the end-users require technical skills in order to understand the opportunities and work with satellite data. These companies argue that this knowledge is often lacking at end-users, which makes the implementation difficult. They often do not see the technological potential, have different expectations, or lack the knowledge to use the applications. When trying to implement satellite data applications at end-users, it "is for many people some sort of abracadabra, or a black box. How it comes about and their feeling with it is limited. That hinders the use of it in the daily water usage. If I just stand next to my grassland and I just look at it, I will always see more than from space. That's what they think, while that is not always the case (VA9)." Also, end-users responsible for implementing such applications at their company encounter such difficulties. They encounter the limited knowledge about such products at managers or policymakers who need to decide on the use of space-based data in their company, which often leads to a neglected use of such application services (ES13). Due to the limited knowledge, value-adding companies and end-users are unaware of the kind of new applications and services that the Copernicus program could offer. Section 4.3.6 will elaborate more upon this.

4.3.3 Guidance of the search

Actors active in the field are generally positive about their expectations on the development of the program. They argue that due to the increasing effects of climate change, the role of space-based data in the water sector will only increase. Policymakers in public and private sectors will need more information on water-related issues, such as the availability and quality of their resources. Also, due to advancements in the development of applications and services, it will be easier to use for end-users, and therefore the barrier will be lower to implement it. Finally, space data could play an active role in handling the Covid-19 pandemic and crisis. It has already helped address immediate issues, such as border control and GPS tracking. Furthermore, the interviewees argue that space data can be of great help in supporting this 'new society' on the long run. The actors are convinced about the ability to stimulate the economy, prevent human interaction, and observe environmental changes due to changing behaviors as opportunities.

However, actors in the field mention the downsides of the technologies' rapid development. A policymaker stated that the sector: "keeps focusing on this rapidly developing technology which brings up new opportunities and we keep up highlighting all the new things coming, but we need to take a step back sometimes and focus on simpler things which are still working and can be implemented more easily and not with a high degree of sophistication (PM1)". Furthermore, there is too much being done for the 'high-level clients', but there is a need to develop something at a scale, which requires less customization and is therefore more affordable. The high-level and high customized solutions often require a lot of maintenance and support and is not sustainable for end-users who do not have the resources to afford this. This is also observed at value-adding companies, who have trouble keeping up with the technological changes. "Innovations go really fast, especially in the IT side. For example, if you head into a certain direction, but four years later it is already going into another direction (VA9)". Above findings indicates that the technological advancements are going very fast, but there is a lack of a solid functioning foundation on which a majority of users can trust.

As described earlier, Copernicus strives to be very user-driven in their ambitions to serve European citizens in their needs towards addressing societal challenges. That means that "the user is positioned centrally and determines the direction of the technology and services" (PM2). In order to do so, the Copernicus Committee has set up the 'User Forum', which is a working group to increase the value of the users by seeking their input from public and private sectors. More explicitly, such forums are used "to gather input for the coming period in which new budget will be made available for the development of the program" (PM3). Although this shift in policy rationale is becoming apparent, it is only in its beginning phase. As a policymaker explains: "until now, the focus was mainly on setting up the service and building an infrastructure, but after five years' time it is time to effective start listening to the users"

(PM2). Their limited input is confirmed by the end-users who argue that they are not always included in the process and there are still many needs that can be filled (ES10).

Different strategies are taken by Copernicus' policymakers to address such user needs and guide the direction of the technological development.. First, if there are indications of a striving need towards certain applications or information, they will try to address these. The first step would be to see if this void can be filled using techniques based on data from already existing sensors. If this is deemed impossible, they will determine whether or not such data needs to be gathered using new data acquisition methods (e.g., a sensor on a new Sentinel). If current data is able to address the needs, they will decide to develop something themselves or leave it up to the market. This is also partly directed by a mandate from the European Commission, stating to which degree of maturity the entrusted entities are allowed to develop services. The main rationale herein is to interfere as little as possible with the commercial downstream sector.

When addressing societal needs and challenges, and Copernicus decides to leave it up to the market, an important instrument is Horizon2020 (which will be Horizon Europe from 2021 onwards). Via this major European program, the Commission tries to spur innovation and technological change, while addressing grand societal challenges and needs. Calls are written out in the program to address these specific challenges. The winners of these calls are supported via funding to execute their proposals. The use of Copernicus data is herein often required in these proposals, which has both implications on the market creation (which will be elaborated on in the next section) and guide the direction of technological advancements, based on societal needs. However, the people writing these tenders often do not have enough knowledge about Copernicus and earth observation (PM1). This often leads to the fact that such requirements (i.e., use of Copernicus/earth observation in projects) may get into the tender documents, but are vague and rarely a mandatory requirement. This causes earth observation to not be seen as a major criterium for assessing such tender and hampers potential technological change (PM1). In order to improve this, "ESA should help write industry standards to help them write these documents (PM1)". These findings are also relating to such innovation programs in the Netherlands. An important tool to advance the innovation in space applications in the Netherlands is the Small Business Innovation Research (SBIR) program, which stimulates the use of satellite data in addressing large societal challenges.

Another important tool to guide the technological development is the presence of regulations and standards. Although some changes are starting to appear, it is still very limited. For example, the commissioner of agriculture included the use of remote sensing in its policy in 2018. It is argued that this is showing quite useful, but more needs to happen in order to stimulate the usage (EX15). In the Dutch water directive framework, which concerns the policies and standards of managing Dutch waters, satellite data is often not favored. It is argued that, without explicitly stating certain techniques for various water-related activities, the use of innovative techniques is often ruled out. Namely, conventional institutions are in place which insist on specific methods to assess indicators on water, which cannot be done through satellite data. For example, the water directive framework continues to require conventional methods for assessing water quality, which can only be achieved by taking samples of the water (EX15). Experts argue that such regulations should not necessarily favor one or another technology, but should not exclude any either. It is stated that from European perspective, more and more is being done to make such formal institutions more flexible, which favors innovative solutions (EX15).

From the perspective of the value-adding sector, there is a need for more standards to guide the technological change. A value-adding business explains: "You could see this industry as a free cowboy world, where a lot is possible with few protocols and standards, but where upscaling is very hard. Maybe we need such protocols standard ways of working, well-regulated innovation…" (VA4). In the last decade, the reigning political parties have been quite conservative regarding the use of such complementary policies, and rather favor a free market (EX15). This can be seen in the high number of subsidy instruments, but relatively limited regulations. Value-adding businesses also lack the existence of an independent quality control organization (VA4). A similar policy as the Environmental Impact Assessment would be necessary for the value-adding sector. In this program, the environmental effects of certain projects will be assessed by an independent organization based on specific indicators on environmental impact. "Currently it seems like you can and may do whatever you want, and believe me my customers are happy, but still there is a need in some sort of general review of what we do and sight on what the competitors are doing and checking if one method is really better than the other one… (VA4)".

The absence of such technical standards is causing difficulties in the development of value-added applications. Currently, value-adding companies have different strategies towards the development of their products, which can either be 'open' or 'closed'. Open products are considered applications or services of which the data's processing and modelling methods are open-source and made available by sharing with the public. By doing so, one can understand what is happening inside the product. This eases assessing the product's quality and stimulates knowledge development based on others' produced applications. On the other hand, closed products keep their data modeling method private and prevent others from taking advantage of their products. At this point, many high-quality products are closed, which hinders the development of the technology (VA4). This furthermore hinders the acceptance because end-users want to assess the quality of the different applications available. The sector, therefore, needs more technical standards on methods that are assured of its quality on which the technology can be developed further.

Finally, the technological development is very much led by strong networks and alliances. A majority of value-adding businesses are relatively small businesses that lack the knowledge or budget to develop high-quality products independently. They almost always need to work together with other parties and form alliances to combine their resources to develop something that has an added value (PM3, VA4, VA5, VA7). Although this is often a strong strategy, it may also lead to difficulties over time. The dependency on these strategic networks is a risk, since these are difficult to maintain over a long period of time and in a sustainable manner (VA7). If the network gets broken, essential resources and knowledge may go missing. Furthermore, the high number of consortia from multiple small businesses comes with a lack of large private businesses. Actors in the field agree that there is a need for an involvement of such large parties to guide the development through the availability of resources and a higher legitimacy (VA4, EX14, EX15).

4.3.4 Market formation

One of the most important strategies from Copernicus is the open and free data policy, based on high-quality satellite data. This decision should lead to the envisioned emerging downstream sector and user uptake. Indeed, the value-adding companies highly value the free and high-quality data, and it led to a sharp increase in such businesses. However, as we have seen in the policy reports in the shaping phase of the development of Copernicus, the formation of the downstream market and user uptake has not been as high as can be expected from the availability of technical resources. This indicates that the earlier strategies from Copernicus by heavily investing and providing the infrastructure and resources to create downstream applications are insufficient to create an actual market. Policymakers in the field acknowledge this issue and note that the market uptake is still lacking (PM1, EX15). Therefore, Copernicus aims to stimulate the creation of a market via various user uptake strategies.

Now that the technological foundations of the Copernicus program are built successful and it has become time for a market to develop, Copernicus tries to open up opportunities for the downstream market. With the six thematic core services, Copernicus has built a strong foundation for technological innovation using their resources and hopes that private business will continue to build upon these possibilities. Instead of advancing their technological progress, they leave opportunities open for the downstream market. A policymaker elaborates: “we are really careful to see if we can do something specific, or we leave it up to the market. It is not our intention to be cannibals of the market” (PM2). However, experts in the field state that the these core services and the executing businesses (i.e., entrusted entities) are already disrupting the market creation. They argue that due to their better access to resources and advantaged position, competing businesses do not have equal opportunities and therefore not always able to step in or take over. “There are all kinds of commercial services that would like to do this, but they would have to buy the data, while these institutes have it. It is the question when there will be a level playing field” (EX14).

Besides developing the services to build a strong technological foundation, the public (i.e., governmental institutes) initially served as a prime user of Copernicus data. In their strategy to create a strong market, they hope that more and more private users would adopt the technology in their businesses as well. So far, this is way below expectations and needs to be worked on (PM2). It is leading to the point that many value-adding companies are pushing governments to buy their applications, but such public institutes are avoiding this as they believe the market should be privatized (EX14). Furthermore, due to already existing conventional networks, new value-adding businesses have trouble penetrating into the market. Public end-users have already established links between their suppliers and built up trust relationships over time. This has led to difficulties for value-adding businesses to enter the field and take over the market. The market is therefore still heavily reliant on the governments as primary end-users

Governments do not only play a crucial role as a end-users and developer of the core services, but also as a facilitator. Various activities are undertaken to increase market creation, such as use-cases, Copernicus incubators, and Horizon2020 projects. value-adding companies are optimistic concerning the number of supportive policies and programs, both national and European, to support innovation and market creation. On a national level, two interviewed value-adding companies mentioned that they used the SBIR to develop a product that is used by governmental end-users. These market incetives are often set up in a way that the businesses will not be funded for the full hundred percent, but they need to invest in it themselves as well. “keeping this in balance, you prevent people living on funding” (VA7). From the European perspective, there are also plenty of relevant market incentives. The different ESA programs and the development of large strategic policies and programs, such as the European Green Deal, Horizon 2020, and the Paris agreement, help value-adding businesses make investments and create products in the water sector.

At the same time, the sector is considered too much depending on governmental funded projects. “Without such a capital injection, we wouldn’t be able to start such a project. That’s at the same time a weakness of what I do. Everything is depending on funding and investments” (VA4). This means that Copernicus is stimulating a lot of innovation regarding their data, but this does not necessarily lead to market creation. Other value-adding companies experience similar problems related to this. They argue that such programs help a lot in experimenting and making prototypes, but the connection to the market is lacking. “The earth observation sector is living on ESA and European funding projects. They call this a market, but in reality this is not the case” (EX15). The businesses rather have that their end-users pay for the applications, but the number of such operational services is minimal. A problem with these funded projects is that the connection with the end-users is often missing (VA9). The projects are very much focused on gathering knowledge to help develop the technological advancements, but the market creation is often neglected. The European Commission is aware of this issue, which can be seen in their recent changes in innovation policies. The classical research and development rationale needed to make place for science and innovation policies (EX15). Also, end-user participation is becoming a mandatory part in such innovation instruments, and only private businesses can apply to stimulate market creation. However, this change in policy rationales requires a shift of mindset, not only at policymakers, but all actors involved, and it will take quite an amount of time in order to succeed in this.

Institutional barriers are another issue that hamper the market creation. Once it is shown that something is technically possible, the implementation process is still a challenges. The earlier mentioned conventional standards play a role in this process as well. These old standards hamper the guidance of the technological development and brings difficulties for markets opportunities. When new methods are not (yet) accepted as a part of formal regulations, such as the water directive framework, it hampers the diffusion of the technology and conventional techniques will be favored over Copernicus. Copernicus applications are also hindered by the existence of privacy regulations and concerns. This is a very sensitive topic, and it is often not clear what kind of information can and cannot be used. This uncertainty is often an issue, because businesses are not sure whether or not the privacy legal aspects may get involved and decide not to engage in it. "Even the indication of problems regarding the involvement of privacy legislation or other legislation can have a disturbing effect on the process of development of a product or service" (PM3).

Another important aspect for the creation of markets is to address the needs of users in order to encourage their involvement. Water managers in the Dutch water sector argue that value-adding companies are currently not responding to their needs regarding solutions for their problems (ES10, ES12). Furthermore, the water managers would be willing to engage in discussions on how to improve current gaps in the applications, but the value-adding businesses are not very willing to improve their products. On the other hand, value-adding companies state that end-user's expectations are often too high (VA6 VA9). As mentioned earlier, the technical knowledge on the technology within end-users plays an important role to temper their expectations. Section 4.3.6 will discuss further about this.

4.3.5 Resource mobilizations

Due to various funding instruments, which have been mentioned earlier, financial resources become available for businesses to engage in innovative activities. these have helped many value-adding businesses to set up their business, engage in internal R&D, and finance their projects. Although these findings are optimistic, it is argued that too many financial resources are put into upstream technology compared to the downstream (EX14, VA4). "Copernicus is trying, but the investments are relative low compared to all the rockets and technologies. Besides, a lot of technology is being made, which is not being used. Which simply does not have end-users (VA4)." Furthermore, as mentioned earlier, in such funding instruments the businesses often need to invest half the resources themselves. Although this prevents businesses from becoming too dependent on funding, this method is not feasible for smaller companies with limited budgets.

There is a huge need for large firms to step into the field, since they can bring huge resources, both financial as human capital (PM1, VA4, EX14). “It is important that businesses engage in business innovation with large firms behind them. I think that is more effective than just start-ups and people with a good idea. That means that large firm who have the facilities and knowledge in house start investing. That will also benefit the quality of the products” (EX14). Furthermore, public and private end-users, who are currently hesitant, can be convinced by the entrance of large businesses. (VA4).

The main reason for large firms not to invest in Copernicus applications and services is that the time horizon is too long. Many businesses look at opportunities and need to see a return on investment in six months, while it may take at least five years before businesses get any profit out of it. Therefore, the risk is too high for such businesses and therefore often do not invest in Copernicus. Additionally, private investors are hesitant to invest in Copernicus applications and services due to the active role of the government as risk-takers by investing and acting as prime users. “The private sector is very conservative when it concerns investing money, let the government take the risk. There should be a moment that the government will pull back from the downstream sector, but first the market should be created” (EX14).

4.3.6 Creation of legitimacy

An important strategy by Copernicus is to become a trusted source of space-based information. “It is our intention a little bit like you have a laptop with Intel inside, we want that as well. Copernicus inside. If a consultant uses Copernicus and the customer says, ‘ah yes that is a sign of high quality’. That is definitively something we want to achieve (PM2).” Unfortunately, ESA and Copernicus have a bad image regarding their data in the satellite earth observation industry (VA7). This image mainly relates to the accessibility of their data, which is not fully justified anymore. Through better data dissemination strategies, such as the DIAS, Copernicus data accessibility have strongly improved in the recent period. Nevertheless, this stigma is still present among users of the data. Another issue Copernicus and the downstream market is facing in achieving their ambitious goals, is that end-users highly doubt the quality of applications based on the Copernicus data.

This lack of trust in the quality is an important factor that leads to the hesitance of end-users about incorporating applications derived from satellite data into their organization. End-users who have been using such applications were not very satisfied, which led to a low trust in the organization (ES11, ES12). Furthermore, the lack of quality validation of such applications hinders the trust. “And we will only find out by using it. So we are in a circle in that you don’t know what the quality is and due to that you don’t use it. But you’ll only know the quality of it, by using it (ES11).” This is also due the fact that many of such products are ‘closed’ and not based on standards and validated models or algorithms. “A good example is the [product] evaporation guessing program from [company], nobody knows what is happening in [product], which hinders the acceptance in the field. (VA4)”. This often leads to the fact that they prefer conventional methods of which they are sure about the quality (ES13). Therefore, the earlier-mentioned lack of guidance of the search hinders the creation of legitimacy within Copernicus and the downstream application and services.

Besides a low trust in the quality, there is a huge lack of knowledge about the possibilities that satellite data can bring. “The biggest barriers are about the awareness of space applications. Many people think about Mars or exotic destinations and difficult technologies when it comes to space, while, especially the European, space programs are very much focused on the earth itself (EX17).” Indeed, many end-users do not directly see a link between space-based applications and their business processes. The space world is often seen as very complicated and therefore often not very appealing for industries outside this sector. Although Copernicus is trying to increase awareness within end-users via various activities, such as use-cases, demonstrators, and events, there is still a long way to go in this process. Indeed, as described in section 4.3.2 there is a need to develop knowledge among end-users about the technology and its opportunities via training and educational modules. These findings also impact the trust in quality, because if people are not yet familiar with a certain technology, the doubt the quality of it. “We encounter many managements who are looking for the tools, but don’t know where to find them. And are not willing to trust them, without having tested them (VA8).” Experts in the field argue that is it important to instead of positioning themselves as a space-based information provider, Copernicus should simply be referred to as a data source of information on the earth. End-users do not care about the source of their information, as long as it serves their needs (EX14).

Another issue that hinders the acceptance in the field is privacy concerns. In line with what hinder market formation, privacy plays a role in the acceptance of the technology. Many end-users are concerned about the technical capabilities of satellite data and fear an invasion of their privacy (ES10, EX17). This fear will only increase when the resolutions of satellite images improve over time. Actors in the field agree that the ethics regarding the use of space data and space law are becoming more and more important. “Space is nobody’s property and information gathered in space is nobody’s property, if this interferes with your private life you’ll think very different about it than the company selling this data. That is a serious issue concerning the acceptance of satellite data” (PM3).

Beyond above-mentioned factors that hinder the acceptance of Copernicus, there is also a large resistance to change. Fueled by both the lack of awareness and low trust, end-users in the water sector are very conservative when it comes to using new techniques in their daily processes. “You know what is funny, in my conversations with [water board authority] everybody is always convinced about the potential, that isn’t very hard, but at the end of the day the jump is still too big. From a horse to a car is too radical and they retain conventional methods. For example, dike inspections, checking if it has any cracks, there was a great innovative way using remote sensing, but in practice it fails and rather use conventional methods like dike watchers etcetera (VA4)." Indeed, the technological change of Copernicus seems for many users in the water world too radical. Water managers who have been practicing their work for decades are not very receptive to new technologies, while they argue that the old methods work perfectly fine. "Unknown makes unloved. Many people have a nine to five mentality, who are doing their measurements for years in the field. I can do my work with that and I am not looking for change at all. Unfortunately, that is also the case still (ES10)."

Another issue that makes make water managers resistant to change is that they see the new technology as a threat. Conservative people working in the field state that their jobs as water manager will become obsolete. "we've heard from some of the practitioners we were working with in some of the ministries is that you might have higher level staff who may be a little bit opponent in adopting the technology, because they might sense a danger of their own position being undermined by these new technologies and probably because they do not fully grasp what can be done as it comes with a lot of uncertainty. What does this technology bring, and will that undermine my position?" (ES13) Again, these concerns come from the fact that there is limited knowledge about the use of satellite data and its applications. Of course, it may indeed replace jobs that will become obsolete, but experts state that it is never a replacement of current ways of working, but rather an addition to.

Luckily, this resistance is slowly changing. Due to the entrance of more young people into the field and increasing needs due to climate change, water managers are becoming more willing to use the innovative techniques (VA5, ES11). Also, the programs to increase awareness are effective (PM3). Besides these, bottom-up processes have led to a better understanding of the technology and its possibilities. Some pioneering users who are aware of this lack of legitimacy are advocating for a better use of satellite data in Dutch water management. A collaboration of various public end-users founded the SAT-Water consortium in 2011 and have been actively promoting the use of satellite data. Their main goal is the acceptance of satellite data in the daily processes by water managers. They increase awareness about the possibilities via networking events, stimulate networking between value-adding businesses and end-users, and lobbying for better standards and regulations. Although they are indeed achieving significant results, there are still challenges to be achieved. "The consortium still has a huge communication challenge. The hydrologists are starting to get along … But we also need to get along our managers, directors and colleagues outside the field. And we are working hard to do so, and I think that in five years we will be much further. I am optimistic. (ES10)"

4.4 System dynamics in the three water segments

In our analysis we have looked at three segments in the water sector. The study has shown that the results of above system functions are very generalizable among all three segments (i.e., risk-mitigation, agriculture, and water quality). Actors, networks, institutions, and the technology share many characteristics in the system. End-users and value-adding businesses are often active in more than one segment. For example, a value-adding company that develops a product or service for farmers is not only concerned with agricultural water management, but risk-mitigation, in forms of abundance or shortages of water, and water quality are also important information for the end-users. Such examples lead to highly intertwined networks as well, since these segments share so many characteristics. Furthermore, formal and information institutions that we have encountered in our analysis, relate to more than one of the segments. Finally, the technology that is of relevance for these segments is also very similar. Actors in all three segments of the field are very much depending on high resolution imagery and heat sensors, mostly from Sentinel 1 and 2, to detect water bodies and its characteristics (e.g. quantity, quality) on and under the surface of the earth.

Nevertheless, focusing on these three segments of the water sector has helped very much in revealing the dynamics in this closely intertwined system. Doing so, the present study was able to identify detailed success factors and blocking mechanism among end-users and value-adding businesses in all three segments. Instead of addressing the whole of the water sector in the Netherlands, the segmented approach helped us identify the micro-processes among end-users and value-adding businesses and their importance in the Copernicus value-chain. More explicitly, we were able to identify, for example, different needs from end-users active in the segments, how the value-adding sector responds to these needs, the difference in expectations between end-users and value-adding businesses, and the role of end-users in the system as a whole.

4.5 Motors of change and system performance

Historically, the development of earth observation and Copernicus was driven by a science and technology push. In the founding phase (1975-1996), the primary goals were to develop scientific and technological knowledge and discover the possibilities of space data. Very much driven by collaborative efforts from European countries and agencies, Europe developed strong expertise in earth observation and advanced in the development of upstream space technologies. In the initial phase (1996-2013), it became apparent that, besides investments in upstream space technologies and scientific knowledge, downstream market opportunities needed to be created and exploited. It was argued that via an active involvement of the government as prime facilitators and users, a market could be created, which would later on be taken over by private parties. This period was therefore mainly driven by strong market formation. In the bridging phase (2013-2016), the opportunities for addressing societal challenges by space applications, and earth observation in particular, became more evident. Furthermore, downstream space was recognized as a high potential in achieving the European long-term goals on sustainable and inclusive economic growth. This also resulted in the long-term agreements and commitments on setting up the Copernicus infrastructure to address sustainability challenges while simultaneously contributing to the European economy by opening up downstream business opportunities and job creation.

The above-described development over time led to the current functioning of the TIS. The strong guidance of the search as a motor of innovation in the bridging (2013-2016) and growth (2016-now) phases has helped to develop the Copernicus infrastructure. This influence can still be seen in the functioning of the system today. The strong visions and willingness to take actions at policymakers at different levels in the system positively influence many aspects of the system. Through various programs (e.g., Horizon2020, Green Deal, SBIR), they are shaping the technological development towards addressing societal challenges while simultaneously contributing to the European economy. This strong guidance positively influences resource mobilization due to the funding mechanisms in such programs, which opens opportunities for entrepreneurial activities. These governmental resources and increased entrepreneurial activities also positively affect the downstream market creation as new entrepreneurs enter the field and downstream value-adding businesses are emerging. Furthermore, the strong guidance of search positively influences market formation directly due to the long-term agreements through space investments and the free and open data policy on which a downstream market is emerging.

On the contrary, these strong visions and commitments have not (yet) led to a high legitimacy on the Copernicus applications. Due to various influences of other system functions, the legitimacy is still one of the weakest aspects of the Copernicus Programme. The lack of knowledge, and resulting unawareness of its possibilities, the absence of large (trusted) firms and resources, conventional regulations, lack of standards and quality assurance, and the conservative characteristic of end-users, lead to a limited trust and willingness of end-users to adopt the technology. This weak legitimacy is central in the innovation system's performance, due to its negative influence on other system functions. It is shown very difficult for the downstream market to convince end-users about the quality and possibilities of their applications. Furthermore, large firms are hesitant in stepping in due to the high risk and weak legitimacy. Their lack of resources allocation is again hampering entrepreneurial activities and downstream market formation. Table 8 below gives an overview of the strengths and weaknesses of each system function in the take-off phase.

System function	Strengths	Weaknesses
F1. Entrepreneurial activities	• Increase in entrepreneurial activities in shaping phase (phase IV). • Lot of room for entrepreneurs to enter the field. • Various programs and policies to increase possibilities for entrepreneur to enter the field.	• Small budget hamper entrepreneurial activities of small companies, they form alliances to combine resources. • High risk and uncertainty discourage entrepreneurs and entrepreneurial activities. • Unclear demand and willingness of end-user to pay for product, which discourages entrepreneurs in their market formation processes towards private end-users. Governments therefore still crucial end-users to de-risk this market. • Too much entrepreneurial activity and incentive programs focused on single cases and are not sustainable. When the case is, the business is not needed anymore. There is a need for higher quality entrepreneurial activities that can result in scale-ups.
F2. Knowledge development	• High amount of knowledge and expertise available in the Netherlands, to fill all elements of the value-chain (i.e. space, data processing, applications and services, and (local) water management). • Advancement of the development of the technology begin to lower the knowledge entrance barrier.	• Entrance barrier due to the broad range and highly specialized expertise that is required. • Few businesses have all knowledge required. • Need of more and user-friendlier training and education on the use of space data. Most are focused on upstream technology and skills • Weak knowledge at end-users of the application opportunities and use of space data.
F3. Knowledge diffusion	• Businesses form alliances to diffuse knowledge among their network in order to acquire all knowledge required in the value-chain. • High amount of specialized knowledge among value-chain due to knowledge diffusion and alliance forming. This positively influences the quality of the applications.	• In order for a better knowledge diffusion, there is need for a more active involvement of the public. By assessing the quality of the diffusion process among value-adding business, it will assure higher quality applications.
F4. Guidance of the search	• Actors have positive visions and expectations about the importance and use of space data in the future. • Direction is set out by the European Commission which strives to be user driven. Main instrument is the 'user forum' which gathers input from different actors to set out the direction of change. • Strong use of complementary policies and programs (e.g. Horizon 2020, SBIR) to steer technological change and address societal challenges.	• Development of technology goes too fast. There is a need for more ready-to-use products that can be implemented easily and cheap. • Until now, focus was mainly on setting up the technology, user-focus is only in its early stages which weakens the guidance of search due to their critical role in enabling the applications to work. • Large European development and funding programs lack the knowledge about earth observation and Copernicus, which leads to weak tenders and neglected use of technology. • Limited technological regulations and standards to guide technological development and help value-adding companies in product development. Existing ones restrict the use of earth observation in assessing water indicators.

		• Many high-quality products and its methods are not made available publically by the value-adding businesses, which hampers the setting of standards and technological development. • Need for independent quality assurance commission or institute.
F5. Market formation	• Free and open data policy leads to the emergence of a potentially strong downstream market. • Opportunities are left open for downstream sector to act upon. • Abovementioned complementary policies and programs support innovation and market creation	• The below-expectation user uptake and market formation indicates that the strategies by Copernicus to invest in technological infrastructure is not enough to maximize the market formation, more and better downstream policies are required. • Governments initial strategy to develop the six core services and act as initial end-user hamper the market formation, due to already existing dependency on the government • The market is very much based on projects, funded by public institutes, which end after a certain amount of time. This hampers the formation of a sustainable market with operationalized applications for paying end-users. • (Inter)national funding and investment in Copernicus project is often too much focused on technological development and knowledge development, but connection to market and end-users is lacking. • Privacy, conventional standards and regulations on assessing water hinder the diffusion and implementation of novel applications. • Better demand articulation necessary between end-users and value-adding businesses to respond the end-user needs.
F6. Resource mobilization	• Many national and international funding instruments to support R&D, projects and entrepreneurial activities.	• Too much financial resources are being put upstream, too little downstream. • Few large firms stepping in. This leads to a lack of mobilization of human and financial resources. • Risk too high for large firms to invest. Return on investment is very uncertain and timely.
F7. Creation of legitimacy	• Clear vision by policymakers on goals of legitimacy: Copernicus as a trusted source of information. • Legitimacy is slowing starting to rise due to less conservative end-users, awareness raising programs, and pioneering end-users forming alliances and advocating for more and better use of space data.	• Stigma of bad accessibly of the data among value-adding companies due to its weak performance in the bridging phase. • Lack of trust among end-users about the quality of space applications, due to lack of standards, quality assurance, knowledge, awareness of possibilities, few large (trusted) firms. • Resistance to change due to conservativity of the water sector, radicality of innovation, privacy concerns, lack of awareness, low trust in quality and fear of becoming obsolete.

Table 8 - Performance of the system functions

4.6 Reflection on mission-oriented innovation policies

Based on the above findings on the shift in Copernicus ambitions towards addressing large societal challenges, It is important to reflect on the effectiveness of the relevant mission-oriented innovation policies in this process. Although the TIS analysis gives a good indication of how the system is functioning around the Copernicus technology, it does not explicitly relate to the context of transformative change. This section therefore assesses the Copernicus TIS development and the relevant policies, based on the transformational system failures concept proposed by Weber and Rohracher (2012).

4.6.1 Directionality

In order to guide the direction of the use of earth observation technologies (i.e., Copernicus) in use for addressing grand societal challenges, there is a strong need to establish shared future visions. As the findings indicate, the European Commission and ESA are committing to achieve such future visions by establishing long-term agreements of the development and use of the Copernicus infrastructure. These commitments indicate the strong dedication to long-term investment in the development of space technologies to address and understand climate change. Furthermore, the commitments of Member States, ESA, and EC to have a free and open data policy to develop a strong downstream market, substantiates the fact that there is a shared future vision and that the governing actors are willing to act upon these commitments.

In order to achieve the goals of these ambitious shared visions, there is strong guidance by these actors via supportive policies and programs. Via European and national programs, such as Horizon2020, SBIR, and de EU Green Deal, policymakers are directing the technological development for achieving their goals. However, the systemic functional analysis shows the lack of knowledge within policymakers responsible for guiding these policies. This inability to execute these policies and programs hampers this strong guidance, and therefore directionality. Adequate knowledge development and diffusion are therefore strongly intertwined with guidance of the search in order to achieve successful directionality. This inability of collective action to guide and consolidate the direction of change can also be seen in the entrepreneurial activities. there are many instruments in place to support entrepreneurial activities, these are often too widespread and lack the ability to choose winners and produce high-end sustainable solutions. Additionally, there is too much focus on the rapid development of the technology, while there is a need for simple ready-to-use solutions to start exploiting the large market potential.

Another important aspect of directionality is the target funding for research, development, and demonstration projects. As mentioned above, many resources are put in place to achieve technological development by investing in space technologies and complementary programs. The current systemic analysis, however, shows that too much focus is still being paid to upstream space development. This lack of adequate resource mobilization leads to a neglected downstream development. Furthermore, it showed that large private firms are hesitant to allocate resources in the downstream market as well. Their role is not only crucial in the allocation of resources, but also in creating legitimacy. At the same time, we have seen that large firms are hesitant to step in due to the weak legitimacy of the Copernicus applications.

Furthermore, there is a potential directionality failure in the form of a lack of regulations and standards in the field, caused by a weak guidance of the search. For value-adding companies there is a need for a better setting of standards and regulations to support them in developing applications. This could not only steer the direction of the technological development, but would also assure the quality. This (perception on) quality directly influences the legitimacy of the technology as well. The trust in the technology would increase when it is based on certain standards and the quality would be assured. Although Copernicus is aware of this legitimacy issue and is acting upon this since the take-off phase (2016-now) onwards, this is still a critical issue in order to more effectively diffuse the Copernicus applications.

4.6.2 Demand articulation

The governing agencies of the Copernicus program are well-aware of the importance of demand articulation in the development of the program. In the most recent phase of the Copernicus development, more attention is being paid to the needs and requirements from the end-users. The program is even labeled as 'user-driven'. Via instruments, such as the user forum, they allow end-users to articulate their demand. Via these, new requirements are collected and future technological developments are based hereon (e.g., new sentinels, sensors, or services). However, in order to leave opportunities for the downstream market, they often do not address end-user needs themselves. Instead, they leave this up to commercial value-adding businesses from whom it is expected that they have a better connection to the market and are able to leverage on user-needs. This should strategy should help to contribute to the European economy by opening up downstream business opportunities and job creation, one of the main goals of the program.

This strategy is, however, hampered due to the initial strategy to create a market via their so-called two-step approach. First they would develop the technological infrastructure and serve as initial users of the program, then it would be the role of the private businesses to take over their role as market facilitators. These procurement policies should stimulate the advancement of novel solutions from the demand side, by showing practical solutions and use-cases. However, the TIS analysis shows that this has led to various issues in the innovation system with respect to demand articulation. First, the downstream sector, that was governed and developed by the public, take away opportunities for demand-oriented value-adding innovators. These actors, from whom is expected to have a better connection to the end-users, are crucial in the demand articulation process, but are limited in their opportunities due to the conventional actors, networks, and institutions, which rely heavily on the government. Second, the high dependency on governmental funding, as well as their major role as end-users, leads to a lack of focus on the actual needs of (private) end-users. This results in a sector that is rather aimed at relatively short-term projects that focus on advancing the earth observation technologies, without considering the development of commercial markets.

The findings above indicate that the goals of Copernicus to address societal challenges while simultaneously creating markets and contribute to the European market work in contradiction. The lack of a focused strategy for the downstream sector led to ineffective demand articulation and, therefore, their societal goals are not always met. The current mission-oriented innovation policies for Copernicus have not successfully streamlined this dilemma, which challenges to achieve the ambitious goals. Furthermore, the two-step approach and shift towards type-II MIP is causing failures in the demand articulation processes. Markets are already heavily dependent on the government as end-users and facilitators, neglecting commercial end-user needs and downstream market formation.

4.6.3 Policy coordination

The different roles of actors involved in the Copernicus program have not been very clear, which hampered the development of a strong downstream market for earth observation applications. Currently, this is improving due to a strong vertical policy coordination. There is a clear governance of responsibilities, objectives, and goals from top to bottom. ESA functions as leading actor for the development of the space infrastructure and the EC as governing agency for all downstream activities. The entrusted entities are responsible for the core services. More locally, the individual member states are responsible for the development of Copernicus and its downstream activities in their own countries, and regional institutions (e.g. ESA Business Incubators) are set up to develop specific regional knowledge and business centers.

At the same time, the earlier analysis shows that horizontal policy is less well-coordinated. Although there are many efforts on engage space in innovation policies, sectoral policies and cross-cutting policies, the coordination and inclusion between these is still lacking and are often considered too narrow. For example, innovation policies such as Horizon 2020 aim to improve technological development and knowledge of the Copernicus Programme and its applications, but lack the inclusion of sectoral end-users herein. Furthermore, sectoral regulatory policies, such as the water framework directive, are rather narrow in scope and do not favor or even hamper the use of space data in methods for assessing water-related indicators.

Then, policy coordination failure also relates to private sector institutions. The present findings indicate the lack of standards and regulations to help value-adding businesses guide their application development. There is also a lack of private and public-private institutions in taking the lead in the process of standardizing and legitimizing certain processes in the earth observation sector for water management. This lack of coherent standards and regulations in industrial policies and current mission-oriented innovation policies hinders business in creating applications and services using the Copernicus technology. Finally, the earlier-mentioned two-step approach can also be considered a policy coordination failure. Instead of developing the technology and market simultaneously, to prevent a technology-push problem, they decided to engage in this sequential process. This has led for the innovation system to develop in a trajectory in which the industry is highly dependent on the government as investors and users. This overall causes poor market development due to the hesitance of large private investors.

The above results show that the strong vertical policies need to be accompanied by better horizontal policies. The clear vertical governance of the Copernicus Programme provides a strong foundation for innovation, but is rather limited in the coordination of cross-cutting policies. Policies are too much targeted in its own domain and lack the inclusion and conjunction with other policies, such as sectoral. There is also a lack of leading private agencies that engage in standard-setting. Current mission-oriented innovation policies on the Copernicus program therefore lacks effective policy coordination to engage in these industry policies via (public-private) standard setting or a more active involvement in the assurance on quality, hampering market development and legitimacy.

4.6.4 Reflexivity

The Copernicus program centers the role of users in providing core feedback to the future development of the program. But the earlier analysis shows that only recently the participation of users in this process becomes active. Until now, the goal was maily setting up the infrastructure of the technology and responding to needs of value-adding businesses. In order to be fully reflexive, all relevant actors need to be involved in this process of governance.

Another important aspect of reflexivity is the ability to monitor performance on addressing its goals, and adapt policies accordingly. As the earlier development analysis showed, Copernicus is constantly assessing their performance on various aspects. They conduct independent reviews on, for example, the technical performance, the market, and user uptake. Additionally, they assess how well Copernicus is doing in their ambition to address societal challenges by studying the impact of Copernicus on these problems, such as Sustainable Development Goals. The TIS analysis indicates the policymakers' awareness on the program's current performance and that they adapt their strategies and policies accordingly. The strong guidance by policymakers in reflexing and adapting their policies upon this also shows improvement in legitimacy. This also leads to positive visioning among other actors. Table 9 below summarizes the effectiveness of the relevant mission-oriented innovation policies based on the transformational system failures concept, along with the related system performances.

Transformational system challenges	Structural-functional systemic performance	Assessment of mission-oriented innovation policies
Directionality	• Weak technical knowledge (F2/F3) among policymakers to execute complementary policies and programs (F4) hamper high-end and sustainable entrepreneurial activities (F1) and therefore the development of the technology in the guided direction. • Weak creation of legitimacy (F7) and weak allocation of resources (large firms and focus on upstream) (F6) reinforce each other, which negatively influences the setting of directions	• Complementary European programs to achieve Copernicus transformation towards addressing societal challenges lacks effectivity. • Strategies on investing in the upstream infrastructure as the main priority causes a neglected downstream development, hampering the successful diffusion. • Strong focus on rapid development causes failure in operational market processes, due to limited large-scale legitimate applications.
Demand articulation	• Strong guidance of the search (F4) and market formation (F5) lead to a neglected demand articulation by policymakers. Efforts to open up opportunities for markets result in certain requirements to stay unaddressed.	• Addressing societal needs and challenges while creating opportunities for economic development work in contradiction. • Sequential market and technological development caused a technology push and governmental dependency
Policy coordination	• Strong structural governance with clear visions and guidance (F4) make up for a strong vertical policy coordination. • The lack of market creation (F5) in complementary policies and programs (e.g., Horizon2020) (F4) shows weak horizontal policy coordination.	• Strong vertical policies are not sufficient for achieving transformation change. Need for better integration into sectoral policies. • Lack of involvement (e.g., public-private partnerships and quality assurance) on setting standards in industries, hampers the market development and legitimacy.
Reflexivity	• Strong guidance and visions (F4) help develop reflexive capabilities of policymakers in setting up assessment studies and actor involvement.	• Positive results on the assessments of achieving missions positively influence the legitimacy. • Although framed differently (Copernicus is often framed as a user-centered program), there is a weak inclusion of bottom-up actors in governance processes.

Table 9 - Transformational system challenges and assessment of mission-oriented innovation policies

5 Conclusions

This study aims to answer the following overarching research question:

RQ: What are the success factors or blocking mechanisms that stimulate or hamper the diffusion of the Copernicus applications?

To do so, a desk study on scientific literature, policy documents and market- and company reports was used to analyze the development of the Copernicus program and the shift in relevant policies. Next, through data from seventeen interviews with a broad set of relevant actor groups in the field, the present study analyzed the Copernicus TIS in the take-off phase (2016-now). Finally, insights from innovation policy studies helped to assess the effectiveness of relevant mission-oriented innovation policies on the diffusion of the Copernicus applications in the take-off phase. In this chapter, the above main research question will be answered through the following three sub-questions:

SQ1: How has the European earth observation program developed since its inception and how have the relevant policy rationales shifted over time?

The findings in this study show that the European policy approach on the development and use of earth observation has shifted from type-I towards type-II mission-oriented innovation policies over the years. Due to internal and external pressures (i.e. increasing emphasis on addressing societal challenges and pressure to show value of space in other sectors), the objectives of ESA were no longer purely based on gaining knowledge on the earth and space exploration. This shift in innovation policies led to the current take-off phase in the development of the Copernicus, whereby its goals are no longer solely based on science and economy, but simultaneously tries to address complex societal challenges. According to Mazzucato's (2016) definition on type-II MIP, today's Copernicus program is strongly characterized by such elements: (1) It tries to address broad complex challenges, (2) there is strong coordination and visions on the long-term development of the program, (3) a broad range of actors involved, (4) and active public involvements on creating downstream markets and addressing end-user needs.

SQ2: How has the Copernicus TIS developed in the Dutch water management sector over time, especially in the most recent years?

While the government had a very central role in the first three phases, other actor groups started to emerge in the innovation system and became of major influence on the development in the take-off phase. This mostly includes the role of (commercial) value-adding businesses and the more central role of sectoral end-users (e.g., water managers). Furthermore, the program's shift towards societal objectives has led to a more active role of central European organizations besides ESA, such as the EC and EUMETSAT. Due to the necessity of bringing space value to other domains, the EC became a core driving actor on the development and diffusion of earth observation technologies. Its main objective is to stimulate the downstream sector to create market applications, which aim address end-users' needs. Their major strategies to do so include the open and free data policy and other complementary innovation programs, such as Horizon2020 and demonstrators. Regulations and standards in the practical application domains, however, form a blocking mechanism in the downstream development due to favoring conventional methods for assessing certain indicators, such as indexes on the water quality.

In terms of TIS functions, the development of the innovation policies has led to a shift in the driving motors of the innovations system. The science and technology push in the founding phase was replaced by a strong market formation motor in the initial phase and guidance of the search in the bridging and take-off phases. This shift was mainly caused by the increasing potential of market applications and later increasing focus on societal benefits. Strong guidance of the search from policymakers is currently strongly shaping the development of the TIS by setting up complementary policies and programs on national and international levels. However, the limited legitimacy among end-users and the value-adding sector prevents the program of fully exploiting its potential. An important factor for the weak legitimacy among end-users is that the sector is still very much depending on publicly funded projects, whereby the needs of end-users are often not addressed. Furthermore, due to the historic strategies (i.e. two-step approach), governments are still the major end-users of applications from Copernicus. This high governmental dependence and little focus on commercial end-users is a critical blocking mechanism on the development of an actual commercial downstream market and hampers the creation of legitimacy among end-users and value-adding businesses.

SQ3: How effective are the current innovation policies on the diffusion of the Copernicus applications?

The Copernicus TIS analysis of this study, complemented with the transformational system failures concept proposed by (Weber & Rohracher, 2012), identified challenges in the relevant mission-oriented innovation policies. (1) In terms of directionality, policies on the diffusion of the Copernicus applications are failing due to a lack of technical knowledge among policymakers. This causes an inefficient execution of the complementary programs, such as Horizon2020, aimed to direct the technological change and address societal challenges. Furthermore, there is still too much policy focus on upstream technological development, while there is a need for more downstream support in order for the market to develop and the technology to diffuse. (2) Current innovation policies are causing challenges in demand articulation. Because of the strategic efforts to leave opportunities for downstream businesses, Copernicus is not always responding to businesses and end-users' needs. These strategies are part of the Copernicus' strong vertical policy coordination to interfere as little as possible with downstream businesses. This strategy allows for many market opportunities deriving from their data. (3) However, strong horizontal policy coordination is not in place to align the upstream space infrastructure and its applications and services into the different application domains. On the contrary, the strong shared visions and guidance by policymakers are leading to successful reflexive processes. Despite the high complexity of the goals, Copernicus is assessing its performance on addressing such challenges. The study identified that the rather agile reflexivity through these assessments, along with the strong dedication among policymakers in driving directionality, show promising signs of an improvement on the programs legitimacy, one of the major blocking mechanisms in the current innovation system.

6 Discussion

This section will first present the theoretical implications drawn from this study and gives avenues for future research. Next, policy recommendations based on the findings in this study will be discussed. Finally, this chapter provides a discussion on the limitations of the study.

6.1 Theoretical contributions

While studies on mission-oriented innovation systems are still underway (Hekkert et al., 2020), the present approach adds to this strand of literature. It is among the first to follow the proposed concepts of understanding and assessing innovation dynamics from a mission-oriented perspective. More explicitly, it assessed the development of the Copernicus TIS, along with the shifting policy rationales, based on Robinson and Mazzucato (2019) and Wanzenböck et al. (2020). Connecting these studies helped to couple the shifting policies (i.e., type-I towards type-II MIP) with the Copernicus program (solution in search of a problem). The diffusion of the Copernicus applications had been assessed by a TIS study on the water management in the Netherlands. Insights from transformational system failures concept (Weber & Rohracher, 2012) were used to analyze the effectiveness of the relevant mission-oriented innovation policies. This approach therefore allows to draw implications of these findings on mission-oriented innovation policies for the development of the Copernicus program and similar large publicly funded missions. Section 6.2 will elaborate on these implications and gives recommendations accordingly.

Other application domain under the Copernicus umbrella will most likely deal with similar challenges that have been raised in this study. Promising areas, such as marine or traffic management, also deal with highly institutionalized settings in which the Copernicus applications will still have to maximize its potential. Nevertheless, future studies should be conducted on this topic. Due to the relative novelty of the Copernicus infrastructure, it would be interesting to understand how it will further develop over time. While the study shows strong policymaking and guidance due to the shift of its rationales, its impact may be lagging. Although the results of this study already give interesting insights on the success factors and blocking mechanisms and the implications of relevant mission-oriented innovation policies, future assessment might be relevant to gain more insights on the long-term development of the program. Furthermore, future work on the assessment of large publicly funded programs from a mission-oriented perspective may be helpful. This study used the transformational system failures concept to assess the TIS from such a perspective, other literature strands focusing on addressing societal challenges may be used to broaden this view.

6.2 Policy implications

Based on the results presented in section 4.6, policy recommendations can be given. The study indicated the strong visions and dedication by policymakers on achieving the ambitious goals of the program. This can be seen through the presence of national and international complementary policies, and the high investments in the technological infrastructure. However, the execution of these policies often lacks extremely critical aspects for its successful application. The limited technological knowledge among policymakers is currently causing weak requirements on the use of earth observation in tender documents. The mandatory use of Copernicus in future complementary innovation programs, such as Horizon Europe (2021-2027), may help to improve and direct the development of the program, create a commercial downstream market, and improve the legitimacy of the program. Furthermore, a better inclusion of end-users in these innovation programs is needed to increase legitimacy and market creation. Then, to enhance the effectiveness of type-II MIP for Copernicus, more focus could be paid towards a better allocation of financial resources for successful diffusion of the technology and downstream market creation. Over the years, main policy focus was paid towards the development of the infrastructure, but this study shows the need to better support downstream processes.

The high dependency on the government that has been set in motion due to the two-step approach for the Copernicus case would be hard to divert, but future publicly funded programs may learn from these insights. A better approach when shifting towards type-II innovation policies could be to simultaneously develop the technology and create a market, to prevent a governmental dependency. Furthermore, this study showed the challenges caused by dealing with the dilemma for the current mission-oriented innovation policies of Copernicus to create economic opportunities while simultaneously addressing user needs. On the one hand, policymakers on Copernicus are trying to become user-centered and solving societal challenges through addressing these user needs. On the other hand, they try to interfere as little as possible in this downstream sector to allow for many business opportunities and create a commercial downstream sector,. A better alignment and coordination on these paradoxical goals may help future MIP on coping with such dilemmas.

The findings of this study and the relevant policy implications may be relevant for similar large publicly funded programs. According to the framework from Wanzenböck et al. (2020), the Copernicus program can be categorized as a solution in search of a problem, that is now moving to an alignment in the problem-solution space. The results of this study can be related to the development of Copernicus in this problem-solution space. For example, the shift from type-I towards type-II MIP led to the concrete technological diffusion to address societal challenges. Technologies and related innovation policies that are shifting towards addressing societal challenges and fall into the same category (i.e., solution in search of a problem) as defined by Wanzenböck et al. (2020), such as self-driving cars and blockchain technologies, could learn from this study.

6.3 Limitations

This study adopted the TIS framework to analyze the success factors and blocking mechanisms of Copernicus for water management in the Netherlands. Besides the TIS, this study aimed to provide insights from a MIP perspective. The presented approach of adopting transformational system failures concept to analyze the results from such a perspective is still new and needs to be broadened and empirically tested in other studies. Doing so, the construct validity, one of the most important criterium for the quality of a study (Bryman, 2016), may be strengthened.

Secondly, to gain in-depth understanding of the systemic processes within the Copernicus TIS, the case of water management in the Netherlands was selected. Furthermore, the segments of risk-mitigation, agriculture, and water quality were selected to analyze detailed processes. For the purpose of this study, this approach was considered highly useful. However, it limits the external validity as described by Bryman (2016). Although the water sector and the Copernicus Programme are highly emblematic, as explained in section 3.6, the particular focus on the water management sector and the selected segments limits the generalizability to other societal settings. To improve the external validity, the framework from Wanzenböck et al. (2020) is used to categorize the current case and draw implications towards similar large publicly funded programs. Nevertheless, future studies should broaden the scope of this research by addressing application domains of Copernicus outside the water sector, and assess the functioning of similar large publicly funded programs other than Copernicus.

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Appendix A: Interview guide English

Thank you for participating in this research by doing this interview. Before I will start with the questions, I will highlight some practicalities. Of course, the interview is for academic purposes only and the data won't be shared with anyone outside the university. Furthermore, the data is only used for analyzing and it will be made anonymously. Then I would like to ask your permission to record the interview, this will allow me to analyze the data. (Yes) Then I will start the recording now.

As mentioned beforehand this interview will be held to study the factors that hamper and support the diffusion of the Copernicus Programme, focusing on the water management sector. Your insights will give a better understanding of different factors that play a role herein. With the results of this study we hope to identify weak and strong points of the Copernicus Programme and the innovation system it is involved in, doing so will give us the opportunity to address these points and give policy recommendations in order to foster the uptake of the program and serve its purpose.

I will start with some introductory questions to get a better understanding of your organization and the relationship with (Copernicus) satellite data.

Questions for end-users

1. Can you explain me a bit about what you and your organization do?

2. Do you use satellite data in your organization?
    a. How? (commercial product, directly from ESA/NASA/etc.)
    b. For what purpose? In which markets? Where?
    c. Does any of this data come from the Copernicus program?
    d. What is the value of this data for your organization?
    e. Do you see your organization as one of the early/ pioneering users of the Copernicus data? What was the vision and motivation behind it?

3. Do you contribute to the goals of Copernicus? (economic and societal value)

4. Do you think the investments in Copernicus are legitimate?
    a. What do others think?
    b. Do you think the Copernicus program has strengthened the position of the EU in the global space sector?
    c. And do you think the structure of the Copernicus program as overly bureaucratic and so less efficient in facilitating market creation?

The following questions are focused on the perception of the use of satellite data. If there is anything unclear, let me know so I will provide some additional context.

5. What is your opinion about the use of satellite data in your field?
    a. Why?
    b. What are the opinions of other people in your field?
    c. Do you and other people know about the possibilities of it?
    d. How did you find out about the availability of these data?
    e. Is it hard to convince people about the possibilities?
    f. Are people willing to use such innovative techniques?

6. Satellite data has a lot of potential in the field of water management. Shouldn't it be used more?
    a. Why (not)?
    b. How?

7. Challenges
    a. Any policy and regulatory barriers in the Netherlands (for example) for your organization to fully use the data?
    b. What are the challenges to deal with your suppliers (in this case the value adding companies)?
    c. Do your suppliers understand and address your problems and needs?
    d. Any coordination issues between you and your suppliers when you use the data on-ground? How are the after-sale services and on-ground support?
    e. What are your organization's strategies to overcome these barriers or challenges?
    f. As a user, does your organization have to be innovative in using these data and services as well? Any trials or experimentations done by your organization?

8. Are there any initiatives to stimulate the use of satellite data? Any specific networks, associations, alliances, sharing platforms, etc.?
    a. Who are responsible of these?
    b. Are these successful?
    c. Can they be improved?
        i. How?

9. Are there enough companies with the capabilities of selling satellite data applications?
    d. Is the quality high enough of the applications?
    e. it difficult for you, as an end-user, to use the satellite data products/services (user-friendly, easy to understand, etc.)?
    f. What do you and others think about the costs for the use of satellite application services?

10. Future prospects
    a. What do you think about the future prospects of these Copernicus satellite data?
    b. Do you think that markets will rely more and more on these data to better conduct water resource management as well as in other sectors?
    c. Do you think that these data and technologies could be better deployed in developing countries? Will there be bigger markets?
    d. In other words, will we see an increasing uptake of the Copernicus data and technologies?

Questions for value-adding companies

1. Can you explain me a bit about you and your organization?

2. How do you use Satellite data in your organization?
    a. To what extend is of value for your organization?

3. Do you use data from the Copernicus programme?
    a. How much?
    b. As an addition to other data?

4. What is your position in the Copernicus value chain?

5. Do you contribute to the goals of Copernicus? (economic and societal value)

6. Do you think the investments in Copernicus are legitimate?
   a. What do others think?
   b. Is it hard to convince people from the potential and opportunities of the program?

The following questions are focused on the market creation process by companies using Copernicus data. If there is anything unclear, let me know so I will provide some additional context.

1. What are the market segments you are focusing on as an organization? (e.g. water quality, draughts, agriculture, etc.)

2. What is the size of the market? How big is the demand to your applications?

3. Is there a lot of entrepreneurial activity in the industry? (many start-ups, experiments etc.)
   a. Do you often try and validate new products or services? If so, how?

4. Where do you get the expertise from? Are there enough resources for this expertise?

5. What is the most critical expertise required in this sector? (Technological/geosciences/etc.)

6. Are there enough financial resources to developed applications from satellite data? (funding/investments/etc.)

7. Do you have any examples of users/customers that are using your services?

8. What is the character of these users? (local/international, size, NGO/governmental, etc.)

9. How do you engage in addressing these users? (ask about intermediary organizations)
   a. What does this process look like?

10. Are there any barriers/incentives in this process? (formal/informal rules, funding, etc.)

11. Since the Copernicus is a large European funded project with ambitious goals, what do you think about their approach? Do you think these goals will be met with the current approach?
    a. What makes sure it does?

12. How can the barriers that have been mentioned in policy, regulations and public opinion, etc. be overcome? (What is your strategy herein?)

13. Now we've almost reached the end of the interview I'd like to ask what your long-term vision is on the Copernicus program? Do you think it will stay an important part for many applications? Or will it be a challenges to integrate Copernicus herein?

14. Thank you very much! Then I'd like to ask if there is anything that you would like to mentioned that might be relevant for this research?

Questions for policymakers/experts

1. Can you explain me a bit about what you and your organization do?
    a. How does this relate to satellite data?
    b. How does this relate to the Copernicus program?
    c. What is your role or the role of your department in this?
    d. Is this especially active in the Netherlands?

2. What do you think about the possibilities of satellite data?
    a. Is this already utilized enough?
    b. Where lay the biggest opportunities?
    c. To what extent is satellite data being used in the water sector?
        i. How?
        ii. Who are active?
        iii. How is this in the Netherlands?

3. What do you think about the Copernicus program?
    a. Do you think the investments herein are legit?
    b. What do others think?
    c. Are these investments already being returned?
    d. Is there still more potential that is not fully utilized?
        i. Why (not)?
        ii. Where lays this potential?

4. What do you think of the goals of the Copernicus program? (economic and societal value)
    a. How is this trying to be achieved?
    b. Are you participating in achieving these goals?
    c. Is the technology helping in achieving these goals?
    d. Are there complementary policies in order to achieve the goals?
    e. Since the Copernicus program is very much aimed at monitoring or accelerating the attainment of the SDGs, was the conception of the program designed based on the needs of the developing countries? Or would you say that is has rather been a 'technology push' approach? What's your professional view on your experience? What would you say?
    f. Is the Copernicus program also aimed at strengthening the position of Europe in the global Space competition? And how is related to the longer-term positioning of ESA internationally?

5. And what are the strategies to ensure the success and ambitions of Copernicus? What is being done in order to foster the use of satellite and Copernicus data? Any specific networks, associations, alliances, sharing platforms, etc.?
    a. Broad strategies (if any)
    b. How about in the NL? In the water sector?
    c. Are these successful?
    d. How can this be (even) more successful?

6. Market
    a. Is the market for the use of satellite data and Copernicus large enough?
    b. What type of end-users are there?
    c. Are the end-users considered in the development of the technology?

7. Are there any barriers that hamper the full uptake of the Copernicus program? (regulations, policies, etc.)

a. Specifically, in NL? In the water sector?
b. How does this hamper the use?
c. And in terms of competition? Are there alternative satellite systems in place that can deliver better data and services than Copernicus? Is there room for joint collaboration or will Copernicus strive to be an independent system?
d. How can all these challenges or barriers be overcome?

8. Development countries
    a. Do you think that these data and technologies could be better deployed in development countries? Will there be bigger markets?
    b. What are the main challenges and barriers to deploy these technologies or create the relevant markets in these development countries?
    c. Are the current policies and regulations conductive enough to help us better understand the needs of users on-ground such as farmers or flood prevention managers in these countries?
    d. How about the local national policies and regulations in these user countries? Are they open for changes or rather setting the barriers for the use of Copernicus data?

9. Future prospects
    a. What do you think about the future prospects of the Copernicus program?
    b. Do you think that markets will rely more and more on these data to better conduct their processes?
    c. In other words, will we see an increasing uptake of the Copernicus data and technologies?
    d. Do you think the Copernicus program will succeed in achieving the ambitious goals? Or are other technologies needed?

That were all the questions. To conclude, I would like to ask if you have any other remarks that might be relevant for this research? If you do not have any questions at the moment, I would like to thank you for your time and help! It has been really helpful, and this should definitely benefit the research. Then I would also like to ask if you can recommend anyone that might be relevant to talk to for this research? (Thank again)

Appendix B: Interview guide Dutch

Fijn dat je tijd kon maken om mij te helpen vanochtend/vanmiddag. Voordat ik begin met het stellen van de vragen zal ik eerst wat praktische zaken toelichten. Namelijk dat dit onderzoek enkel voor academische doeleinden is en voornamelijk voor mijn masteronderzoek. De data zal niet worden gedeeld met mensen buiten de universiteit om. Ook zal de data alleen gebruikt worden voor de analyse en worden de namen van alle deelnemers geanonimiseerd. Zoals eerder gezegd kan ik de resultaten van het onderzoek met jou of jullie bedrijf delen zodra dit is afgerond. Tot slot zou ik je willen vragen of het goed is als ik dit interview opneem? Dit stelt mij in staat om het achteraf goed te analyseren. (Ja) – Dan start ik het opnemen bij deze.

Zoals ik in de mail al had aangegeven probeer ik met dit onderzoek een beter beeld te krijgen van de factoren dat het gebruik van satellietdata positief en negatief beïnvloeden. Ik focus me voornamelijk op het Europese programma Copernicus voor de watersector. Jouw inzichten zal helpen bij dit onderzoek, wat uiteindelijk weer kan leiden tot aanbevelingen in het beleid omtrent satellietdata en het Copernicus programma.

Ik zal beginnen met een aantal introducerende vragen om beter beeld te krijgen van jouw organisatie en de relatie met satellietdata en het Copernicus programma.

Questions for end-users

1. Kan je mij vertellen wat jij en jouw bedrijf/organisatie doet?

2. Gebruiken jullie al satellietdata bij jullie organisatie?
    a. Op wat voor manier? (Een commercieel product / directe data van ESA/NASA/etc.)
    b. Voor welk doeleinde?
    c. Komt de data ook van het Copernicus programma?
    d. Wat is de waarde van deze data voor jouw organisatie?
    e. Zie je jouw organisatie een early-adopter / pionier in het gebruik van Copernicus data? Wat was je motivatie hierachter?

3. Draag je bij aan de sociale en economische doelen van het Copernicus programma? (*Sociaal*: Het toegankelijk maken van informatie die inzicht geven over de aarde en klimaatverandering. *Economisch*: Europese ontwikkelingen dmv de publiek beschikbare data die de Europese economie stimuleren)

4. Vind je dat de Europese investeringen in het Copernicus programma waardevol zijn?
    a. Wat vinden anderen?
    b. Vind je data het Copernicus programma de positie van de EU versterkt in de wereldwijde ruimte sector?
    c. Wat vind je van de structuur van het Copernicus programma? En maakt dit de markt-creatie minder efficiënt?

Nu ik een beter beeld heb van het bedrijf en jullie relatie met satellietdata en het Copernicus programma, wil ik graag wat dieper ingaan op zaken die betrekking hebben tot de perceptie op het gebruik van satellietdata. Als er vragen onduidelijk zijn, hoor ik dat graag dan kan ik wat extra context geven. Ook als je vragen niet kan of wilt beantwoorden is dat geen probleem.

1. Wat is je mening over het gebruik van satellietdata in jouw werkveld?
    a. Waarom?

    b. Wat vinden anderen in jouw omgeving?
    c. Weet men de mogelijkheden van satellietdata?
    d. Hoe ben je erachter gekomen dat deze mogelijkheden hier liggen?
    e. Is het moeilijk om mensen te overtuigen van de mogelijkheden?
    f. Zijn mensen bereidt om zulke innovatieve technieken te gebruiken?

2. Satellietdata heeft veel potentie op het gebied van watermanagement. Zou het niet meer gebruikt moeten worden?
    a. Waarom wel/niet?
    b. Hoe dan?

3. Uitdagingen
    a. Zijn er politieke of reglementaire barrières die het gebruik van satellietdata beperken?
    b. Zijn er uitdagingen waar jullie mee om moeten gaan met betrekking tot jullie leveranciers van satellietdata producten/diensten?
        i. Begrijpen jullie leveranciers deze problemen en doen ze er wat aan?
    c. Wat doen jullie om deze problemen aan te pakken?
    d. Als een gebruiker, moeten jullie zelf ook innovatief zijn om in het gebruik van deze producten en diensten? Doen jullie zelf veel aan experimenteren en uitproberen?

4. Zijn er initiatieven om het gebruik van satellietdata te bevorderen?
    a. Wie zijn hier verantwoordelijk voor?
    b. Zijn deze initiatieven succesvol?
    c. Kunnen ze nog beter?
        i. Hoe?

5. Zijn er genoeg bedrijven in staat om satellietdata producten en diensten te leveren die voldoen aan jullie eisen?
    a. Is de kwaliteit van deze producten en services goed genoeg?
    b. Is het moeilijk of makkelijk om deze producten en diensten te gebruiken? (gebruiksvriendelijk, makkelijk te begrijpen, etc.)
    c. Wat vind jij en anderen van de prijs die gevraagd wordt voor deze producten en diensten?

6. Toekomstperspectief
    a. Zie je nog veel toekomst in het gebruik van Copernicus data?
    b. Denk je dat partijen in de watersector meer en meer gebruik gaan maken van satellietdata? En andere sectoren?
    c. Denk je dat deze data en technologieën nog beter kunnen worden toegepast in ontwikkelingslanden? Liggen daar nog onbenutte makten?
    d. In andere woorden? Gaan we een toename zien in het gebruik van Copernicus data en technologieën?

7. Heel erg bedankt! Dan wil ik nog vragen of er nog iets is waarvan je denkt dat relevant is voor het onderzoek waar ik wellicht vergeten ben naar te vragen?

Questions for value-adding businesses

1. Kan je mij vertellen wat jij en jouw bedrijf/organisatie doen?

2. In hoeverre en op wat voor manier gebruik je satellietdata in je bedrijf?
    a. Hoe belangrijk is dit voor je bedrijf?

3. Gebruik je ook data van het Copernicus programma?
    a. Hoe veel?
    b. Als aanvulling op andere data?

4. Wat is je rol binnen de value-chain van het Copernicus programma?

5. Draag je bij aan de sociale en economische doelen van het Copernicus programma? (*Sociaal*: Het toegankelijk maken van informatie die inzicht geven over de aarde en klimaatverandering. *Economisch*: Europese ontwikkelingen dmv de publiek beschikbare data die de Europese economie stimuleren)

6. Vind je dat de Europese investeringen in het Copernicus programma waardevol zijn?
    a. Wat vinden anderen?
    b. Is het moeilijk om mensen te overtuigen van de potentie en mogelijkheden van het programma?

Nu ik een beter beeld heb van het bedrijf en jullie relatie met satellietdata en het Copernicus programma, wil ik graag wat dieper ingaan op zaken die betrekking hebben op het creëren van een markt omtrent jouw/jullie producten en diensten. Als er vragen onduidelijk zijn, hoor ik dat graag dan kan ik wat extra context geven. Ook als je vragen niet kan of wilt beantwoorden is dat geen probleem.

1. Welke marktsegmenten focus je/jullie op als bedrijf/organisatie? (e.g. waterkwaliteit, droogtes, agricultuur, etc.)

2. Hoe groot is deze markt? Hoe groot is de vraag naar producten en diensten zoals die van jou/jullie?

3. Is er veel ondernemersactiviteit in deze industrie? (e.g. veel start-ups, nieuwe experimenten)
    a. Ben je zelf veel bezig met het testen en ontwikkelen van nieuwe producten en diensten of basis van het Copernicus programma?

4. Waar haal je de kennis vandaan om je producten en diensten te ontwikkelen? (e.g. hoogopgeleide werknemers van bepaalde universiteiten?)

5. Wat is het meest belangrijke kennisgebied dat nodig is voor jouw bedrijf en in de industrie? (e.g. technisch/aardwetenschappen/etc.)

6. Zijn er genoeg financiële middelen om producten en diensten te ontwikkelen op basis van het Copernicus programma (e.g. fondsen/investeringen/etc.)

7. Wat zijn voorbeelden van eindgebruikers die gebruik maken van jouw/jullie diensten en producten?

8. Wat zijn de karakteristieken van deze gebruikers? (Locatie, nationaal/internationaal, grootte, publiek/privaat, etc.)

9. Hoe benader je deze eindgebruikers? (tussenpartijen?)

    a. Hoe ziet dit proces eruit?

10. Zijn er problemen en/of juist hulpmiddelen in dit proces? (e.g. Formeel: regelgeving dat ouderwetse technieken hanteert. Informeel: Stigma omtrent het gebruik van satellietdata, men vertrouwt het niet. Fondsen vanuit de overheid die het proces bevorderen, etc.)

11. Sinds het Copernicus programma een groot Europees gefinancierd project is met zeer ambitieuze doelen, wat vind je van de aanpak van het programma? Denk je dat op de huidige manier deze doelen kunnen worden behaald?
    a. Wat zorgt ervoor dat dit wel/niet lukt?

12. Hoe kunnen alle genoemde barrières gerelateerd aan het beleid, reguleringen, publieke opinie, etc. kunnen worden overkomen? (Wat is jullie strategie hierin? Samenwerken met andere bedrijven/organisaties? Etc.)

13. Nu we bijna aan het einde van het interview zijn aanbeland wil ik je nog vragen wat jouw lange termijnvisie is op het Copernicus programma? Denk je dat het een zeer belangrijk onderdeel wordt voor vele diensten en producten? Of blijft het een uitdaging om de Copernicus data te integreren hierin?

14. Heel erg bedankt! Dan wil ik nog vragen of er nog iets is waarvan je denkt dat relevant is voor het onderzoek waar ik wellicht vergeten ben naar te vragen?

Questions for policymakers/experts

1. Kan je vertel wat jij en je organisatie zoal doen?
    a. Hoe is dit gerelateerd tot satellietdata?
    b. Hoe is dit gerelateerd tot het Copernicus programma?
    c. Wat is jouw rol of de rol van de afdeling hierin?
    d. Is dit specifiek actief in Nederland?

2. Wat vind je van de mogelijkheden van satellietdata?
    a. Worden deze mogelijkheden al genoeg toegepast?
    b. Waar liggen de grootste mogelijkheden?
    c. In hoeverre wordt satellietdata gebruikt in de watersector?
        i. Hoe?
        ii. Wie zijn actief hierin?
        iii. Hoe is dit in Nederland?

3. Wat vind je van het Copernicus programma?
    a. Vind je dat de investeringen hierin legitiem zijn?
    b. Wat denken anderen?
    c. Worden deze investeringen al terugbetaald?
    d. Is er nog meer potentie dat nog niet optimaal benut wordt?
        i. Waarom (niet)?
        ii. Waar ligt de potentie?

4. Wat vind je van de doelen van het Copernicus programma? (economisch en sociale doelen)
    a. Hoe moeten deze doelen behaald worden?
    b. Werk jij er aan om deze doelen te behalen?
    c. Helpt de technologie aan het behalen van deze doelen?

d. Is er aanvullend (politiek) beleid dat helpt om deze doelen te behalen?
e. Aangezien het Copernicus ook sterk bedoeld is om de SDG te monitoren en te behalen, is Copernicus programma ontwikkeld aan de behoeften van ontwikkelingslanden?
f. Is het Copernicus programma ook bedoeld om de Europese positie in de ruimtevaart te verbeteren? Hoe is dit gerelateerd aan de lange termijn positionering van ESA internationaal?

5. Wat zijn de strategieën om de successen en ambities van Copernicus waar te maken? Wat wordt gedaan om het gebruik hiervan te stimuleren? Zijn er specifieke netwerken, samenwerkingen, kennisplatforms, etc.?
   a. Brede strategieën
   b. Hoe zit dit in Nederland? In de watersector?
   c. Zijn deze succesvol?
   d. Hoe kunnen deze (nog) succesvoller worden?

6. Markt
   a. Is de markt voor het gebruik van satellietdata groot genoeg?
   b. Wat voor soorten eindgebruikers zijn er?
   c. Worden de eindgebruikers meegenomen in het ontwikkelen van de technologie?

7. Zijn er barrières die het gebruik van het Copernicus programma negatief beïnvloeden?
   a. Specifiek in NL? In de watersector?
   b. Hoe benadeelt dit het gebruik?
   c. En op het vlak van competitie? Zijn er soortgelijke systemen die hetzelfde doen? Is er ruimte voor samenwerkingen of zal Copernicus individueel blijven functioneren?
   d. Hoe kunnen al deze barrières en uitdagen overwonnen worden?

8. Ontwikkelingslanden
   a. Denk je dat deze data en technologieën beter kan worden toegepast in ontwikkelingslanden?
   b. Wat zijn de grootste barrières en uitdagingen om deze technologieën toe te passen en market te creëren in ontwikkelingslanden?
   c. Is er beleid of regelgeving om de behoeften van eindgebruikers zoals boeren of waterbeheerders beter te begrijpen?
   d. Hoe zit het met lokaal nationaal beleid en regelgeving in deze landen? Staan ze open voor verandering of is dit eerder een barrière?

9. Toekomstperspectief
   a. Wat verwacht je van het Copernicus programma in de toekomst?
   b. Denk je dat markten meer en meer afhankelijk worden van deze data om hun werk uit te voeren?
   c. In andere woorden, gaan we een toename zien in het gebruik van Copernicus data en technologieën?
   d. Denk je dat het Copernicus programma gaat slagen in al haar ambitieuze doelen? Of zijn er andere technologieën nodig?

Dat waren alle vragen, ik wil je nogmaals bedankt voor je tijd en moeite om mee te werken aan dit onderzoek. Nogmaals, ik zal je op de hoogte houden van de uitkomsten van het onderzoek. Ook zou ik je graag nog willen vragen of je nog relevante personen kent die ik kan benaderen voor een soortgelijk interview? (Nogmaal bedanken)