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The Ministry of Higher Education and Science

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MAPPING OF THE KINGDOM OF DENMARK'S USERS OF SPACE GENERATED INFORMATION AND SPACE INFRASTRUCTURE IN THE ARCTIC

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1. EXECUTIVE SUMMARY

The purpose of this report is to provide a mapping and analysis of the central stakeholders in the Kingdom of Denmark with space-related activities in the Arctic by their activities, collaboration and network engagement. Further, the report provides an analysis on the mapped stakeholders' value creation, experienced barriers and mentioned untapped potentials.

The stakeholder landscape in the Kingdom of Denmark

In mapping the stakeholders in the Kingdom of Denmark who are engaged in space-related activity in the Arctic, we first examined the existing knowledge of potentially relevant stakeholders identified as part of the analysis "Statistik om Rumerhvervet" (Rambøll, 2018). These companies were then screened, and companies with more than 20% of their revenue from space related activities were included in the further analysis. Next, the list of extracted stakeholders was then further narrowed down, when it was investigated which of the selected stakeholders that had activities in the Arctic. To identify additional central stakeholders a systematic internet search was undertaken.

With the central stakeholders mapped, the next step in the analysis was to gather information about collaboration and network engagement of these stakeholders. This knowledge was gathered a) in parallel to the search on key terms mentioned above, b) through 6 explorative interviews with selected key stakeholders and c) through a phone survey.

In mapping the **stakeholders with significant[1] space-related Arctic activity**, the study has identified 46 stakeholders. Of these, 16 are companies, 10 are public authorities[2] and 20 are research institutions. Four research institutions are represented through various faculties and departments, thus counting as individual operators. These are the University of Copenhagen (KU), the Technical University of Denmark (DTU), Aarhus University (AU) and Aalborg University (AAU). To various degrees, many of these stakeholders also use downstream 2 information in their work. However, it is not their primary space activity.

Space information is used across **various sectors** in the Arctic. 9 sectors have a high number of stakeholders engaged in space related activities. These are mining and quarrying (23), risk assessments (23), aerial services (22), tourism (21), sovereignty assertion (21), communication (20), telemedicine (20), lake and land measurement (20), environmental and biodiversity (20), and fishing (19).

With regards to space related activities in the Arctic **within earth observation, navigation, and communication**, the survey shows that stakeholders engage equally in the three types of activities. Most of the survey respondents use satellite information for both earth observation (75%), navigation (78%) and communication (75%), while less than half of the respondents is engaged in other upstream activities than satellites (47%).

[1] For definition, see abbreviations

[2] The three identified departments of the Government of Greenland count as one public authority.

The study also examines the **collaboration within space technology, information and infrastructure in the Arctic**. In total 148 collaboration linkages, encompassing 42 stakeholders in the Kingdom of Denmark and spanning five collaboration categories (knowledge sharing, data exchange, project collaboration, product collaboration and research collaboration) have been mapped. Most collaboration linkages are related to project collaboration (56), followed by exchange of data (30), product collaboration (25), knowledge exchange (20), and lastly research collaboration (17). The frequency of collaboration also varies. Most collaboration is on a yearly (55) or monthly basis (52), and a minor part on a weekly basis (22) and daily basis (18).

The most significant **national networks** can be divided into three types; 1) research networks, 2) defence networks, and 3) other (for instance, informal networks or networks with a primary focus on the Arctic). The research networks are Forum for Arctic Research, Villum Research Institution, Nuuk Basic, and ISAAFFIK. The defence networks identified are Censec, Danish Defence and Security Industries Association (DI FAD) and Defend Arctic. Other networks are the Arctic Space Partnership, Mariot and an informal EMSA-network.

The relevant **international networks** can be divided into two overall categories based on a distinction of the organisation and purpose of the network; intergovernmental networks and research networks. The identified intergovernmental networks are ESA networks, The Nordic Council, and the Arctic Monitoring and Assessment Programme (AMAP). The key international research networks identified are Greenland Ecosystem Monitoring (GEM), INTAROOS, ESA Climate Change Initiative (ESA CCI), Ice Arc, Programme for Monitoring of the Greenland Ice Sheet (PROMICE), and Arctic Science Partnership (ASP).

Mapping value creation, potential and barriers

This part of the analysis focuses on mapping socio-economic value creation, barriers and value-creating untapped potentials resulting from the use of space-generated data and space infrastructure identified by key representative stakeholders. The analysis in the previous phase informs this phase, along with 10 semi-structured, in-depth interviews with selected key stakeholders. Moreover, the results of the interviews were supplemented with responses provided from the phone survey.

In **mapping the activities related to the use of space information and infrastructure**, value is created through a *combination* of activities and use of services and products among the stakeholders, rather through a single line of activities. For the **public authority stakeholders**, the primary activities are monitoring (earth and marine activities) and communication. The value creation for society from the governmental activities stems from enforcing regulations and national sovereignty, providing security and lowering risk for marine traffic. This supports (increased) activities in the Arctic to the benefit of local and national businesses and citizens. Some government stakeholders are also involved in mapping and monitoring land areas, which supports both local environmental protection and conservation as well as municipal activities such as land planning.

For the **companies**, their main activities are related to delivering commercial raw and/or processed data, analyses and data infrastructure to other stakeholders. The stakeholders receiving this data then engage in activities that drive value creation within a wide range of areas

such as (local) economic growth, environmental protection and climate issues, among others. Most of the activities mentioned by the **research institutes** are related to earth observational data and used for mapping, monitoring and modelling local environmental and climate factors. These activities drive value creation mainly on climate policy, environmental and cultural protection, education as well as indirectly supporting (local) economic development. The activities of the research institutes also contribute to the continuation of and/or expansion of research within these fields by providing new research.

In **mapping the barriers**, it is seen that these are mainly related to inadequate geographic coverage, timeliness and the price of the data. These barriers mainly affect the enforcement of regulations and national sovereignty, search and rescue missions and the support of political activities of collaboration and defence and security. When looking at the correlation between the stakeholders' engagement in networking and collaboration and the identified barriers, the following characteristics emerge:

- the more engaged the stakeholder is in networking and/or collaboration more and more often barriers are expressed,
- lack of information is most frequently expressed by the stakeholders who are either highly engaged or not at all engaged in networking and collaborative activities, and
- barriers are generally experienced across the networks.

The most frequently mentioned **potentials** were to establish datahubs (for researchers as well as general use) and to improve collaboration among stakeholders in accessing and analysing data. Also, there is potential value to be had for society in addressing the complexity currently inherent in accessing and using the satellite data. A datahub could support this, as could an earlier introduction of the uses of satellite data in complementary university subjects to raise awareness. Both stakeholders with frequent collaboration and stakeholders with low collaboration highlight access to information as an untapped potential. In particular, stakeholders with frequent collaboration see a potential for streamlining their existing activities further and thereby gaining more value from the collaboration. Stakeholders with low levels of collaboration see a potential in better access to data, which eases the access to information and knowledge about the potential for using space related data in the Arctic.

2. RESUME

Formålet med denne analyse er at kortlægge de centrale aktører i Kongeriget Danmark med rumrelaterede aktiviteter i Arktis på baggrund af deres aktiviteter, samarbejde og netværksengagement. Derudover har vi analyseret den værdiskabelse, rumrelaterede aktiviteter i Arktis giver, samt de oplevede barrierer og uudnyttede potentialer for øget aktivitet.

Overblik over interessenter i Kongeriget Danmark

I kortlægningen af interessenter i Kongeriget Danmark med rumrelateret aktivitet i Arktis, har vi taget udgangspunkt i de interessenter, der blev identificeret som en del af analysen "Statistik om Rumerhvervet". Disse virksomheder blev screenet, og virksomheder med mere end 20% af deres indtægter fra rumrelaterede aktiviteter blev inkluderet i den videre analyse. Dernæst undersøgte vi interessenternes aktiviteter i Arktis. De interessenter, der ikke havde aktiviteter i Arktis, blev frasorteret.

For at identificere yderligere centrale interessenter, som ikke var blevet fanget i ovenstående metode, udførte Rambøll en systematisk internetsøgning på udvalgte søgeord.

Med de centrale interessenter kortlagt var næste trin i analysen at indsamle information om samarbejde og netværksengagement blandt disse interessenter. Denne viden blev samlet a) i den systematiske internetsøgning nævnt ovenfor, b) gennem 6 kvalitative interviews med udvalgte nøgleinteressenter og c) gennem en telefonundersøgelse.

I kortlægningen af interessenter med betydelig[3] rumrelateret aktivitet i Arktis har vi identificeret 46 interessenter. Af disse er 16 virksomheder, 10 offentlige myndigheder og 20 forskningsinstitutioner. Fire forskningsinstitutioner er repræsenteret gennem forskellige fakulteter og afdelinger og tæller således som individuelle operatører. Disse er Københavns Universitet (KU), Danmarks Tekniske Universitet (DTU), Aarhus Universitet (AU) og Aalborg Universitet (AAU). Flere af disse interessenter arbejder også med downstream 2-aktiviteter, uden at dette dog er deres primære rumaktivitet.

Ruminformation bruges i forskellige sektorer/områder i Arktis. Det største antal interessenter, der beskæftiger sig med rumrelaterede aktiviteter, er aktive indenfor de følgende 9 områder: minedrift (23), risikovurderinger (23), luftfartstjenester (22), turisme (21), suverænitetshævdelse (21), kommunikation (20), telemedicin (20), hav- og landmåling (20), miljø- og biodiversitet (20) og fiskeri (19).

I forhold til rumrelaterede aktiviteter i Arktis inden for jordobservation, navigation og kommunikation viser undersøgelsen, at der er en lige fordeling af interessenter i de tre aktiviteter. De fleste respondenter bruger satellitinformation til både jordobservation (75%), navigation (78%) og kommunikation (75%), mens mindre end halvdelen af de adspurgte beskæftiger sig med andre upstream-aktiviteter end satellitter (47%).

[3] Mere end 20% af omsætningen stammer fra rumrelaterede aktiviteter

Undersøgelsen har også kortlagt, i hvor høj grad aktørerne samarbejder inden for rumteknologi, information og infrastruktur i Arktis. I alt er der kortlagt 148 samarbejdsrelationer, der omfatter 42 interessenter i Kongeriget Danmark og spænder over fem typer af formål. De fleste samarbejder er relateret til projektsamarbejde (56), efterfulgt af dataudveksling (30), produktsamarbejde (25), vidensudveksling (20) og endelig forskningssamarbejde (17). Analysen viser også, at hyppigheden af samarbejdet i netværkene varierer: Det meste samarbejde foregår årligt (55) eller månedligt (52) og en mindre del på ugentlig basis (22) og daglig basis (18).

Netværkene med deltagelse af aktører baseret i Kongeriget Danmark kan opdeles i tre typer: forskningsnetværk, forsvarsnetværk og andre (for eksempel uformelle netværk eller netværk med et primært fokus på Arktis). Forskningsnetværkene er Forum for arktisk forskning, Villum forskningsinstitution, Nuuk Basic og ISAAFFIK. De identificerede forsvarsnetværk er Censec, Danish Defence and Security Industries Association (DI FAD) og Defend Arctic. Andre netværk er Arctic Space Partnership, Mariot og et uformelt EMSA-netværk.

De internationale netværk kan opdeles i to overordnede kategorier; mellemstatslige netværk og forskningsnetværk. De identificerede mellemstatslige netværk er ESA, Nordisk Råd og det arktiske overvågnings- og vurderingsprogram (AMAP). De identificerede internationale forskningsnetværk, er Greenland Ecosystem Monitoring (GEM), INTAROOS, ESA Climate Change Initiative (ESA CCI), Ice Arc, Program for Monitoring of the Greenland Ice Sheet (PROMICE) og Arctic Science Partnership (ASP).

Kortlægning af værdiskabelse, potentiale og barrierer

Denne del af analysen fokuserer på den socioøkonomiske værdi, som rumrelaterede aktiviteter i Arktis skaber i Kongeriget Danmark. Endvidere har vi identificeret barrierer og uudnyttede potentialer, som interessenterne oplever i forhold til arbejdet med rumrelaterede aktiviteter i Arktis. Analysen baserer sig på viden fra den forrige fase, sammenholdt med 10 semistrukturerede dybdeinterviews med udvalgte nøgleinteressenter. Desuden blev resultaterne af interviewene suppleret med svar fra telefonundersøgelsen.

Analysen viser, at den samfundsmæssige værdiskabelse af rumrelaterede aktiviteter i Arktis især sker gennem en *kombination* af aktiviteter blandt interessenterne snarere end gennem enkeltstående typer af aktiviteter. De **statslige** aktiviteter i Arktis koncentrerer sig især om overvågning af aktiviteter både på land og til søs, samt kommunikation. Nogle statslige interessenter er også involveret i kortlægning og overvågning af landområder. Den samfundsmæssige værdi fra de statslige aktiviteter er dermed en bedre håndhævelse af regler og national suverænitet, samt en øget sikkerhed for især trafikken til søs.

Virksomhedernes rumrelaterede aktiviteter i Arktis relaterer sig især til at levere data, analyser og datainfrastruktur, til brug for andre interessenter. De interessenter, der modtager disse data, deltager derefter i aktiviteter, der skaber samfundsmæssig værdi inden for en lang række områder såsom (lokal) økonomisk vækst, miljøbeskyttelse og klimaspørgsmål.

De fleste af de rumrelaterede aktiviteter i Arktis, der er nævnt af **forskningsinstitutionerne**, er relateret til jordobservationsdata og bruges til kortlægning, overvågning og modellering af lokale

miljø- og klimafaktorer. Disse aktiviteter skaber blandt andet samfundsøkonomisk værdi i forhold til bedre afsæt for at kunne rådgive om klimapolitik og miljøbeskyttelse samt indirekte støtte til (lokal) økonomisk udvikling.

Kortlægningen af barrierer for øget rumrelateret aktivitet i Arktis viser, at disse hovedsageligt omfatter utilstrækkelig geografisk dækning, manglende aktualitet i data samt høje priser for rekvirering af data. På et samfundsøkonomisk niveau medvirker disse barrierer til at hindre optimal håndhævelse af regler og national suverænitet, eftersøgnings- og redningsopgaver. Desuden kan de potentielt udfordre det politiske samarbejde omkring forsvar og sikkerhed.

Barriererne ovenfor fremhæves hyppigst af de interessenter, der oftest deltager i netværk, hvilket antyder, at det er vedvarende barrierer, der er tale om. Det ses da også, at barriererne opleves på tværs af typerne af netværk, altså både i forskningsnetværk, forsvarsnetværk, og de øvrige netværk.

Især et potentiale for at mindske barriererne og øge de rumrelaterede aktiviteter i Arktis fremhæves af interessenterne. Den påvirker især de barrierer, der handler om data og omhandler muligheden for at gøre det lettere at dele data, for eksempel gennem en central dataplatform. En sådan platform forventes at kunne forbedre muligheden for at dele data, skabe opmærksomhed om mulighederne for dataanvendelse og potentielt muliggøre, at data kan genbruges eller gensælges.

Både interessenter, som deltager hyppigt i netværk, og interessenter, som ikke så ofte deltager i netværk, fremhæver adgang til information som et uudnyttet potentiale. Især ser interessenter med hyppigt samarbejde et potentiale for at strømline deres eksisterende aktiviteter yderligere og derved få mere værdi af samarbejdet. Interessenter med lav hyppighed i samarbejdet ser et potentiale for bedre adgang til data, hvilket letter adgangen til information og viden om potentialet for at bruge rumrelaterede data i Arktis.

3. INTRODUCTION

In 2016, the then government launched Denmark's first strategy on how space activities can contribute to growth while helping to solve several key issues for society. Since then, the Ministry of Higher Education and Science has initiated an Arctic partnership focusing on the opportunities in the use and dissemination of space-generated information, technologies and infrastructures across authorities, researchers and companies in the Arctic. However, in order to take full advantage of these opportunities, it is essential to have a solid overview of supply, potential customers and types of services.

The purpose of this report is threefold:

- to provide a mapping of the central stakeholders in the Kingdom of Denmark and their activities related to space-generated data and infrastructure in the Arctic,
- to investigate their engagement in collaboration and networking, and
- to assess the value creation of the use of space-generated for society.

Delimitations of focus areas and actors

The following delimitations have been used throughout the analysis:

The first of these is to only include significant stakeholders in the analysis. With significant is meant stakeholders where 20% or more of their revenue can be ascribed to space and arctic related activities. This is done in order to ensure that the analysis focus on the most relevant stakeholders.

The second of the delimitations follows in essence from the first, as it is a limitation on the scope of stakeholders to include in the mapping and further analysis. The delimitation has been done to mainly include upstream and downstream 1 stakeholders, with addition of any significant (see above) downstream 2 stakeholders. In general, what is meant by "upstream activity in the Arctic" vary between the types of actors. The identified companies with upstream activities are primarily engaged in satellite development, whereas the research institutions are engaged in other forms of upstream activity e.g. the development of measuring stations and uploading of in-situ data. A number of survey respondents state that they are involved in 'other activities than satellite development e.g. the development of measuring stations' but does not regard themselves as being involved in upstream activities. This calls for cautious use of the term going forward, as very clear definitions are needed in order to avoid misunderstandings.

Summary of analysis method

In performing the mapping and analysis, the process was structured into two main phases;

Phase 1 which consisted of a combination of desk-research, interviews and phone surveys to uncover the list of central stakeholders, their space- and Arctic related activities, collaborations and network engagements.

Phase 2 which consisted of in-depth interviews with key identified stakeholders to explore value-creation streams, barriers and potentials in the use of space-generated data and infrastructure.

4. ABBREVIATIONS AND DEFINITIONS

Technical abbreviations

AIS	Automatic identification system
DANCEA	Danish Cooperation for Environment in the Arctic
GIS	Geographic Information System
GNET	Greenland GNSS Network
GPS	Global Positioning System
PROMICE	Programme for Monitoring of the Greenland Ice Sheet
SAR	Search and Rescue
UAS	Unmanned Aerial Systems
VDES	VHF Data Exchange System

Stakeholder abbreviations

AMAP	Arctic Monitoring and Assessment Programme
Arctic SDI	Arctic Spatial Data Infrastructure
ASP	Arctic Science Partnership
AU	Aarhus University
AU ARC	Aarhus University Arctic Research Centre
AUSAT	Aarhus University Satellite Project
Censec	Center for Defence, Space & Security in Denmark
DALO	Danish Defence Acquisition and Logistics Organization
DANCEA	Danish Cooperation for Environment in the Arctic
DCDA	Defence Command Denmark
DDIS	Danish Defence Intelligence Service
DFM	Danish Foreign Ministry
DI FAD	Danish Defence and Security Industries Association
DMA	Danish Maritime Authority
DMI	Danish Meteorological Institute
DTU	Technical University of Denmark
EMS	Copernicus Emergency Management Service
EMSA	European Maritime Safety Agency
ESA	European Space Agency
ESA CCI	ESA Climate Change Initiative
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAMRI	Havstovan Faroe Marine Research Institute
GEM	Greenland Ecosystem Monitoring
GEUS	Geological Survey of Denmark and Greenland

GG	Government of Greenland[4]
GINR	Greenland Institute of Natural Resources
KU	University of Copenhagen
MARIOT	Maritime IoT
PROMICE	Programme for Monitoring of the Greenland Ice Sheet
SDFE	Danish Agency for Data Supply and Efficiency
SDU	University of Southern Denmark
SDU UAS	SDU Unmanned Aerial Systems Center
UFM	Ministry of Higher Education and Science
VØRS	Faroe Ministry of Fisheries
AAU	Aalborg University

Definitions

Upstream	Production of space-related products Focus area 1: Development of space-related instruments, measuring stations or missions where the purpose is to gather new data or ways of using data.
Downstream 1	Services from satellite operators Focus area 2: The use or processing of raw data from or via satellites for e.g. cryosphere research, climate research, land and ocean ice movements, geology, environment and geomagnetism.
Downstream 2	Services provided to consumers Focus area 3: The use of processed data from or via satellites for e.g. communication and navigation at sea, on land and in the air, maritime security, monitoring, weather forecasts, ice-maps, fishing and communication systems.
Stakeholders	Companies, public authorities and researchers who are based in the geographic area defined as the Kingdom of Denmark
Significant space-related activity	The term "significant" in this context means where 20% or more of company revenue can be ascribed to space and arctic related activities. For significant space-related activity by public authorities and research institutions this has been assessed individually from stakeholder to stakeholder.
Space-related solutions	Solutions that lies within the segments of upstream/focus area 1, Downstream 1/focus area 2 and Downstream 2/focus area 3
The Arctic	The definition as developed and described by the Arctic Council (see "Forsvarsministeriet, 2016: Forsvarets fremtidige opgaveløsning I Arktis")

[4] We use the term used by the Government of Greenland itself, see https://naalakkersuisut.gl/en/Naalakkersuisut

5. MAPPING THE STAKEHOLDER LANDSCAPE FOR SPACE INFORMATION AND INFRASTRUCTURE IN THE KINGDOM OF DENMARK

This chapter provides an overview of stakeholders in the Kingdom of Denmark with activities related to space information and infrastructure in the Arctic. The chapter gives an overview of relevant upstream and downstream stakeholders, their activity related to space information and infrastructure, and their collaboration – both bilaterally and in formalised networks.

When reading this chapter, it should be noted that it has not been within the scope of this mapping to assess and weigh the stakeholders' size (such as number of employees) in relation to the mapped activity. This means that the tables illustrate the number of stakeholders engaged in a specific area, but not the magnitude of the activities.

The chapter has three subsections. The first section will give an overview of central stakeholders with significant Arctic space activity in the Kingdom of Denmark, and these stakeholders' specific activity related to space information and infrastructure in the Arctic. The stakeholders are divided into three groups by their general type:

1) Companies
2) Public authorities
3) Research institutions

The second section will focus on collaboration linkages and forms between central stakeholder types, and the third section will provide overview of central international and national networks.

5.1 Stakeholders with significant space-related Arctic activity

This section outlines the companies, public authorities and research institutions identified with significant space-related activity in the Arctic.[5] Furthermore, the section illustrates whether the stakeholders engage in upstream or downstream activity, and whether their focus is on earth observation, navigation and/or communication.

The study has identified 46 stakeholders engaged in significant space-related activity in the Arctic. Of these, 16 are companies, 10 are public authorities[6] and 20 are research institutions. Four research institutions are represented through various faculties and departments, thus counting as individual operators. These are University of Copenhagen (KU), Technical University of Denmark (DTU), Aarhus University (AU) and Aalborg University (AAU). To various degrees, many of these stakeholders also use downstream 2 information in their work, yet not being their primary space activity, why it is not highlighted in Table 5-1 below.

[5] Significant space-related activity has been defined differently depending on the type of stakeholder. For companies the study has set a threshold which define significant as when app. 20% or more of the stakeholders' activities rely on the use of space-related information or infrastructure. Significant space-related activity by public authorities and research institutions has been assessed individually from stakeholder to stakeholder. All identified stakeholders with significant space-related activity has been included if they have any Arctic activity.

[6] The three identified departments of the Government of Greenland count as one public authority.

In general, relatively few stakeholders are engaged in upstream and downstream 2 only. In some categories only two types are represented. In downstream 1 without upstream there are no public authorities, and in downstream 2 only there are no research institutions. The space activities differ crosswise of companies, research institutions and public authorities. Most research institutions are engaged in downstream 1 and/or upstream activities, while no one is having downstream 2 activities only.

For companies, the majority are engaged in downstream 1 activities, while there is an even split in the last three categories. In relation to public authorities, the large majority of these either having downstream 1 activities or upstream and downstream 1 activities. Relatively few are engaged in upstream or downstream 2 activities only.

Table 5-1 Overview of stakeholders in the Kingdom of Denmark with significant space-related activity in the Arctic

Upstream (8)	Downstream 1 (14)	Upstream and downstream 1 (18)	Downstream 2 only (6)
• Terma • Gomspace • Spaceinventor • Danish Defence Acquisition and Logistics Organisation (DALO) • Danish Defence Intelligence Service (DDIS) • Danish Transport and Construction Authority / Naviair (Aireon) • Security DTU • SDU Unmanned Aerial Systems Center (SDU UAS)	• Harnvig Arctic Maritime • Satlab • Royal Greenland • Polaris Electronics • Asiaq • Orbicon Arctic • DHI Gras • Navicon • DTU Aqua • DTU Civil Engineering • AU Department of Bioscience • AU Department of Environmental Science • AAU Arctic • Havstovan Faroe Marine Research Institute (FAMRI)	• RadioLab Consulting • GateHouse Group • Agency for Data Supply and Efficiency (SDFE) • Danish Meteorological Institute (DMI) • Geological Survey of Denmark and Greenland (GEUS) • Government of Greenland • DTU Space • Arctic DTU • AU Arctic Research Centre • AU Faculty of Technical Sciences • AAU Department of Electronic Systems • AAU Department of Planning • KU Faculty of Science • KU Department of Biology • KU Department of Geography • KU Arctic Station • KU Niels Bohr Institute • Greenland Institute of Natural Resources (GINR)	• Sternula • Scandinavian Avionics • TELE Greenland • Defence Command Denmark (DCDA) • Danish Maritime Authority (DMA) • Faroe Ministry of Fisheries (Vørn)

Green = companies / Blue = public authorities / Magenta = research institutions

5.1.1 Companies

In 2018, the amount of national companies engaged in the space industry of the Kingdom of Denmark, amounted to 199[7]. Relative to this figure, fewer national companies are engaged in space-related activities in the Arctic.

In total, 36 national companies have been identified to have space-related activity in the Arctic region. This include companies engaged in both upstream and downstream 1 and 2 activities. Of the 36 companies, 15 are engaged in upstream activities, 8 in downstream 1 activities and 27 in downstream 2 activities.

However, of these 36 companies, only 15 have significant space-related activity in the Arctic. These companies are primarily engaged in upstream and/or downstream 1 activities and are illustrated in Table 5-2 below.

The analysis has been delimited to only include the most central stakeholders who are engaged in the use of processed space-generated data (downstream 2), such as companies using GNSS information for modern navigation. This delimitation follows from the purpose of the analysis, which is to map the central, i.e. significant, stakeholders where use of space-generated data and space infrastructure comprises a key component within the stakeholders' activities. The downstream 2 stakeholders identified, with such significant activities and selected to be included in the analysis, is listed along with the Upstream and downstream stakeholders in Table 5-2 below. More downstream 2 navigation stakeholders are, however, represented[8].

The table is structured in such a way that companies with a high part of space-related activity are placed at the top, and those with less activity at the bottom.

The table reveals that companies engaged in upstream activity only (Terma, Gomspace, SpaceInventor), in general have less space-related activity than those engaged in several types of space-related activities. Furthermore, it shows that most companies involved in downstream 1 activities are also engaged in downstream 2 activities, and that those companies engaged in several space-related activities often use space information for both earth observation, navigation and communication (Harnvig Arctic and Maritime IVS, Satlab, RadioLab Consulting, Royal Greenland, Polaris Electronics, Asiaq Greenland Survey, GateHouse Group). Companies engaged only in downstream 1 activities (Orbicon Arctic and DHI Gras), focus merely on earth observation.

[7] Rambøll (2018), Opdateret statistik om rumerhvervet samt analyse af rumerhvervets vækstpotentiale.

[8] These include Greenland Oil Spill Response, Nordic Bulk Carriers, and Royal Arctic Line.

Table 5-2 Companies in the Kingdom of Denmark with significant space-related activity in the Arctic

		SPACE ACTIVITY			FOCUS AREA		
COMPANY	SPACE-RELATED ACTIVITY	Upstream	Downstream 1	Downstream 2	Earth observation	Communication	Navigation
Harnvig Arctic and Maritime	Harnvig Arctic and Maritime IVS provide services for exploring activities in relation to oil, gas and minerals in the Arctic region.		X	X	X	X	X
Satlab	Satlab specializes in advanced radio systems for highly embedded applications.		X	X	X	X	X
Sternula	Sternula offers Arctic VDE-SAT connectivity for maritime authorities and industry through their own fleet of advanced micro satellites in Low-Earth Orbit (LEO) which will be operational from 2022.			X		X	
RadioLab Consulting	RadioLab provides consultancy within space-related activities in the Arctic, including satellite communication, navigation, space technology, missions and system design, proposal writing to ESA, other space agencies and space companies.	X	X	X	X	X	X
Terma A/S	In the Arctic, Terma focuses on navigation/warnings and securing communication. Termas Command & Control System, C-Flex, is installed in all Danish Defence naval units. In addition, the Danish Defence system, Arctic OPVs, also holds Terma's SCANTER 4100 radar system,	X			X		
Orbicon Arctic	In the Arctic, Orbicon Arctic provides consultancy within environment, utility, infrastructure and construction, among other services.		X		X		
Scandinavian Avionics	Globally and in the Arctic, Scandinavian Avionics provides complete turn-key avionics solutions for civil and military aircraft, helicopters and UAS.			X		X	
Royal Greenland	Royal Greenland A/S is a fishing company in Greenland, owned by the Government of Greenland, using modern satellite navigation and downstream 1 activities.		X	X	X	X	X

		SPACE ACTIVITY			FOCUS AREA		
COMPANY	SPACE-RELATED ACTIVITY	Upstream	Downstream 1	Downstream 2	Earth observation	Communication	Navigation
TELE Greenland	TELE Greenland is the largest telecommunication company in Greenland. It has multiple telecommunication infrastructure technologies, including submarine fibre network, radio links, satellites, satellite connections.			X	X	X	X
DHI Gras	In the Arctic, DHI Gras carries out satellite data analysis and remote sensing for hydrology, water quality, environmental assessment and land cover mapping.		X		X		
Polaris Electronics	Polaris Electronics A/S delivers communication and navigation systems to the maritime market. They have developed NAVTEX, active antennas and tracking systems, being sold worldwide.		X	X	X	X	X
Asiaq Greenland Survey	Asiaq Greenland Survey undertakes surveys and research projects based on non-living physical data from the environment in Greenland. Asiaq is 100% owned by the Greenlandic Government and has surveyed all around in Greenland for more than 60 years.		X	X	X	X	X
GateHouse Group	Gatehouse is specialised in satellite communication and maritime surveillance and has their own Arctic satellites, which can deliver good quality data and pictures with high frequency and resolution. Gatehouse monitors more than 200.000 ships and delivers both communication and navigation services.	X	X	X	X	X	X
GomSpace	GomSpace is a global leading manufacturer and supplier of cubesat and small satellite solutions. In 2018, Gomspace launched the GOMX-4A satellite as part of the GOMX research and development mission, including 2 satellites and 3 partners: DALO, DTU, and ESA.	X			X	X	X

		SPACE ACTIVITY			FOCUS AREA		
COMPANY	SPACE-RELATED ACTIVITY	Upstream	Downstream 1	Downstream 2	Earth observation	Communication	Navigation
Space Inventor	Space Inventor is one of six partners in the MARIOT project (Maritime IoT), which aims at developing a satellite based maritime IoT network to demonstrate selected maritime/arctic services using VDES. Space Inventor is responsible for the overall satellite platform for the MARIOT-1 satellite, which will be the first of 50 satellites to be launched by the operator and leading project partner Sternula.	X			X	X	X
Navicon	NAVICON provides software for AIS, VTS, Command- and Control, and Navigation Systems. They are prime contractor for the Royal Danish Navy Command Control and Information System		X	X		X	X

Source: Ramboll

5.1.2 Public authorities

The Ministry of Higher Education and Science is responsible for the coordination and framework development among public authorities with space-related responsibilities in the Kingdom of Denmark. The ministry has set up the Interministerial Space Committee with representatives from eight ministries. These are: 1) Ministry of Higher Education and Science (chair), 2) Ministry of Defence, 3) Ministry of Environment and Food, 4) Ministry of Finance, 5) Ministry of Industry, Business and Financial Affairs, 6) Ministry of Transport and Housing, 7) Ministry of Foreign Affairs, 8) Ministry of Climate, Energy and Utilities.

Eight agencies have been identified from these above-mentioned ministries having significant space-related activity in the Arctic (see Table 5-3 below). Three relevant agencies have also been identified under the Government of Greenland, and one from the Government of Faroe Islands**.** These agencies, and their space-related activities, are described in the table below.

Table 5-3 Public authorities in the Kingdom of Denmark with significant Arctic activity

		SPACE ACTIVITY			FOCUS AREA		
MINISTRY	AGENCY	Upstream	Downstream 1	Downstream 2	Earth observation	Communication	Navigation
Ministry of Climate, Energy and Utilities (KEFM)	Agency for Data Supply and Efficiency (SDFE)	X	X	X	X		
	Danish Meteorological Institute (DMI)	X	X	X	X		
	Geological Survey of Denmark and Greenland (GEUS)	X	X	X	X		
Ministry of Defence	Defence Command Denmark (DCDA)			X	X	X	X
	Danish Defence Acquisition and Logistics Organisation (DALO)	X		X	X	X	X
	Danish Defence Intelligence Service (DDIS)	X		X	X	X	X
Ministry of Industry, Business and Financial Affairs	Danish Maritime Authority (DMA)			X			X
Ministry of Transport and Housing	Danish Transport and Construction Authority / Naviair (Aireon)	X		X		X	X
The Government of Faroe Islands	Ministry of Fisheries / Vørn (MRCC Tórshavn Maritime Rescue Co-ordination Center)			X	X	X	X
Government of Greenland	The Ministry of Housing and Infrastructure The Ministry of Labour and Mineral The Ministry of Finance	X	X	X	X	X	X

Source: Ramboll

Ministry of Climate, Energy and Utilities (KEFM)

Agency for Data Supply and Efficiency (SDFE)

SDFE collects, quality assures, compiles and distributes Arctic data for Danish public authorities, the Government of Greenland and research institutions.

GNET was handed over to the Kingdom of Denmark in 2019. In this connection, the overall responsibility as well as the administration of GNET's continued development and maintenance was delegated to SDFE. GNET is the basic geodetic infrastructure in Greenland. GNET is based in measurements performed with high quality and precision. Together the measurements form a geodetic network, which is a prerequisite for accurate land and sea mapping. GNET is therefore currently used primarily for climate research and mapping. With regards to land mapping, SDFE works towards total satellite mapping of the entire ice-free land area in Greenland[9].

[9] The project, which is undertaken in collaboration with the Government of Greenland, the Danish Ministry of Defence, Acquisition and Logistics Organisation and the A.P. Moller Foundation amounts to more than DKK 60 million and will run until 2022.

SDFE has expertise in the collection, interpretation and use of data from drone, aircraft and satellite. There are three central downstream Arctic projects in SDFE, these being vector mapping, orthophotos and a height model covering all of Greenland. Vector mapping is based on data (orthophotos) from the WorldView satellite operated by Maxar. The orthophotos are primarily based on data from Copernicus Sentinel 2, and the measuring points are based on GNSS. Furthermore, SDFE represents Denmark in the UserForum of the joint European satellite program Copernicus and chairs the National Copernicus UserForum.

Finally, SDFE represents Denmark in the joint Arctic initiative, Arctic SDI (Spatial Data Infrastructure), which aims to establish a joint Arctic geographical infrastructure with contributions from the eight member countries of the Arctic Council. Besides representing Denmark, SDFE delivers data to the Arctic SDI Geoportal, providing digital topographic maps and geodata of the Arctic.

Danish Meteorological Institute (DMI)
DMI has several important roles in relation to downstream and upstream activity in the Arctic. In the Arctic, DMI is responsible for climate monitoring, in particular of ocean and sea ice surface temperature, sea ice extent, concentration and thickness. In addition, DMI has various marine activities in the Arctic, including ocean currents, sea ice and wave forecasting. DMI's Ice Service is responsible for operational ice charting of the Greenlandic waters as well as for identification and mapping of icebergs for marine safety. The satellite data supports safety at sea through remote sensing data.

DMI primarily uses geostationary and polar orbiting satellites, processes satellite data internally and ensures distribution to public authorities, Copernicus, ESA, EUMETSAT, research institutions etc. In addition to the free products on the website ocean.dmi.dk, DMI offers consultancy services in the Arctic using satellite data within areas like ocean data, user-specified forecasts for ocean or ice, analysis and professional advising.

DMI also supports ESA, Copernicus and EUMETSAT in the development of the next generation of satellites.

Geological Survey of Denmark and Greenland (GEUS)
GEUS uses downstream data to exploit and protect geological resources in Greenland. On an overall level, GEUS monitors land ice, whereas DMI monitors sea ice. This includes monitoring of ice extent, altitude changes of inland ice and iceberg production through Sentinel and geostationary satellites. In Greenland, GEUS also uses satellite data to map landslides. The primary sources are radar satellites and SAR from Sentinel 1 as well as optical data from Sentinel and Insat (India). Furthermore, GEUS uses multispectral data for detecting minerals.

Over the past 20-30 years, GEUS has collected a large amount of airborne geophysical and remote sensing data in Greenland. Land data have been collected in ice-free and coastal areas from aircraft and/or helicopters with a focus on systematic regional mapping. Mining companies operating in Greenland benefit greatly from GEUS regional data (Pedersen, 2016).

GEUS also heads the Programme for Monitoring the Greenland Ice Sheet (PROMICE), which is monitoring the mass loss from the ice sheet. The glaciological data includes measurements of ice

melt, climate and ice movement from 25 monitoring stations as well as monitoring data from aerial measurements and satellites.

Ministry of Defence

Defence Command Denmark (DCDA)
DCDA holds the overall responsibility for policing and defence of The Kingdom of Denmark, including Greenland, the Faroe Islands and the adjacent Arctic area. DCDA utilizes satellite information for earth observation, navigation and communication. The tasks being solved with assistance from satellite data include: surveillance and enforcement of sovereignty claims, fisheries inspection, search and rescue service and environmental monitoring.

The main task is surveillance and enforcement of sovereignty, which is undertaken with assistance from various radar satellites, including Radarsat2, Sentinel 1 & 2 and Tecsar. The primary data provider is EMSA providing analysed radar photos correlated with AIS signals for ship detection and identification. DCDA also uses data from Iridium for communication and data from EMS for search and rescue tasks.

Danish Defence Acquisition and Logistics Organisation (DALO)
DALO has the overall responsibility for the defence equipment and IT systems and supports DCDA with resources and advice for optimized use of satellite-based information. Furthermore, DALO is the link between DCDA and government agencies, universities and commercial operators. DALO works primarily with a broad range of satellite data, including radar, optical, thermal, AIS as well as data from other sensors, primarily in relation to land, sea and air surveillance tasks.

In the research and development mission GOMX-4, conducted by GomSpace, the satellite GOMX-4A was sponsored by DALO. The satellite was launched in 2018 for the purpose of contributing to surveillance of the Arctic. The GOMX-4A demonstration was part of an analysis and experimentation programme seeking to identify best practice and future efforts in reinforcing surveillance of the Arctic within the Kingdom of Denmark. The satellite has been named "Ulloriaq", meaning star in Greenlandic.

Danish Defence Intelligence Service (DDIS)
DDIS actively uses all technological opportunities, including the development of space technology and sensors. Space technology is used to follow the strategic developments in the Arctic, including the security policy conditions and stakeholders in the region, to support the central administration, the armed forces as well as Greenland and the Faroe Islands in their execution of authority and the maintenance of sovereignty.

DDIS uses various technological acquisition capabilities to support the effort, including satellite-based capture in the form of satellite images and other types of data. Furthermore, DDIS also retrieves data from other operating satellites. Finally, DDIS carries out various forms of technology development with the aim of continuously updating and developing their capabilities in line with the general technological development.

Ministry of Industry, Business and Financial Affairs

Danish Maritime Authority (DMA)

DMA ensures safe navigation in Greenland's and the Arctic waters, relying on the use of satellite information. Ship traffic around Greenland is monitored through compulsory ship reporting systems[10], and DMA is responsible for securing the framework conditions for these. The ship reporting systems include AIS (Automatic Identification System), which transmits data messages about location and scheduled route. Ship traffic can then be monitored from satellites equipped with AIS receivers but is depending on the vessels identifying themselves.

To increase the safety of navigating in the Arctic, the Danish Maritime Authority has taken the initiative to develop ArcticWeb. ArcticWeb is a web application collecting and presenting relevant information to you sailing in the Arctic region, including Greenland waters. ArcticWeb is currently being operated by the Norwegian Coastal Administration. The Danish Maritime Authority is data supplier and partner.

Ministry of Transport and Housing

Naviair

Naviair has been designated by the Danish Transport and Construction Agency to provide aviation infrastructure and has activities both in Danish airspace and in the North Atlantic airspace. Naviair, together with the Canadian and Icelandic air navigation service providers, NavCanada and Isavia, provide air navigation services in the North Atlantic airspace. Naviair provides air traffic information service and NavCanada and Isavia provide air traffic control service. Naviair is one of the partners in the joint venture company, Aireon[11], launched in 2011. Aireon is providing the first ever global air traffic surveillance system that meets the strict, real-time Air Traffic Service (ATS) surveillance requirements for air traffic separation services anywhere in the world. This includes the Arctic, a region previously without civil air traffic monitoring due to restrictions in relation to terrestrial equipment or obstacles between aircraft and terrestrial receiver.

The Government of Greenland

The Government of Greenland use of satellite information is centred around three ministries; the Ministry of Housing and Infrastructure, the Ministry of Labour and Mineral Resources and the Ministry of Finance.

The Ministry of Housing and Infrastructure is involved in various tasks involving satellite information, e.g. navigation, aviation and telecommunication in Greenland. Focus is on safe maritime and aerial navigation through improved regulatory frameworks and use of GNSS procedures as well as telecommunication for remote teaching, telemedicine and improved municipal administrative connectivity.

[10] GREENPOS and KYSTKONTROL.

[11] Aireon manufactures, deploys and operates a global aircraft tracking and surveillance system utilizing satellite-based receivers to monitor the existing ADS-B transmissions of aircraft for global air traffic surveillance. The other owners are the US telecommunications company Iridium Communications Inc. (35.8%) and the ANSPs NAV Canada (37.2%), ENAV (9.1%), the IAA (4.4%) and UK NATS (9.1%) as the most recent ANSP to join the group of owners.

The Ministry of Labour and Mineral Resources uses GIS for area allocation, research trips, nature management (area protection and monitoring), collaboration with municipalities, monitoring of contaminants and RAMSAR areas.

The Ministry of Finance and the Department of Finance at the National Planning Department have the overall responsibility for the strategic development of NunaGIS[12]. NunaGIS is Greenland's system for publishing geodata on the Internet and consists of websites, databases and servers for online handling of maps and location-specific information.

5.1.3 Research institutions

Space-related Arctic research activities in the Kingdom of Denmark is centred around seven central institutions and their various departments. In total 21 research operators have been identified (see Table 5-4 below). Five institutions are engaged in both upstream and downstream activities. These are Technical University of Denmark (DTU), Aarhus University (AU), Aalborg University (AAU), University of Copenhagen (KU), and the Greenland Institute of Natural Resources (GINR). Aside from these, University of Southern Denmark (SDU) has upstream activity, and Havstovan Faroe Marine Research Institute has downstream activity.

Table 5-4 below displays these universities, including relevant departments, and whether they engage in upstream and/or downstream activities. For Aalborg University and University of Copenhagen, both faculties and departments are highlighted as operators, albeit the departments are within the faculties. This is to provide a more detailed picture of the use of space information in the universities identified.

Table 5-4 Research institutions engaged in space-related activity

		SPACE ACTIVITY			FOCUS AREA		
NAME OF INSTITUTION	**DEPARTMENT**	Upstream	Downstream 1	Downstream 2	Earth observation	Communication	Navigation
Technical University of Denmark (DTU)	DTU Space[13]	X	X	X	X	X	X
	Arctic DTU	X	X	X	X		
	Security DTU [14]	X		X		X	X
	DTU Aqua		X	X	X		
	DTU Civil Engineering		X	X	X	X	X

[12] The company Asiaq has the overall responsibility for the operation of NunaGIS, and SDFE has an important role in the future development of NunaGIS.

[13] Including DTU Space Drone Center.

[14] DTU Space, DTU Compute, Mechanical Engineering, and Electrical Engineering.

NAME OF INSTITUTION	DEPARTMENT	SPACE ACTIVITY			FOCUS AREA		
		Upstream	Downstream 1	Downstream 2	Earth observation	Communication	Navigation
Aarhus University (AU)	AU Arctic Research Centre	X	X	X	X	X	X
	AU Faculty of Technical Sciences[15]	X	X	X	X	X	X
	AU Department of Geoscience	X	X	X	X		X
	AU Department of Bioscience		X	X	X	X	X
	AU Department of Environmental Science		X	X	X	X	X
Aalborg University (AAU)	AAU Arctic		X	X	X	X	X
	AAU Department of Electronic Systems	X	X	X	X	X	X
	AAU Department of Planning	X	X	X	X		X
University of Copenhagen (KU)	KU Faculty of Science	X	X	X	X	X	X
	KU Department of Biology	X	X	X	X	X	X
	KU Department of Geography	X	X	X	X	X	X
	KU Arctic Station	X	X	X		X	X
	KU Niels Bohr Institute	X	X	X	X	X	X
SDU Unmanned Aerial Systems Center		X			X	X	X
Greenland Institute of Natural Resources (GINR)		X	X	X	X	X	X
Havstovan Faroe Marine Research Institute			X	X	X	X	X

Source: Ramboll

Technical University of Denmark (DTU)

DTU Space is engaged in various Arctic upstream and downstream activities. DTU Space was a knowledge partner on the GOMX-4 project, with responsibility for the research work on the development of satellite equipment. In the Arctic, DTU Space also collaborates with DMI on sea extent mapping and with GEUS on risk assessments regarding landslides and research on glaciers and inland ice. They also advise the Danish Ministry of Foreign Affairs on continental shelf conditions in relation to nautical limits, supervises the Danish Defence on satellite use and work with ESA, EMSA and NASA on the future of satellites. Furthermore, DTU Space is an advisor on GNET in collaboration with SDFE, has research projects with Asiaq and collaborates with DHI Gras on sea and Arctic route optimization.

In collaboration with Arctic DTU, DTU Space also delivers sea ice data to Copernicus marine environment monitoring service as well as various data generating research and project collaborations with public authorities and research institutions. These include Global Archer, which focuses on conducting research, monitoring and surveillance through unmanned aerial systems in the Arctic [16], and Nunataryuk, which studies the impact of thawing permafrost in

[15] The Department of Physics and Astronomy, The Department of Engineering and The Department of Geoscience.

[16] This project focuses on conducting research, monitoring and surveillance through unmanned aerial systems in the Arctic.

Arctic coastal communities [17]. Copernicus and Galileo are the two primary sources for cross-unit research purposes, accounting for app. 2/3 of satellite data used and specifically for sea ice monitoring, Sentinel-1 (Copernicus) is the primary source.

Security DTU (which is part of DTU Space) is engaged in upstream activities through development of defence technology, military and civilian monitoring in the Arctic regions, as well as rescue, environmental emergency contingency plans and security in connection with natural disasters. DTU Aqua uses processed and unprocessed satellite data for research on oceanography, marine populations and ecosystem dynamics. Since 2016, DTU Civil Engineering has offered the Arctic Semester at Arctic DTU Campus Sisimiut. Topics include geodetic issues such as satellite positioning and surveying and the establishment of local coordinate systems.

Aarhus University (AU)

AU Arctic Research Centre, which is an interdisciplinary thematical centre anchored at the Department of Bioscience, is primarily engaged in downstream 1 and 2 activities, but has also some upstream activities. In general, AU Arctic Research Centre has several research streams[18] that, to varying degrees, are involved in the production of in-situ data. Unprocessed earth observation data is used for research on Arctic land-based ecosystems, sea ice studies, model descriptions of atmospheric compositions and air pollution[19] and in biology to identify relevant areas for research. The AU Department of Bioscience also produce in-situ data. The department contributes with data for GEM, where Aarhus University is in the steering committee alongside University of Copenhagen.

The AU Department of Environmental Science, which is part of AU Arctic Research Centre, runs the secretariat for the Villum Research Center Greenland. The research centre is actively engaged in producing in-situ data on e.g. sea ice and air pollution. The interdisciplinary station (biology, geology, chemistry, physics, and climate research) uploads data two times daily, which is sent by Iridium. Iridium also enables drone controlling at the research station. The department also uses ESA GOME satellites to make atmospheric mercury measurements.

Three departments within the AU Faculty of Technical Sciences has launched the upstream project AUSAT[20]. AUSAT is a strategic project aiming at assessing, designing and developing nanosatellites for research and education at Aarhus University. This is done in close collaboration with the industry partner GomSpace A/S. The project is not directly relatable to the Arctic but may be in the future due to the need for nanosatellites in the Arctic.

Aalborg University (AAU)

AAU Arctic[21], AAU Department of Electronic Systems, and AAU Department of Planning are engaged in upstream activities. The Department of Electronic Systems has significant Arctic activity, and 80% is focused on developing satellite earth observation platforms from space, tracking ships in Arctic waters, including safety and rescue. Research related to upstream activity

[17] This project is studying the impact of thawing permafrost in Arctic coastal communities.

[18] These include WP1 The polar climate system, WP2 The cryosphere & oceanography, WP3 Arctic ecosystems, WP4 Contaminants & Sediments, and WP5 New technologies and innovation.

[19] Airborne Pesticides and heavy metals.

[20] The Department of Physics and Astronomy, The Department of Engineering and The Department of Geoscience.

[21] AAU Arctic was started in 2016 as a cross-platform for researchers at Aalborg University, who work with the Arctic and Arctic issues. It has not been possible to get information for this study from AAU Arctic on their space-related activities.

in the AAU Department of Planning includes remote sensing, sea ice and space weather. Furthermore, AAU has AAU Student Space which is also engaged in Arctic upstream activity making communication satellite modules.

University of Copenhagen (KU)

The KU Faculty of Science and the two key institutes, Institute for Geography and Institute for Biology, are engaged in in-situ data development centred around the KU Arctic Station. The KU Arctic Station is a new third Greenland Ecosystem Monitoring (GEM) main site at Disko Island. Disko Island together with Arctic Station will be included as long-term multidisciplinary monitoring site for GEM, using its location on the boundary between High-Arctic and Low-Arctic to expand the climatic gradient covered by GEM.

Greenland Institute of Natural Resources (GINR)

GINR is engaged in in-situ activity. The institute is also in the steering committee of GEM. Monitoring cruises take place in Greenlandic waters and Icelandic waters several times a year by the Greenland Institute for Natural Resources and Icelandic Marine and Fishery Research Institute. This is part of the GEM MarineBasis Programme. GINR also uses downstream satellite data for various research projects, including distribution of populations, mapping of food availability as well as oceanic climate, ocean currents and sea ice. Distribution of populations is through tagging, satellite tracking and genetic analysis. Mapping of food availability is done by satellite photography in combination with vegetation and plankton analyses. Oceanic climate, ocean currents and sea ice are done by satellite imagery and measurements of physical and chemical parameters[22]

University of Southern Denmark (SDU) Unmanned Aerial Systems Center

SDU UAS has the upstream project ArtDrone. The ArtDrone project aims to help the Arctic Shipping Companies by using drones or UAS for detection and tracking of potentially dangerous icebergs. To do this, researchers at SDU UAS Center will develop a long-range drone completed with ice protection systems and infrared cameras mounted in a stabilised frame.

Havstovan Faroe Marine Research Institute (FAMRI)

FAMRI is primarily engaged in downstream 2 activity, but also has some downstream 1 activity. They focus on earth observation, navigation and communication based on nanosatellites. FAMRI uses satellite data to conduct research on the marine environment and biodiversity.

5.2 Survey results on Arctic space activity by stakeholders in the Kingdom of Denmark

This section analyses the use of satellite data for space related activities (both upstream and downstream). It gives an overview of space related activities in the Arctic within central sectors, and across the three main areas earth observation, navigation, and communication. The section is based on quantitative results from the conducted survey comprising 36 stakeholders with Arctic space-related activity (17 companies, 2 public authorities and 17 research institutions).

[22] https://natur.gl/about-us/naturinstituttet/?lang=en

Arctic space activity within different sectors

Space information is used across various sectors in the Arctic. Figure 5.1 below illustrates the most central sectors and the number of companies, public authorities and research institutions that are engaged in space activity within these.

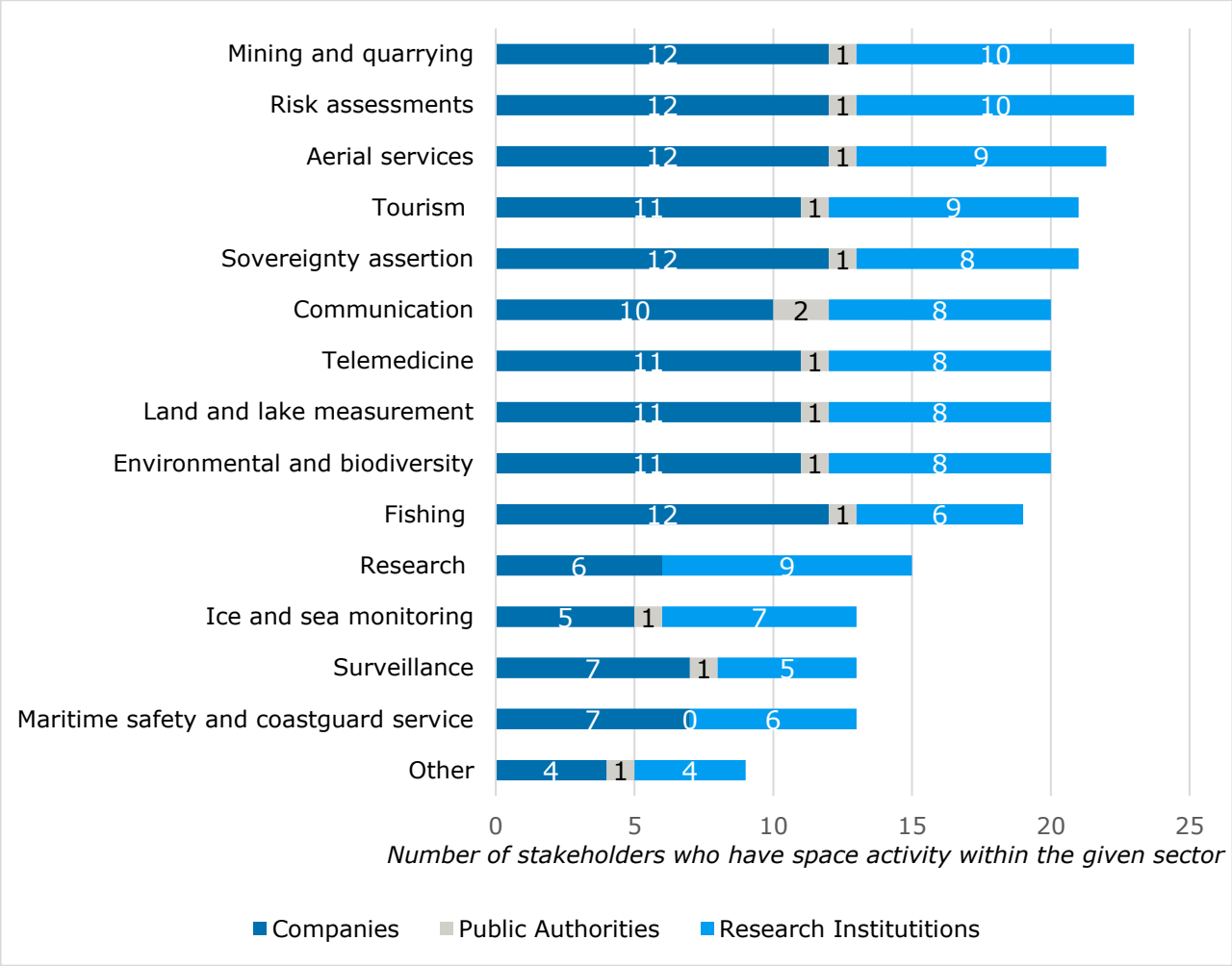
9 sectors have a high number of stakeholders engaged in space related activities (from 23 to 19 stakeholders found among the interviewed parties). These are mining and quarrying (23), risk assessments (23), aerial services (22), tourism (21), sovereignty assertion (21), communication (20), telemedicine (20), lake and land measurement (20), environmental and biodiversity (20), and fishing (19).

The three sectors with the least stakeholder engagements in space related activity are surveillance (13), maritime safety and coastguard service (13), and other[23] (9). The stakeholder engagement in the two sectors surveillance, and maritime safety and coastguard services, is surprisingly low. The relatively low level of engagement may however be due to overlap with the above sectors of risk assessments and sovereignty assertion, or simply that the survey respondents are specialized within other areas.

Besides identifying sectors where space information is an important asset, these figures also reveal that in general, the identified stakeholders have space activity within a lot of different sectors. The survey reveals the average stakeholder engagement in a sector to be 18. Figure 5.1 below shows that half of the total number of stakeholders are active in 10 of the sectors included in this study.

[23] Sectors which are highlighted as 'other' are air monitoring, navigation warnings, monitoring of environmental data, data management, and drone operations

Figure 5.1 overview of space related activities in the Arctic within various sectors



Source: Ramboll. N = 36 (comprising 17 companies, 2 public authorities and 17 research institutions). Respondents could choose one or more categories.

Arctic space activity within earth observation, navigation, and communication

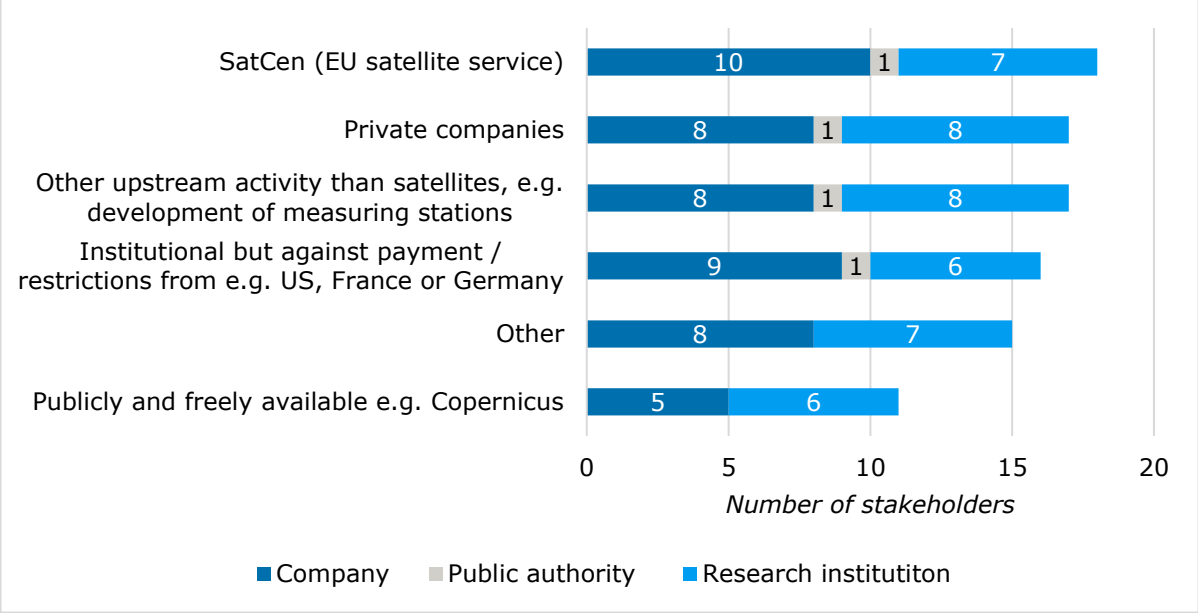
With regards to space related activities in the Arctic within earth observation, navigation, and communication, the survey shows that there is an equal distribution of stakeholders in the three activities. Slightly fewer stakeholders are involved in "other upstream activity than satellites", e.g. development of measuring stations.

Furthermore, the overview demonstrates that most of the survey respondents use satellite information for both earth observation (75%), navigation (78%) and communication (75%), while less than half of the respondents is engaged in other upstream activities than satellites (47%). The section below outlines detailed information on satellite use within each of these three categories, with further specification on the particular use of satellite information.

Earth observation

27 survey respondents use earth observation satellite information (75%). Figure 5.2 below shows that the most widely used earth observation satellite information is from SatCen (EU Satellite service), followed by private companies, institutional but against payment, other and lastly publicly and freely available. Both KU and AAU state that they generate earth observation satellite information themselves. Across all categories of satellites, there is an almost equal split between companies and research institutions, indicating that these two types of stakeholders share similar preferences for earth observation satellite information.

Figure 5.2 Primary source for earth observation satellite information

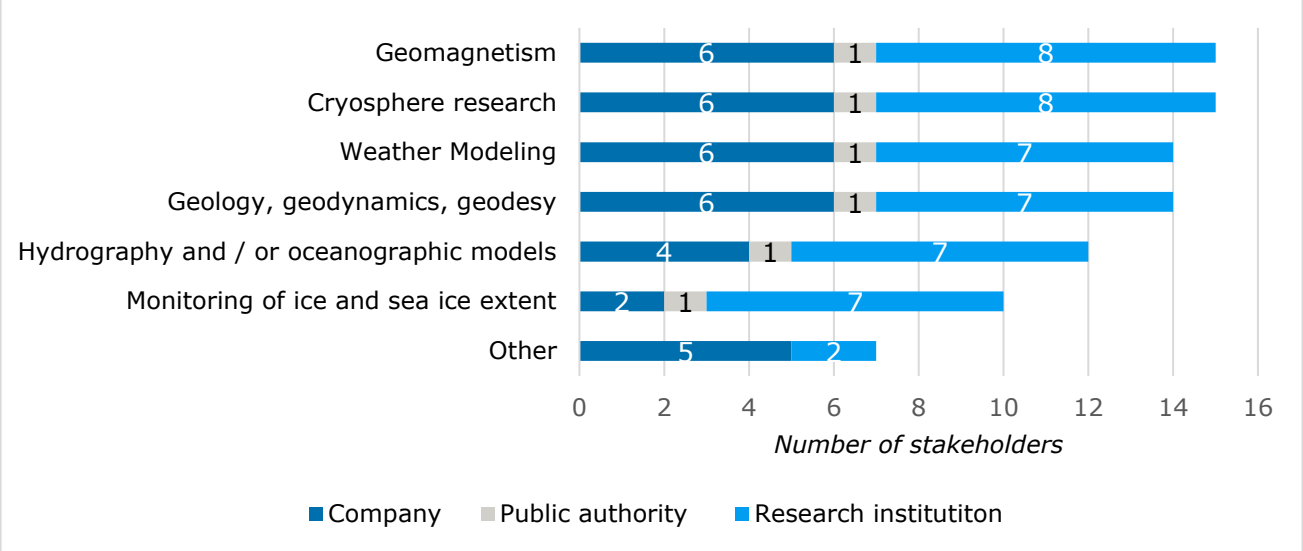


Source: Ramboll. N = 36 (comprising 17 companies, 2 public authorities and 17 research institutions). Respondents could choose one or more categories.

Within earth observation it is interesting to look at how the stakeholders use raw data from or via satellites in the Arctic. Figure 5.3 below reveals that companies and research institutions primarily use raw data for activities related to geomagnetism (15), cryosphere research (15), weather modelling (14), and geology, geodynamics, and geodesy (12). Within these four categories there is an almost equal divide between companies and research institutions.

There is however a larger relative difference within the group hydrography and/or oceanographic models (12) and monitoring of ice and sea ice extent (10), where few companies relative to research institutions are engaged. This is not surprising given the global research focus within these two areas, yet the low company engagement may indicate an opportunity for value creation from increased collaboration and company engagement in these areas. It is the opposite with the category "other", where more companies than research institutions are present. The "other" category responses include alternative climate parameters, ice characteristics and sea circulation.

Figure 5.3 use of raw data from or via satellites in the Arctic

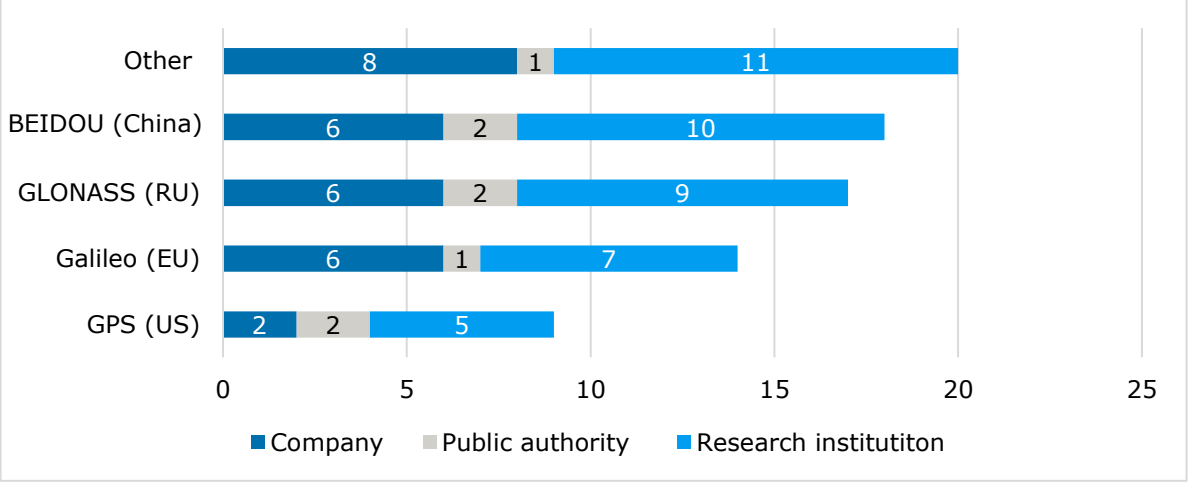


Source: Ramboll. N = 36 (comprising 17 companies, 2 public authorities and 17 research institutions). Respondents could choose one or more categories.

Navigation

28 survey respondents use navigation satellite information (78%). Figure 5.4 below shows that more research institutions than companies use satellite information for navigation. It also shows that "Other" is the most widely used satellite information for navigation. Few respondents have elaborated on this answer stating that they use AIS and VDES. Next is the Chinese BEIDOU satellite with 18 users, followed by GLONASS from Russia (17), Galileo from EU (14) and lastly GPS from the US (9).

Figure 5.4 primary source for navigation satellite information



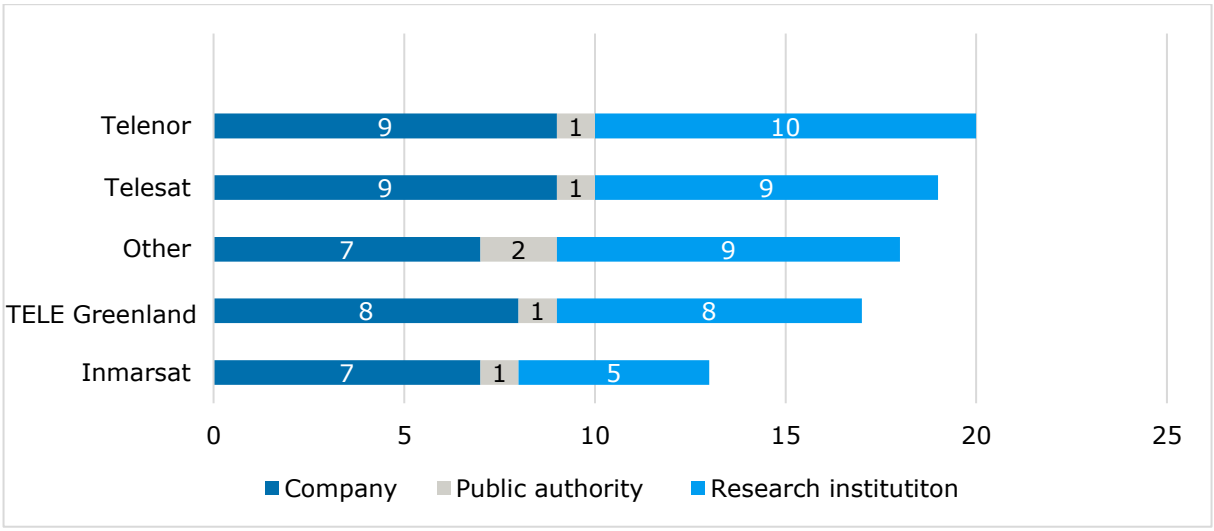
Source: Ramboll. N = 36 (comprising 17 companies, 2 public authorities and 17 research institutions). Respondents could choose one or more categories.

The results in the figure represents the number of respondents who have indicated that they use the navigational systems in question.

Communication

27 survey respondents use satellite information for communication (75%). The satellite communication systems most widely used by both companies and research institutions are Telenor (20), Telesat (19) and "Other" (18). Six stakeholders state that they are engaged in their own communication satellite systems.

Figure 5.5 Primary source for communication satellite information



Source: Ramboll. N = 36 (comprising 17 companies, 2 public authorities and 17 research institutions). Respondents could choose one or more categories.

As with the responses for Navigation above, few respondents have explained their choice of "other" further. This could be a result of the respondent not being aware of the primary source which they use for communication.

5.3 The landscape of collaboration within space technology, information and infrastructure in the Arctic

Five primary forms of collaboration have been identified amongst key stakeholders with space related activity in the Arctic[24]. These collaboration forms are: 1) knowledge sharing, 2) data exchange, 3) project collaboration, 4) product collaboration and 5) research collaboration. Furthermore, the section distinguishes between four kinds of stakeholders; 1) Companies, 2) research institutions, 3) international organisations, 4) public authorities.

While there are overlaps between the five collaboration forms, there is also distinctive characteristics within each form which supports the grouping into the following:

[24] The results are based on interviews and a survey with 36 respondents.

1. *Knowledge sharing* covers various types of informal and formal dialogue between stakeholders. This could be knowledge sharing between a company and a public authority regarding new technological opportunities, or between two companies in relation to new business opportunities.
2. *Exchange of data* covers both data to and from the identified stakeholders but does not distinguish between whether the exchange relationship is reciprocal or unilateral.
3. *Project collaboration* includes various types of downstream 1 and 2 activities. This includes collaboration on surveillance, monitoring, automation, standardisation, sea ice mapping, the future of satellites and advisory services.
4. *Product collaboration* is mostly related to upstream activity and covers the manufacturing or development of space materials (e.g. satellite) or immaterial products (e.g. software).
5. *Research collaboration* covers all kinds of Arctic research projects where space-related information or infrastructure is used.

The following section describes and analyses the collaboration amongst the stakeholders identified within each of these five categories[25].

In total 148 collaboration linkages, encompassing 42 stakeholders within the Kingdom of Denmark and spanning the five collaboration categories have been mapped. Most collaboration linkages are related to project collaboration (56), followed by exchange of data (30), product collaboration (25), knowledge exchange (20), and lastly research collaboration (17). The frequency of collaboration also varies. Most collaboration is on a yearly (55) or monthly basis (52), and a minor part on a weekly basis (22) and daily basis (18).

There are some stakeholders which are central across collaboration forms. Of the research institutions, DTU[26] is the organisation with most linkages, followed by AU[27], KU[28], GINR and AAU[29]. The two central public authorities are SDFE and DMI, followed by GEUS and the Danish Defence[30]. The companies are anonymized, yet they are included to give an overview of clusters. Companies within the Kingdom of Denmark are named "national Companies" and assigned with a letter. International companies are named "International Companies".

In the following graphics, the size of the box with the name of the stakeholder corresponds to the number of relations that the stakeholder is engaged in. The more relations, the larger the box. Likewise, a thick arrow indicates more frequent collaboration. There are four types of arrows representing four frequencies: 1) on a yearly basis (thinnest), 2) on a monthly basis (slightly thin), 3) on a weekly basis (slightly thick) and 4) daily basis (thickest). The direction of the arrow represents which stakeholder has highlighted the collaboration linkage, and if there are two arrows, both stakeholders have highlighted the other stakeholder.

[25] For a full picture of all stakeholder collaborations and relations, please see Appendix 8.1, and for the methodology section please see Section 7.
[26] Survey responses from DTU Security and DTU Space, and interview with Henning Skriver from DTU Space.
[27] Survey responses from AU Artic Research Centre, AU Department of Geography, and AU Department of Biology.
[28] Survey responses from KU Faculty of Science, KU Department of Biology, KU Department of Geography, KU Arctic Station, and KU Niels Bohr Institute, and interview with Henrik Skov from AAU Arctic Research Centre.
[29] Survey responses from AAU Department of Electronic Systems, AAU Department of Planning, and AAU Space Center.
[30] Survey responses from Defence Command Denmark (DCDA) and Danish Defence Acquisition and Logistics Organisation (DALO).

Knowledge sharing

Knowledge sharing covers various types of informal and formal dialogue between stakeholders. This can be knowledge sharing between a company and a public authority on new technological opportunities, or between two companies on new business opportunities. The linkages among stakeholders within this category are illustrated in Figure 5.6 below.

In total 20 knowledge sharing collaborative relations are mapped. This number is relatively low compared to other collaboration forms, e.g. project collaboration or data exchange (see the following sub-sections). A reason for this may be that respondents were asked to give their primary form of collaboration, and that knowledge sharing is implicit in the other forms of collaboration.

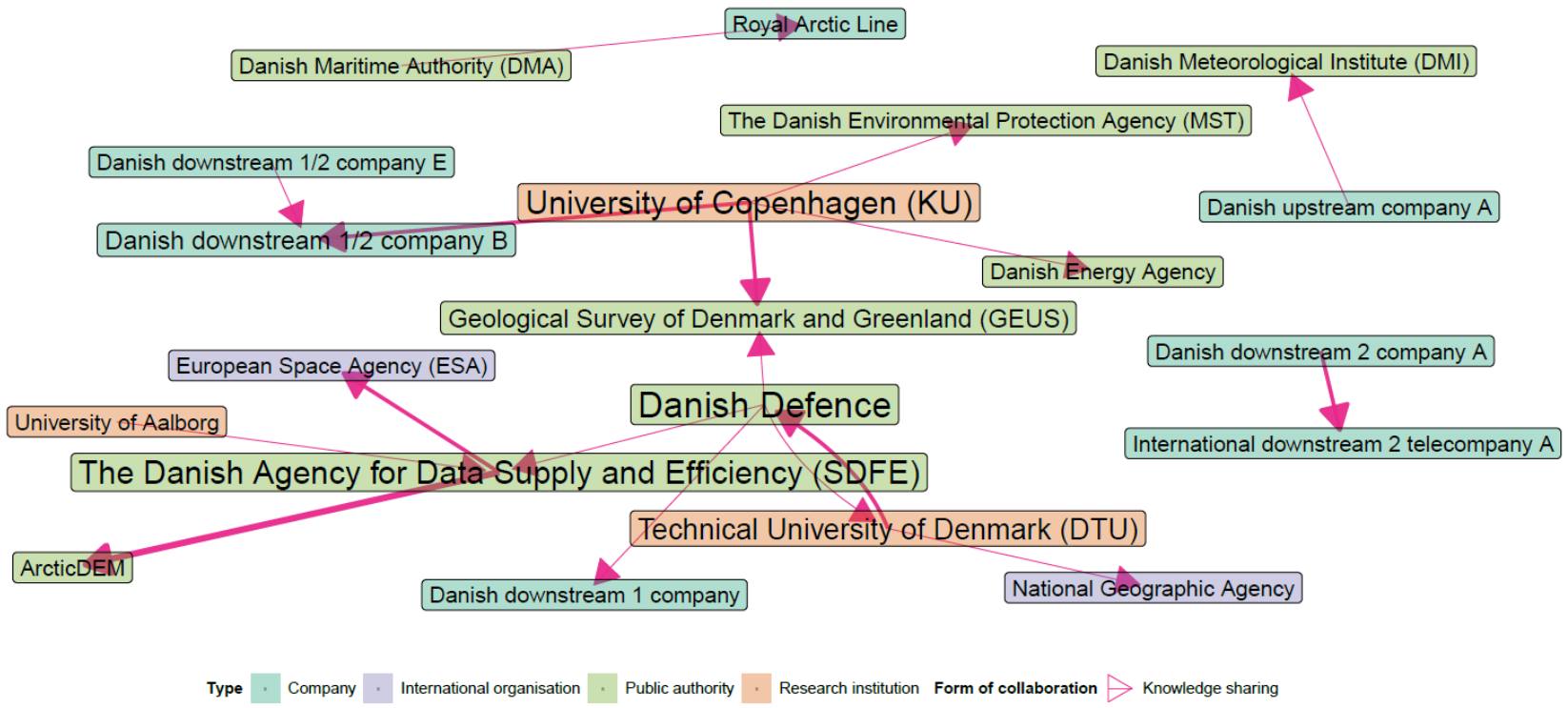
Overall, the mapping reveals that knowledge sharing is centred around three public authorities (SDFE, the Danish Defence and GEUS) and two educational and research institutions (DTU and KU). In fact, GEUS is highlighted as an important knowledge sharing partner by both KU and the Danish Defence. Also, there is a reciprocal knowledge sharing relationships between DTU and the Danish Defence. Furthermore, KU has linkages to two downstream 1 or 2 companies, as the only research institution.

SDFE is internationally oriented as it shares knowledge frequently with ESA and ArcticDEM[31] (SDFE also use free data from ArcticDEM for the new Greenland height model). There are, however, also other stakeholders sharing knowledge with ESA, e.g. DTU, AU and DMI, yet these stakeholders have either not specified this form of collaboration with ESA, or they have highlighted other forms of collaboration with ESA.

With regards to frequency all the illustrated knowledge sharing relationships, except from the linkage between SDFE and ArcticDEM, have either a yearly or a monthly frequency. This makes good sense, since more frequent knowledge sharing if often part of data exchange, project and/or product collaboration.

[31] ArcticDEM is a public-private initiative between The National Science Foundation (NSF) and the National Geospatial-Intelligence Agency (NGA) producing a high-resolution, high quality, digital surface model (DSM) of the Arctic using optical stereo imagery, high-performance computing and open source photogrammetry software.

Figure 5.6 Linkages of collaboration and their frequency – knowledge sharing



Source: Based on interviews and a survey with n=36. The thicker the arrow, the more collaboration. There are four types of arrows representing four frequencies: 1) on a yearly basis (thinnest), 2) on a monthly basis (slightly thin), 3) on a weekly basis (slightly thick) and 4) daily basis (thickest).

Exchange of data

Exchange of data covers both data to and from the identified stakeholders but does not distinguish between whether the exchange relationship is reciprocal or unilateral. In total, 29 data exchange linkages are mapped in Figure 5.7 on the next page.

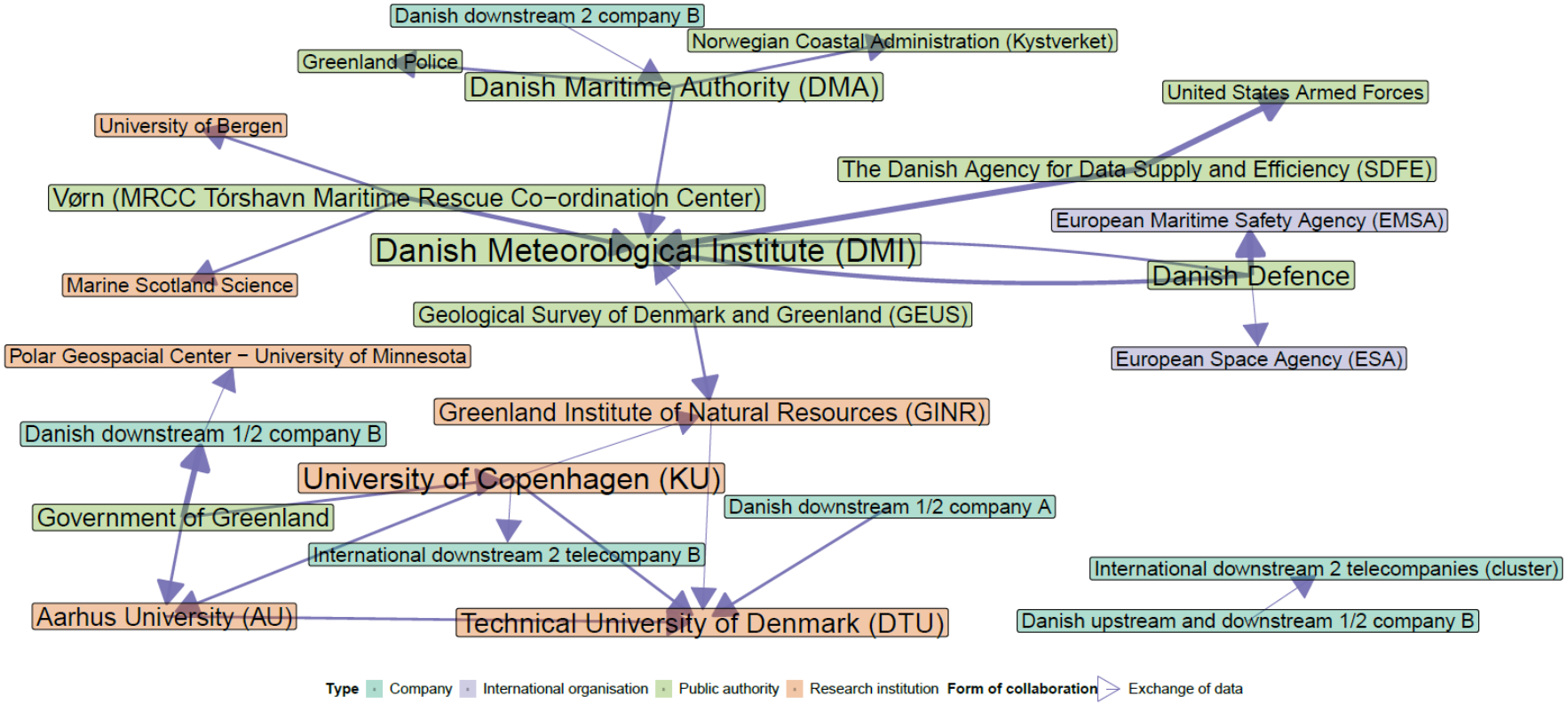
The mapping illustrates that the data exchange linkages in general have a high frequency with many linkages being daily. There are two central focal points for exchange of data, these being DMI and KU. DMI is highlighted as an important data exchange partner by the Danish Defence, SDFE, GEUS and Vørn, where e.g. SDFE download DMI generated data in real time both in Denmark and Greenland. Likewise, KU is highlighted by GINR, DTU, AU and the Government of Greenland, as an important data exchange partner.

The Danish Defence has EMSA as an important data provider with daily interaction and data delivery for surveillance and sovereignty assertion. For the Danish Defence, Copernicus Emergency Management Service (EMS) provides satellite imagery, primarily optical images, in emergency situations such as landslides, volcanic eruptions or major natural events which support the emergency work to be done.

Also central are AU, DTU, KU and GINR who all has between 2 to 5 data exchange linkages. These linkages are mostly with each other, represented by the cluster of the four research institutions. However, they do also have linkages with other downstream companies and public authorities in the Kingdom of Denmark.

In the periphery, the Danish Maritime Authority has its own data exchange linkages with The Norwegian Coastal Administration and the Greenland Police. Likewise, Vørn is also situated in the periphery of data exchange, connected with DMI, and with linkages to two international research institutions, Marine Scotland Science and the University of Bergen.

Figure 5.7 Linkages of collaboration and their frequency – exchange of data



Source: Based on interviews and a survey with n=36. The thicker the arrow, the more collaboration. There are four types of arrows representing four frequencies: 1) on a yearly basis (thinnest), 2) on a monthly basis (slightly thin), 3) on a weekly basis (slightly thick) and 4) daily basis (thickest).

Project collaboration

Project collaboration covers various types of downstream 1 and 2 activities. This include collaboration on surveillance, monitoring, automation, standardization, Ph.D. students, the Mariot project, logistics, sea ice mapping, strategic dialogue on the future of satellites and advisory services. The results are illustrated in Figure 5.8 on the next page.

In total, 57 project collaboration linkages are mapped. Project collaboration is the category with most collaboration linkages, which is not surprising, given the broad category formulation. In addition, the qualitative interviews revealed that much space related activity in the Arctic stems from project collaboration. Thus, stakeholders mainly collaborate when projects are carried out and not necessarily in-between projects. The category mostly reflects collaboration between research institutions, public authorities and downstream 1 or 2 companies, albeit there are few upstream companies. There are several central stakeholders with many project collaboration linkages. Central research institutions are DTU, AU, AAU and GINR (see Figure 5.8).

DTU is central in project collaboration linkages. This include scientific research based advisory services for the Danish Defence, and projects with DMI on sea ice, the Ministry of Foreign Affairs on continental shelf conditions, SDFE on GNET, GEUS on satellite imagery for assessing land slide risks, and with DHI Gras on route optimization in the Arctic. Furthermore, the figure also shows that many upstream and downstream companies highlight DTU as an important project collaboration linkage. DMI is also central and is the link between various research institutions such as GINR, KU, the Havstovan Faroe Marine Research Institute, and a national downstream company,

On the other side, the Government of Greenland has many isolated relations and is "only" connected to the rest of the stakeholders via the Danish Maritime Authority, AU and SDFE. With regards to space information, SDFE assist the Self Government of Greenland, and the financial department, on their basic data program, the development of legislation, and land use/extraction of raw materials. The relatively low number of project collaborations may be due to a focus or prioritisation on other kinds of collaborations. In the qualitative interview the representatives[32] of the Government of Greenland highlighted research collaborations with Danish universities or potential future collaboration with international companies, such as SpaceX and/or OneWeb[33] on low-orbit satellites, rather than specific project collaboration.

Lastly, there are many downstream 1 or 2 companies engaged in project collaboration. These companies appear scattered and collaborate equally with national public authorities and research institutions, as well as international organisations. Company project collaborations include selling AIS data to public authorities, providing technological analysis, standardization and surveillance of Greenland.

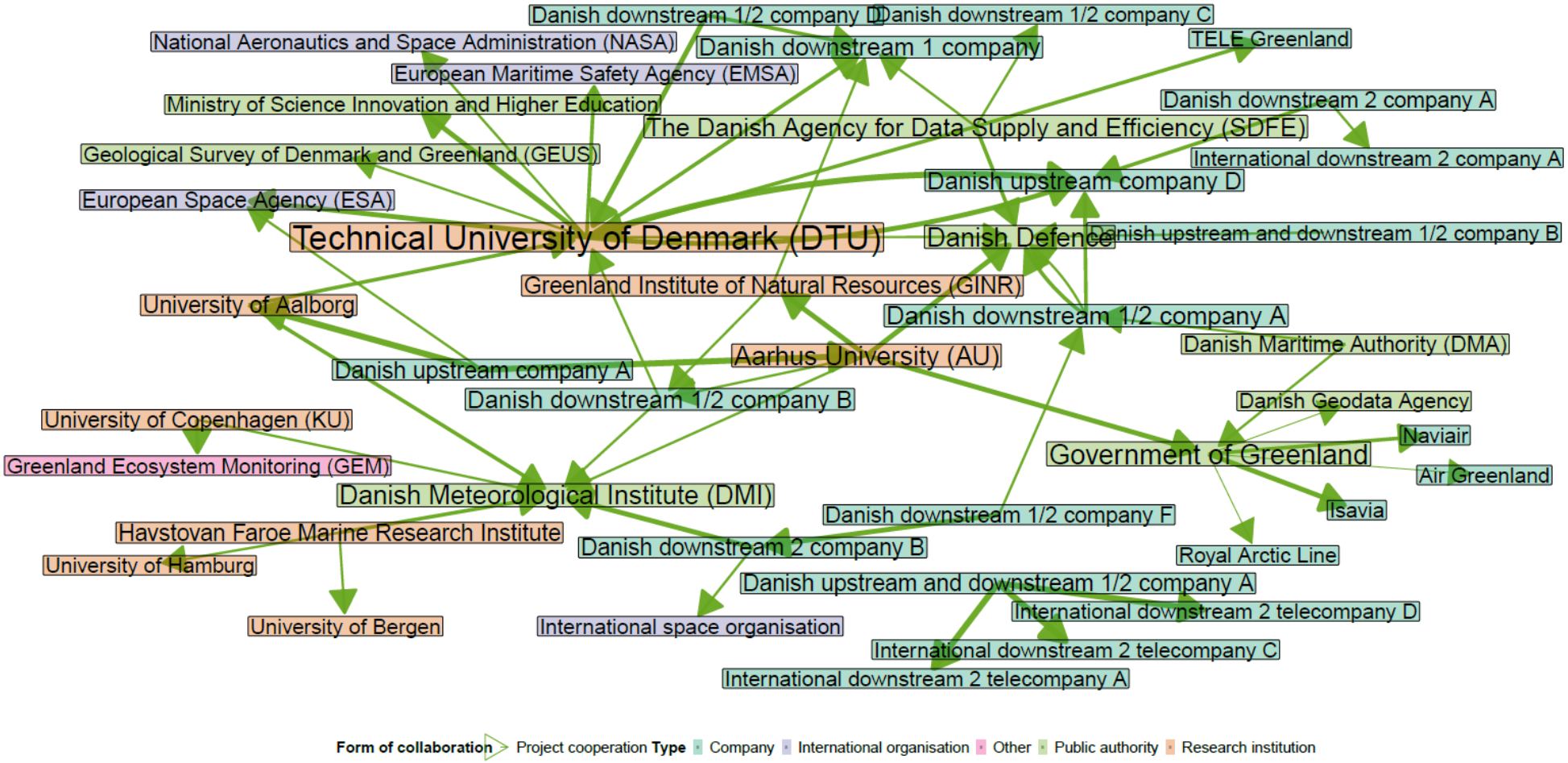
Product collaboration

Product collaboration covers the manufacturing or development of a material (e.g. satellite) or immaterial (e.g. software) product. The results are illustrated in Figure 5.9 below.

[32] Public authority representatives from *The Ministry of Housing and Infrastructure* and *The Ministry of Labour and Mineral Resources*

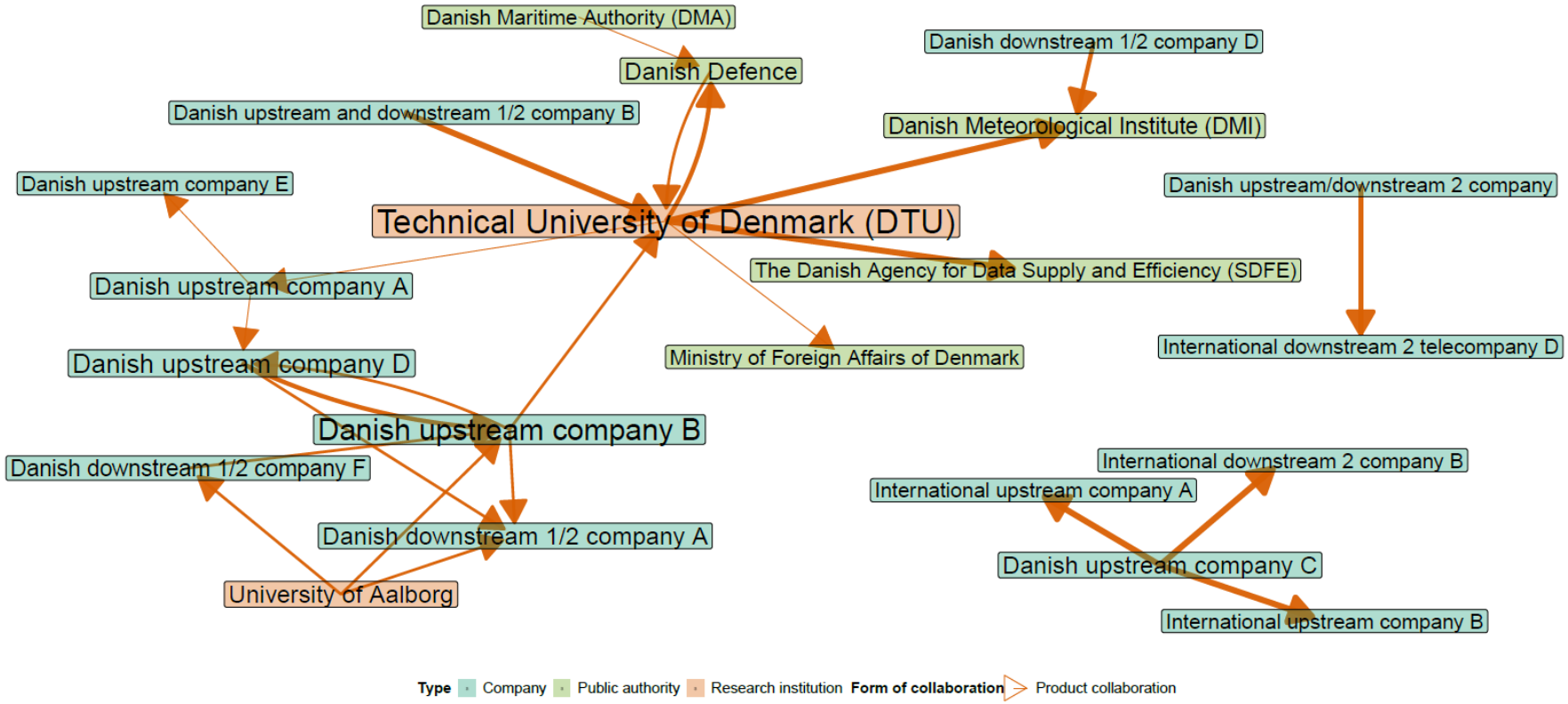
[33] OneWeb filed for bankruptcy in March 2020

Figure 5.8 Linkages of collaboration and their frequency – project collaboration



Based on interviews and a survey with n=36. The thicker the arrow the more collaboration. There are four types of arrows representing four frequencies: 1) on a yearly basis (thinnest), 2) on a monthly basis (slightly thin), 3) on a weekly basis (slightly thick), and 4) daily basis (thickest).

Figure 5.9 Collaboration linkages and frequency – product collaboration



Source: Based on interviews and a survey with n=36. The thicker the arrow, the more collaboration. There are four types of arrows representing four frequencies: 1) on a yearly basis (thinnest), 2) on a monthly basis (slightly thin), 3) on a weekly basis (slightly thick) and 4) daily basis (thickest).

25 product collaboration linkages are mapped in the figure above. Product collaboration linkages exist primarily between upstream companies and public authorities.

In the mapping AAU and DTU are the only two research institutions having product collaboration. DTU serves as the link between a group of national upstream companies and public authorities such as DMI, SDFE, Danish Defence and the Ministry of Foreign Affairs. AAU has product links with two downstream companies and an upstream company.

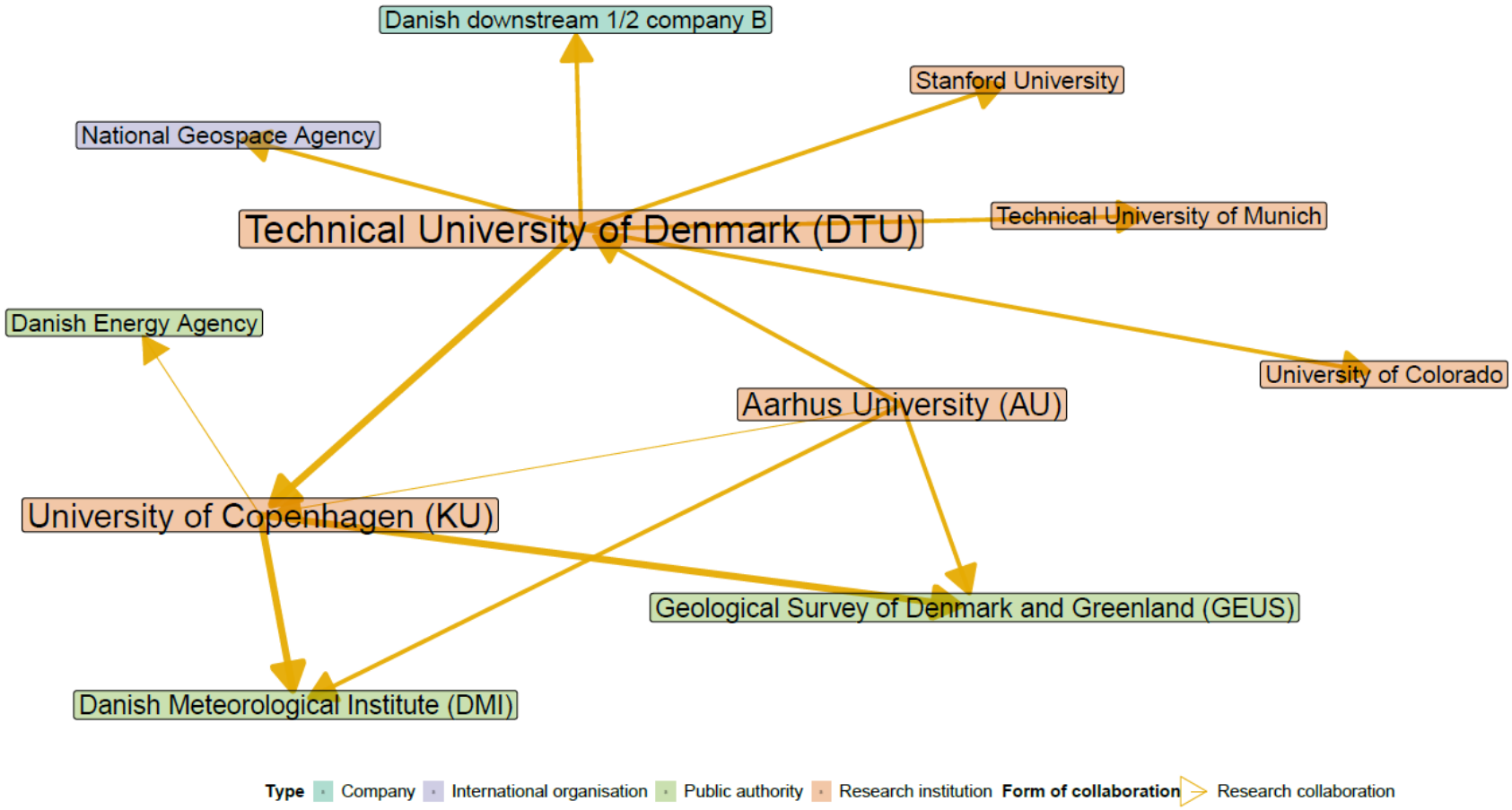
The interviews also revealed that there are different forms of product collaboration between the research institutions. DTU primarily research and work with large satellites, whereas AU and AAU are focusing more on smaller and nano satellites.

There are also two isolated clusters with each one national company (one upstream and one upstream/downstream) and several international companies. These companies highlight different product collaborations including; development of software for sea ice monitoring, development of space applications, development of infrastructure around Arctic research and military stations, and establishing common database for satellite, aerial and drone use.

Research collaboration

Research collaboration covers all kinds of Arctic research projects where space-related information or infrastructure is used. The results are illustrated in Figure 5.10 on the following page.

Figure 5.10 Collaboration linkages and frequency – research collaboration



Source: Based on interviews and a survey with n=36. The thicker the arrow, the more collaboration. There are four types of arrows representing four frequencies: 1) on a yearly basis (thinnest), 2) on a monthly basis (slightly thin), 3) on a weekly basis (slightly thick) and 4) daily basis (thickest).

17 collaboration linkages are mapped in the figure above, which is the lowest number of collaboration linkages. Based on the survey responses there are, however, overlap between research and project collaborations. For instance, exchange of Ph.D. students has been categorized as a project collaboration, albeit it is also a research collaboration. Accordingly, the number of research projects are higher than they appear.

DTU and KU are the two central stakeholders with regards to research collaboration linkages, both with many and frequent linkages to other stakeholders (especially DMI) and each other. This is not surprising given that these two research institutions are central to Arctic space related research. Furthermore, DMI, GEUS and AU have research collaboration with both KU and DTU.

DTU highlight various Danish and international research projects. DTU utilize space infrastructure in their collaboration on mapping the Arctic ice cap and glaciers with KU Niels Bohr Institute. This also goes for measuring gravity fields globally with the National Geospace Agency and Technical University of Munich, and ice thickness with Stanford University.

While AAU is a key stakeholder in knowledge sharing, project collaboration, and product collaboration, they are not represented in this mapping following the methodology of the analysis[34]. However, coupled with the absence of companies engaged in research projects, it may also be an indication of more basic science than applied science using space information in the Arctic.

5.4 Stakeholder engagements in networks

This section illustrates and describes networks both within the Kingdom of Denmark and international networks being central to the stakeholders identified. The networks have been identified based on desk research, qualitative interviews and a survey. The stakeholders highlighted are key stakeholders in the Kingdom of Denmark identified as having significant[35] space-related activity in the Arctic. All networks have additional members than those highlighted.

National networks

Three types of relevant national networks have been identified; 1) research networks, 2) defence networks, and 3) other (for instance, informal networks or networks with a primary focus on the Arctic). Three types of relevant national networks have been identified1) research networks, 2) defence networks and 3) other (e.g. informal networks or networks with a primary focus on the Arctic).

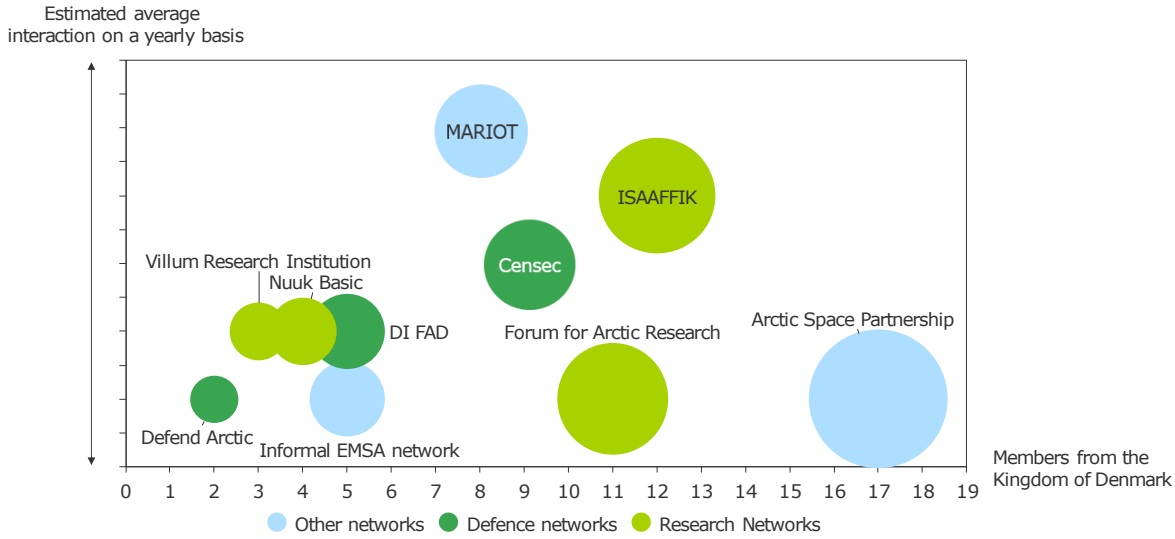
The **research networks** are Forum for Arctic Research, Villum Research Institution, Nuuk Basic and ISAAFFIK. The **defence networks** identified are Censec, Danish Defence and Security Industries Association (DI FAD) and Defend Arctic. **Other** networks are the Arctic Space Partnership, Mariot and an informal EMSA-network.

[34] The mapping in the analysis is based on whether the stakeholder has been mentioned by other stakeholders. This means that fx. AAU may be a key collaborative partner, but if they are not mentioned by the interviewed stakeholders it has not been possible to map the relationship. The lack of mention could be due to the stakeholder relationship not being viewed as primary by the interviewed stakeholder.

[35] For definition, see abbreviations.

The national networks are illustrated in Figure 5.11 below. The y-axis represents frequency with which the members engage in the network[36]. The x-axis is the number of key stakeholders from the Kingdom of Denmark in the given network.

Figure 5.11 Overview of central national networks relevant for space activity in the Arctic



Note: The size of the dot illustrates the number of stakeholders in the network. The larger the dot, the more stakeholders in the network.

The figure shows that the networks with the highest level of participation from stakeholders from the Kingdom of Denmark are Arctic Space Partnership, ISAAFFIK and Forum for Arctic Research. These are followed by Mariot, Censec, DI FAD, Nuuk Basic, Informal EMSA Network, Villum Research Station and Defend Arctic.

There are twenty one of the identified key stakeholders that are engaged in more than one network: AU (6), DTU (5), AAU (5), KU (4), the Government of Greenland (4), DMI (4), Space Inventor (4), GomSpace (4), DCDA (4), Asiaq (3), SDU (3), SFU (3), GINR (3), GateHouse (3) GEUS (2), SDFE (2), Terma (3). Radiolab (2), DHI Gras (2), Scandinavian Avionics (2), and Satlab (2).

Other networks

Arctic Space Partnership (Arktisk Rumpartnerskab) is one of five space networks[37] initiated in 2019 by the Ministry of Higher Education and Science. The partnership includes[38] four Danish universities (DTU, AU, AAU, and KU), seven public authorities (DMI, SDFE, DCDA, UFM, GEUS, Danish Transport and Construction Agency, and the Government of Greenland[39]) and six companies (Gomspace, Terma, Radiolab, Gatehouse, Space Inventor, DHI Gras).

[36] This number is an estimated average based on survey respondents reported frequency of network activity

[37] The other four are Science, Space Exploration, Data use in Denmark, Space based educations.

[38] Besides from the identified stakeholders the partnership includes COWI and the University of Faroe Islands.

[39] Represented through the Greenland Representation in Copenhagen

The **MARIOT** (Maritime IoT) project aims to develop a satellite-based maritime IoT network to demonstrate selected maritime/arctic services using VDES. It is a research/commercial project developing small satellites for improved maritime information and communication technology as well as conducting sharing of data. Two research institutions, one public organisation and four companies are collaborating. The project is led by Sternula, and the project partners are AAU, AU, DMI, GateHouse, Space Inventor and SatLab.

The **informal EMSA network** is a network between public organisations and research institutions, collaborating annually on collecting their orders of satellite data from EMSA. The collaborators include DTU, SDFE, FMI, DCDA and the Danish Geodata Agency.

Defence networks

Censec is a cluster organisation for suppliers to the defence, space and security industry as well as the maritime industry. Censec has 140 members, of which six are central companies identified in this study. These are GomSpace, Radiolab, Space Inventor, Scandinavian Avionics, Satlab and Harnvig Arctic and Maritime. In addition to these companies, DTU Space is also a member.

DI FAD is a trade organisation representing Danish defence and aerospace companies. DI FAD has 89 members, including SDU, GomSpace, Terma, Gatehouse and Scandinavian Avionics.

Defend Arctic is a collaboration between several SMEs, SkyWacth, SpaceInventor and Aalborg University acting as coordinator. Their focus is on responses to accidents and disasters in the Arctic.

Research networks

Forum for Arctic Research (Forum for Arktisk Forskning) was launched in December 2013. The forum is intended to ensure better impact and coordination of development and research activities in relation to Arctic research. It has 14 members and four observers. Of these, Arctic DTU, AU Arctic Research Centre, AU Institute for Bioscience, KU, SDU, GINR, DMI, the Greenland Government, UFM and UM have space-related activity in the Arctic.

Villum Research Station is hosting scientific projects focusing on atmospheric, marine and terrestrial research. The station is operated by AU Arctic Research Centre, the Greenland Government and DCDA in cooperation.

Nuuk Basic is a climate change effect monitoring programme with its study area in low arctic west Greenland near Nuuk, the capital of Greenland. The programme studies the effect of climate variability and changes on marine and terrestrial ecosystems. In terms of scientific concept, Nuuk Basic copies the investigations carried out by the older counterpart monitoring programme, Zackenberg Basic, at Zackenberg Research Station in northeast Greenland. The programme is operated in collaboration between AU, KU, GINR and Asiaq.

ISAAFFIK is a portal supporting arctic research and collaboration between scientist in the Kingdom of Denmark. It connects six research institutions and six public organisations. These are

DTU, AU Arctic Research Centre, AAU, KU, SDU, GINR, GEUS, DMI, the Greenland Government, DCDA, UFM and Asiaq.

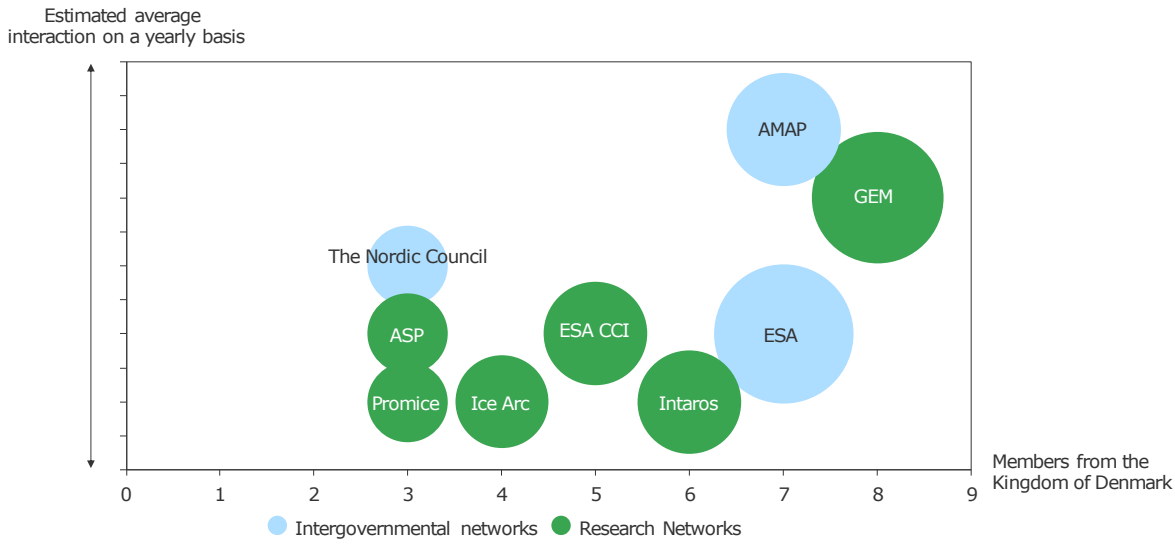
International networks

The relevant international networks can be divided into two overall categories based on a distinction of the organisation and purpose of the network; intergovernmental networks and research networks. These may, however, overlap as research is undertaken in the intergovernmental networks, and national representatives are represented in research networks.

The intergovernmental networks identified are ESA networks, The Nordic Council and the Arctic Monitoring and Assessment Programme (AMAP). The key international research networks identified are Greenland Ecosystem Monitoring (GEM), INTAROOS, ESA Climate Change Initiative (ESA CCI), Ice Arc, Programme for Monitoring of the Greenland Ice Sheet (PROMICE) and Arctic Science Partnership (ASP).

These international networks are illustrated in Figure 5.12 below. The y-axis represents the frequency with which the members engage in the network[40]. The x-axis is the number of key stakeholders from the Kingdom of Denmark in the given network.

Figure 5.12 Overview of central international networks relevant for space-related activity in the Arctic



Note: The size of the dot illustrates the number of stakeholders in the network. The larger the dot, the more stakeholders in the network.

The figure shows that the networks with the highest level of participation from stakeholders of the Kingdom of Denmark are AMAP, GEM and ESA. These are followed by Intaros, ESA CCI, Ice Arc, The Nordic Council, ASP and PROMICE. There are eight identified key stakeholders that are

[40] This number is an estimated average based on survey respondents reporting frequency of network activity.

engaged in more than one international network; DTU (8), KU (5), GEUS (5), DMI (5), AU (4), GINR (4), AAU (3) and Asiaq (4)[41].

Intergovernmental networks

ESA has various networks[42] that connects different organisations from the 22 member states. Seven stakeholders, covering both research institutions, public authorities and companies, have stated that they participate in ESA networks relevant to space-related activity in the Arctic. These are DTU Space, KU, SDFE, DCDA, UFM, Sternula and Asiaq.

AMAP is a working group under the Arctic Council, which connects public organisations and research institutions. The common goal is to monitor and assess climate and environment of the Arctic region.[43] The study shows that AMAP is one of the two central intergovernmental networks, alongside ESA. It has five participants among the respondents: DTU Space, AU Arctic Research Centre, AAU, FAMRI, the Government of Greenland. The Danish Ministry of Foreign Affairs follows the work of AMAP, but is not directly involved.

The Nordic Council connects Nordic organisations in their joint arctic collaboration programme focusing on contributions to the sustainable development of the region and that specific needs of the Arctic are recognized. The new Nordic Council of Ministers' Arctic Co-operation Programme will be in force from 1 January 2018 until 31 December 2021. Stakeholders highlighting this network are DTU, DMA and Orbicon Arctic.

International research networks

GEM is an integrated monitoring and long-term research programme concerning ecosystems and climate change effects and feedbacks in the Arctic. Based on the interviews and survey, GEM is identified as the most central international research network in the Kingdom of Denmark. The members are DTU, AU Arctic Research Centre, AAU, KU/KU Arctic Station, GINR, GEUS and Asiaq.

INTAROS aims to develop an efficient integrated Arctic Observation System by extending, improving and unifying existing and evolving systems in the different regions of the Arctic. The project receives funding from the EU Horizon 2020 Research. It is identified to be the second most important international research network, with four of its members being research institutions (DTU, AU, KU, and GINR), alongside GEUS.

ESA CCI is a research programme with various parallel project streams with the objective to realize the full potential of the long-term global earth observation archives that ESA together with its Member States have established over the last thirty years, as a significant and timely contribution to the essential climate variable databases required by UNFCCC. Project streams that include stakeholders from the Kingdom of Denmark are *Antarctic Ice Sheet CCI* (DTU, GEUS, KU Niels Bohr Institute and DMI), *Greenland Ice Sheet CCI* (DTU, DTU Space (lead), GEUS, KU

[41] For a table overview of all stakeholder participation see Appendix 9.1.

[42] Interviewees and survey respondents have not specified which networks under ESA they take part in.

[43] AMAP is one of six working groups of the Arctic Council.

Niels Bohr Institute, DMI and Asiaq), *Sea Ice CCI* (DMI and DTU) and *Sea Level CCI* (DTU & DTU Space) and .

Ice Arc is a four-year EU project monitoring changes in the Arctic sea ice, and the research partnership consist of 21 institutions from 11 different countries. Amongst these are DTU, GEUS, GINR and DMI.

PROMICE (Programme for Monitoring of the Greenland Ice Sheet) was launched in 2007 by The Danish Energy Agency under the DANCEA[44] programme, with a view to assess changes in the mass balance of the ice sheet. The two major contributors to the ice sheet mass loss are surface melt and larger production of icebergs through faster ice flow. PROMICE is focused on both of these areas. Ice movement and discharge is tracked by satellites and GNSS. PROMICE is operated by GEUS in collaboration with DTU Space and Asiaq.

Arctic Science Partnership (ASP) is an arctic research consortium dealing with climate, cryosphere and ecosystems through research, monitoring and education. It connects ten different, primarily Nordic, research institutions, of which three are from the Kingdom of Denmark (AU, GINR and SDU), with various other collaborators and associate members.

[44] (Danish Cooperation for Environment in the Arctic)

6. VALUE CREATION, BARRIERS AND GAPS IN SPACE-RELATED DATA AND SPACE INFRASTRUCTURE

Setting efficient and targeted policies and strategies to support space-related activities requires knowledge of how and where value is created. Moreover, it is important to understand if the value creation is curtailed due to unintentional barriers and untapped potentials.

Therefore, the objective of this section is to provide insights into how space-related activities facilitate value creation for society and where barriers and potentials exist.

Central to the analysis is the mapping of how one stakeholder's activities are related with other stakeholders' activities and how these create value for society. This provides the basis for analysing how the experienced barriers may limit these activity interrelations and, in the end, curtail value creation. Moreover, the mapping illustrates identified untapped potentials and how these could contribute to improve activity interrelations – or potentially create new ones.

Overall, the analysis shows that 73% of the stakeholders find the use of space-related data and infrastructure of utmost or significant importance to their activities and in creating value. The main areas where the use of space-related data and infrastructure provide value is in relation to improving the quality of existing services, enabling new services and undertaking unique research.

At the same time, the stakeholders experience a range of barriers limiting either the quality of services delivered or the span of activities. While the barriers vary among the stakeholder types, the most prominent barriers across all is lack of space-related data and infrastructure as well as often high prices for accessing non-free space-generated data.

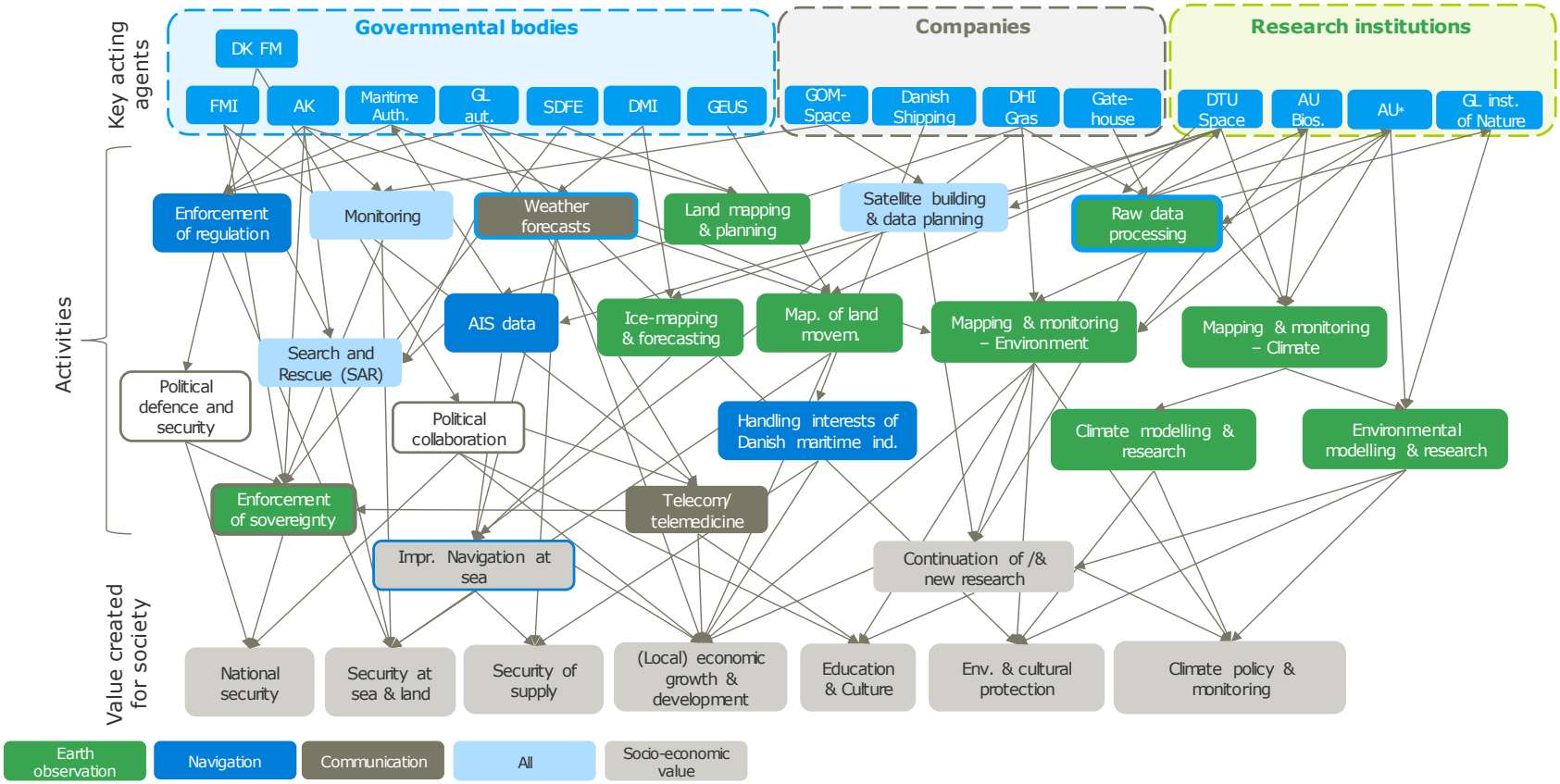
Finally, a range of untapped potentials were addressed by the stakeholders which specifically mentioned the use of publicly available data/satellite hubs. Moreover, it was mentioned that an untapped potential is "re-use" of data to improve the collaboration among the different types of stakeholders and to reduce economic and knowledge barriers associated with the use of space-generated data.

An overview of stakeholder activities and value streams is presented in section 6.1, followed by a presentation of and discussion on value creation in section 6.2, barriers in section 6.3 and untapped potentials in section 6.4.

6.1 Mapping activities related to the use of space information and infrastructure

The stakeholders' activities have been mapped to shed light on the value that the use of space-generated data and infrastructure generate for society. The mapping has been prepared based on the activities expressed by the stakeholders during the interviews in Phase 1 and Phase 2. It is shown in Figure 6.1 below.

Figure 6.1 Mapped activities and interactions related to key stakeholders interviewed in Phase 1 and 2



Source: Ramboll, based on the activities mentioned during the interviews in both Phase 1 and Phase 2.

Note: The activities and interactions mapped in the figure are those mentioned during the interviews. Thus, more activities and interactions among these may exist than what is shown in the figure. The figure will be broken down per stakeholder type in the sections following.

When the activity involves all three focus areas (Earth observation, Navigation and Communication) it is marked instead as the light-blue box "All".

From the mapped interactions (arrows) between activities (boxes) in the figure above, it is clear that value is created through a combination of activities and use of services and products among the stakeholders, rather through single lines of activities. This result aligns with the findings in section 5.3 on the broad and often intertwined collaboration among stakeholders.

For government stakeholders, the activities mapped are mainly concentrated on monitoring (earth and marine activities) and communication[45]. As described in section 5, several of the public authorities are downstream 2, which means that their actions (and the scope of these) are dependent on data processed by other downstream 1 stakeholders in the market.

The value creation for society from the governmental activities are centred around enforcing regulations and national sovereignty, providing security and lowering risk for marine traffic. This supports (increased) activities in the Arctic to the benefit of local and national businesses and citizens. Some government stakeholders are also involved in mapping and monitoring of land areas, which supports both local environmental protection and conservation as well as municipal activities such as land planning.

For the companies interviewed, their main activities are related to delivering commercial raw and/or processed data and analyses and data infrastructure to be used by other stakeholders either directly or indirectly. Where other stakeholders have bought access to these services[46], the services support these stakeholders in delivering on all the mapped value creating aspects for society.

Most of the activities mentioned by the research institutes are related to earth observational data and used for mapping, monitoring and modelling local environmental and climate factors[47]. These activities drive value creation mainly in relation to climate policy, environmental and cultural protection, education as well as indirectly supporting (local) economic development. The activities of the research institutes also contribute to the continuation of and/or expansion of research within these fields by facilitating new research.

In the next section, we present the stakeholder assessment of the value of space-generated data. The section is followed by section 6.3 describing how these barriers curtail specific actions. Section 6.4 provides an overview of (untapped) potentials for additional value creation.

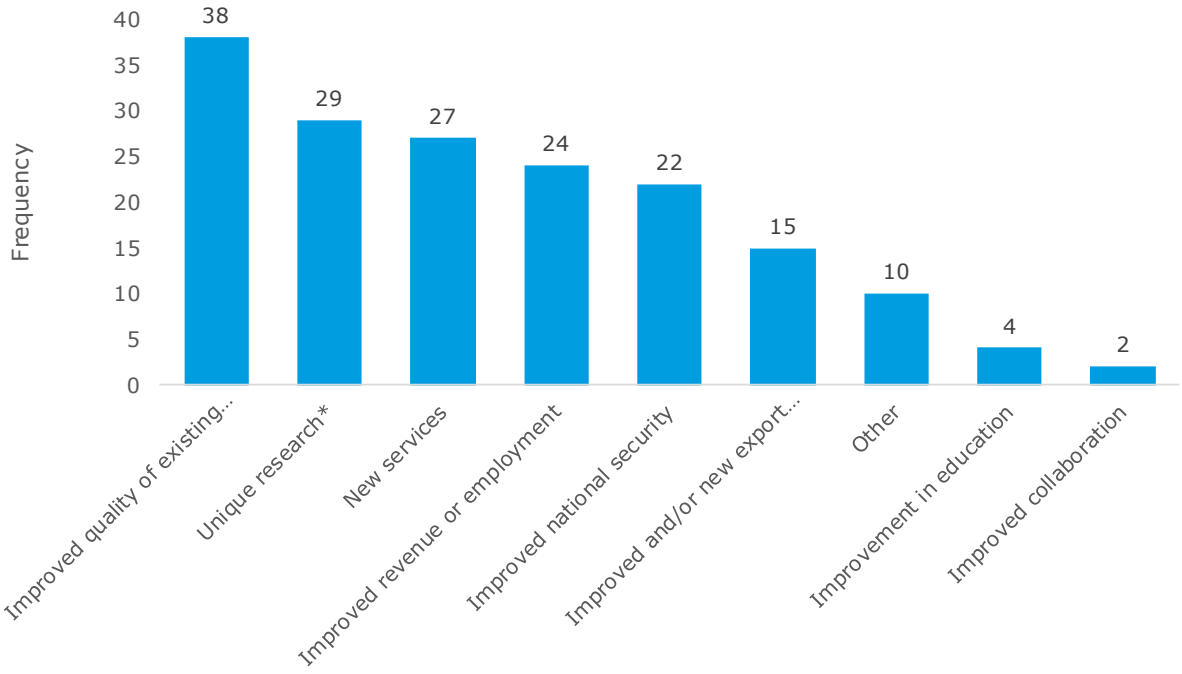
6.2 Access to space-generated data and -space infrastructure supports socio-economic value creation

During phase 1 and 2, the key stakeholders were asked to express importance of space-generated data and space infrastructure to their activities, and hence to the value creation for society. Of the respondents, 73% defined the access as either of utmost or high importance to their activities. None of the 42 respondents defined the access as either of less or no importance.

[45] See Figure 6.4 for a clearer delimitation of activities related to the public authorities' activities and direct or derived value.
[46] See Figure 6.5 for a clearer delimitation of activities related to the companies' activities and direct or derived value.
[47] See Figure 6.6 for a clearer delimitation of activities related to research institutes' activities and direct or derived value.

The respondents were also asked to indicate if and for which areas the access to space-generated data and space infrastructure provided value for them. The results are shown in the figure below.

Figure 6.2 Has the access to space-generated data and/or infrastructure created value in terms of... (across all types of stakeholders)

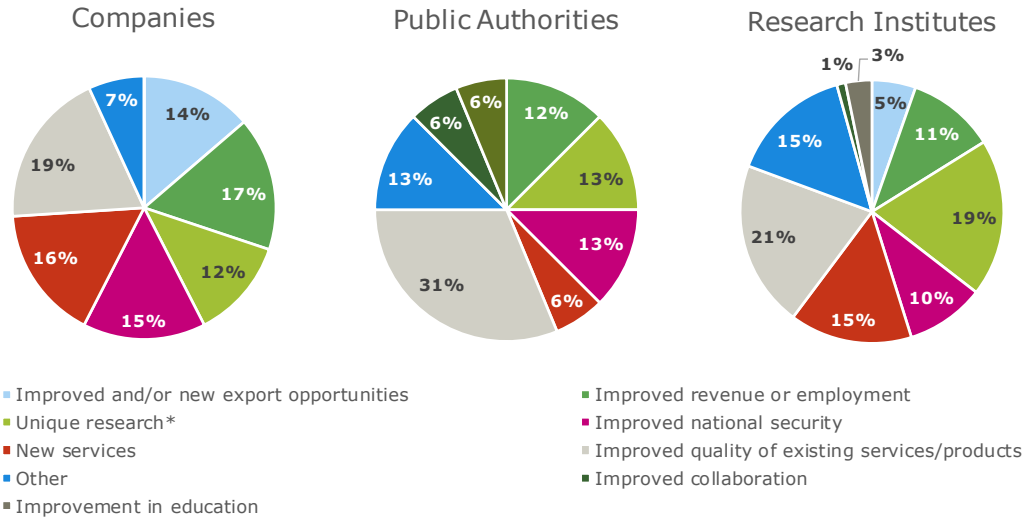


*Source: Ramboll. N = 47 (respondents are from both the conducted phone survey and phase 2 interviews, comprising 20 companies, five public authorities and 22 research institutes). The stakeholders were able to choose more than one category, thus the frequency of responses sum to more than the total number of respondents. The question to the right was "Improved quality of existing services or products", and the second last question in the columns was "Improved and/or new export opportunities". *With unique research is meant research which could not have been performed anywhere else and without this particular information.*

From the results presented in the figure above, it is evident that the most frequently mentioned category is improved quality of existing services/products. This is closely followed by enabling/supporting unique research (29 responses) and developing new services (27 responses). In the "Other" category values such as improving education (4 responses) and collaboration (2 responses) were explicitly mentioned by the respondents.

In the figure below, we have segmented the responses by type of stakeholder:

Figure 6.3 Has the access to space-generated data and/or data infrastructure provided value in terms of… (grouped per stakeholder type)



Source: Ramboll. N = 47 (respondents are from both the conducted phone survey and phase 2 interviews, comprising 20 companies, five public authorities and 22 research institutes).

All stakeholders rate "Improved quality of existing services/products" as the most frequently stated benefit from having access to space-generated data and space infrastructure. However, public authority stakeholders record this benefit more frequently (31%) than the other two types of stakeholders, that is research institutes (21%) and companies (19%).

The second-most value stated by public authorities is enabling unique research and improving national security (13% for both categories).

For companies, the second-most mentioned value is improvement in revenue or employment (17%), followed by development of new services (16%). This indicates that space-generated data and data infrastructure have supported the development of new unique markets for the private industry nationally as well as internationally through export opportunities (14%).

Among the research institutes, unique research (19%) is the second-most stated benefit, followed by the categories "New services" and "Other" (15%, respectively).

The mapping, the survey and interview responses demonstrate that access to space-generated data and space infrastructure is highly important to the respondents, regardless of type. Thus, the access supports a wide range of value creation for society due to enablement of these activities.

However, there are also barriers which curtails the scope[48] of these actions, which further limits the value that these activities could potentially generate for society. These barriers are presented and discussed in the section below.

[48] I.e. the range of effect, quality and usefulness that these activities may have on other related activities, such as those mapped in Figure 6.1.

6.3 Barriers for generating activities and creating value

As discussed in the previous section, access to space-generated data and space infrastructure enables a range of activities for public authorities, companies and research institutes in the Arctic. However, barriers limiting the full potential of value creation, have been identified by the stakeholders in phase 1 and 2 and are addressed in this section.

The stakeholders usually mention the following barriers for the use of/supply to space-generated data and space infrastructure: inadequate geographic coverage, data quality and frequency as well as the price for obtaining commercially generated data. The latter often necessary due to the other barriers mentioned.

Interaction between collaboration and network engagement and expressed barriers

While investigating the correlation between stakeholder engagement in networking and collaboration with the barriers identified, three key issues arise:

1. There is a tendency that the more engaged the stakeholder is in networking and/or collaboration (3, 3+), the more often barriers are expressed (see the table below). This could be due to an underlying correlation between advanced users being more engaged in networks and collaboration, and advanced users being the ones who are more likely to experience barriers.

2. Lack of information as a barrier is most frequently mentioned by the stakeholders, either highly engaged (3, 3+) or not at all (0) in networking and collaborative activities. The same reasoning as for finding one above goes for the highly engaged stakeholders. The less engaged stakeholders may find it hard to overcome the barrier because they are not or less engaged in collaboration or knowledge sharing through networking.

3. There is no tendency that some barriers are experienced more often in some networks than others. Rather, barriers are experienced across all networks.

That barriers exist is not rooted in lack of engagement in neither networks nor collaboration, except to some extent with regard to lack of access to information. That barriers are expressed more frequently among stakeholders highly engaged in networks, could however provide an opportunity. Targeting networks would thus seem to be an efficient way to reach those stakeholders who are limited by the barriers the most.

The average number of barriers expressed, depending on engagement level in networks or collaboration, is summarized in the table below:

Table 6-1 Average number of barriers by frequency of engagement in networks or collaboration

Yearly frequency of engagement in networks/collaboration	Avg. Number of barriers mentioned (Network engaging stakeholder)	Avg. Number of barriers mentioned (Collaboration engaging stakeholder)
0	3	3
1	5	1

2	6	1
3	11	9
3+	N/A	2

Source: Ramboll. N=49 (With respondents from the interviews in Phase 1 and Phase 2).

The table shows that stakeholders engaged in networks, compared to only collaboration, express relatively more barriers on average. In addition, the table shows that the average number of barriers increases with the number of networks in which the stakeholders participate (second column in the table above). This tendency differs for stakeholders engaged in collaboration: here the stakeholders who are either highly (3) or not at all (0) engaged express on average the most barriers (third column in the table above).

A potential reason for the first and last finding above, is the underlying relationship that the stakeholders with frequent and detailed usage of space-generated data or space-infrastructure would be expected to be the ones who are also more highly engaged in networking and collaboration. At the same time, a more frequent or detailed use of space-generated data or space-infrastructure may result in the stakeholder experiencing more barriers than stakeholders who are less frequent users or use less detailed data.

Another potential reason could be that stakeholders experiencing fewer barriers in their use of space-generated data and space infrastructure have less need or fewer incentives to engage in networks or collaboration.

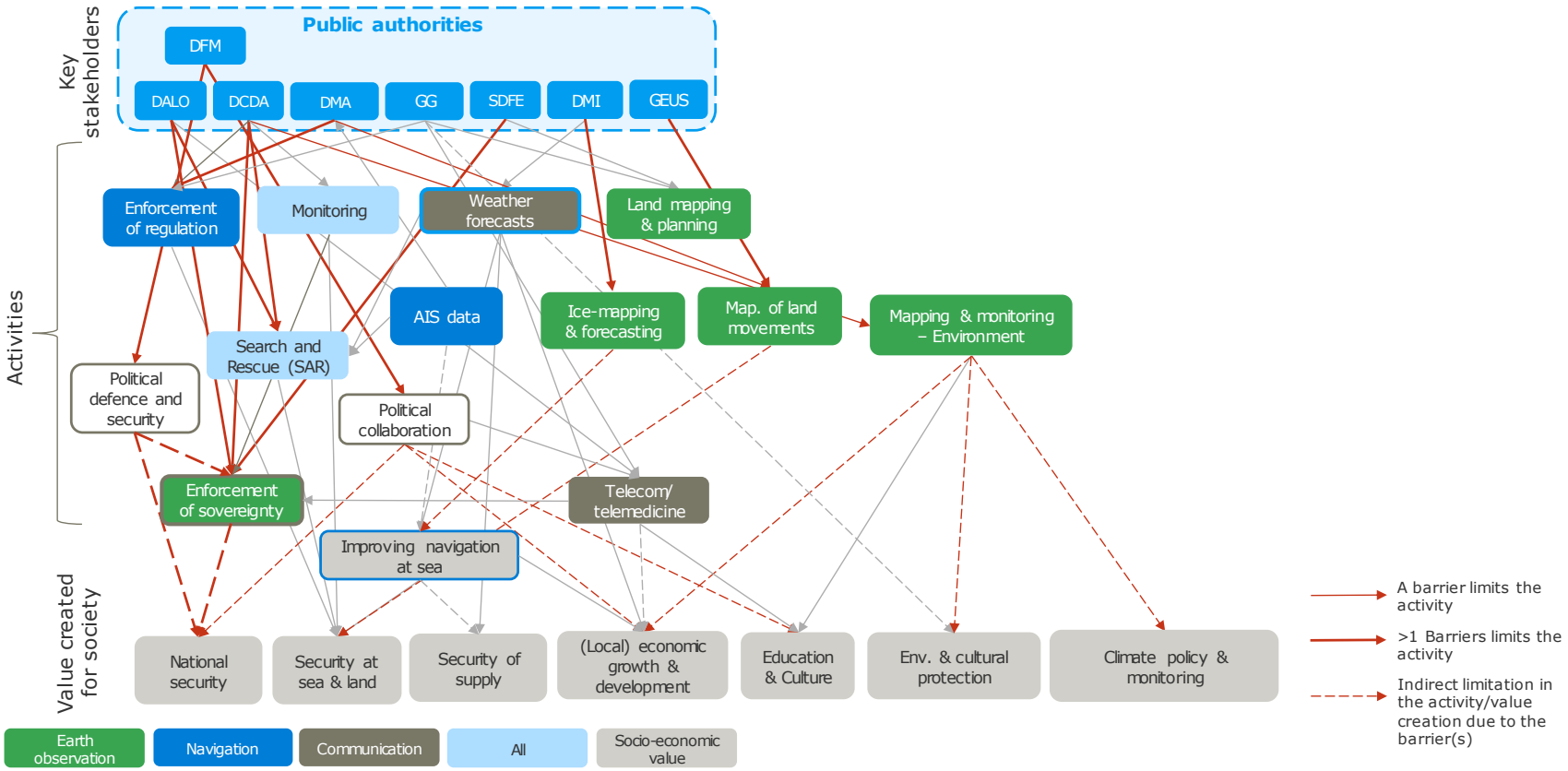
The barriers expressed do, however, vary among the type of stakeholders, and also the extent to which they affect further activities and, in the end, create value for society. Thus, the discussion and presentation of the indicated barriers are further divided into the following four sub-sections: The first section presents the barriers expressed by public authorities, the second section deals with the barriers expressed by companies, the third section introduces the barriers expressed by research institutes and, finally, the last section provides a statistical overview of the barriers expressed in both the survey and the interviews from phase 1 and 2.

Barriers expressed by public authority stakeholders

In mapping the barriers expressed by the interviewed public authorities, we have found that these are mainly related to inadequate geographic coverage, timeliness and robustness of data available. These barriers were mainly expressed as being limited to activities for the enforcement of regulations and national sovereignty, search and rescue missions and in supporting political activities of collaboration and defence and security.

The red arrows in the figure below show how these barriers limit the activities and eventually limit value creation for society. This is followed by a table summarising the barriers expressed by the stakeholders.

Figure 6.4 Mapping of how the indicated barriers limit value-creation – Public authorities



Source: Ramboll, based on the barriers stated by 15 of the stakeholders interviewed in phase 1 and 2.

Note: When the activity involves all three focus areas (Earth observation, Navigation and Communication) it is marked instead as the light-blue box "All".

In the figure, the red arrows indicate where the barriers expressed by the public authorities have been matched to limit the specific activity. The arrow is thicker in case more than one barrier is limiting this activity. The dotted arrows indicate that the limitation to the above activity limits further activities/value creation.

As the figure illustrates, almost all public authorities express that barriers are limiting their activities, and some express several barriers in relation to a single activity. In addition, the barriers affect further value creation for society (dotted red lines), such as the provision of a less than optimal national and local security effort, and research with a potentially narrower/limited scope. This means that research-dependent policies and educational programmes may miss out on other potentially relevant research results. The table below presents an overview of the barriers most frequently expressed by the public authorities:

Table 6-2: Summary of expressed barriers by the public authority stakeholders

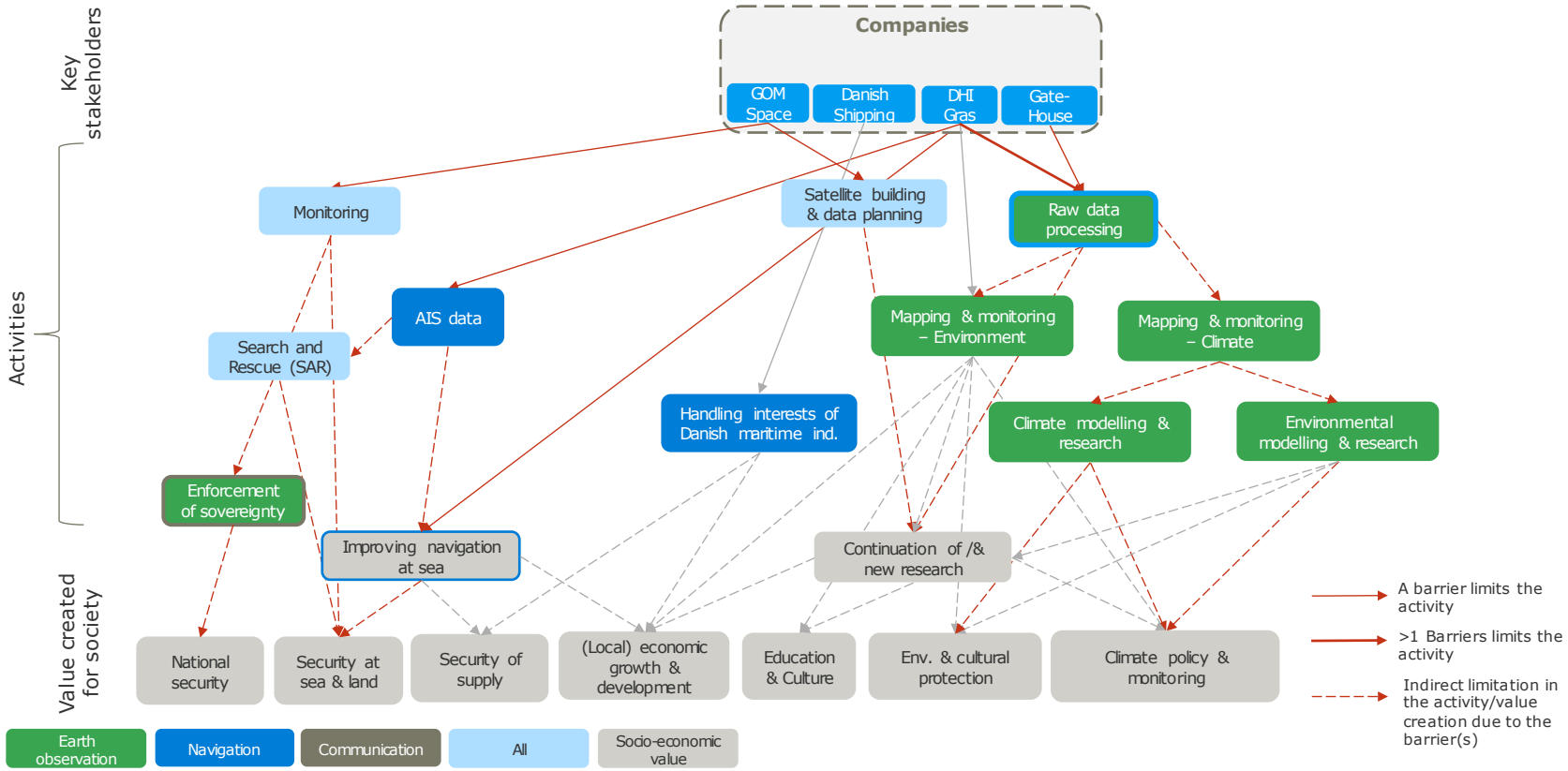
Stakeholder	Barriers expressed		
Joint Arctic Command	Inadequate geographic coverage	Inadequate detail-level of available data	Time delays in data transmission
Danish Maritime Authority	Inadequate geographic coverage	Lack of access to real-time data	Data time-series gaps
Agency for Data Supply and Efficiency	Downsampling of free data due to data rights	The price for obtaining data	Lack of clear guidelines in data access and delivery rights
Danish Meteorological Institute	Lack of resources for data handling	Time delays in data transmission	Data gaps in free data
Danish Defence Acquisition and Logistics Organisation	Lack of access to real-time data	Robustness in data and data availability (risk of disturbances and "jamming")	
Geological Survey of Denmark and Greenland	Inadequate geographic coverage	The price for obtaining data	
Danish Foreign Ministry	Cross-country collaboration	Rapid technological advancement puts strategic political action in a waiting position	Security of systems for sharing data – is data protected well enough when shared

Barriers expressed by companies

Interviews with companies show that barriers are mainly related to access of (public) funding, followed by the speed of which the stakeholder can obtain data. This mainly affects the availability, quality and price of the raw and processed data and related services provided by commercial stakeholders.

In the figure below, the red arrows illustrate how these barriers limit the companies' activities as well as the activities for the related stakeholders:

Figure 6.5: Mapping of how the indicated barriers limits value-creation – Companies



Source: Ramboll, based on the barriers stated by 15 of the stakeholders interviewed in phase 1 and 2.

Note: When the activity involves all three focus areas (Earth observation, Navigation and Communication) it is marked instead as the light-blue box "All".

The barriers experienced by the companies limit the activities of other stakeholders, as the latter cannot use data and services if these are not available to companies. The indirect barriers influencing other stakeholders' activities are shown as red dotted lines in the figure.

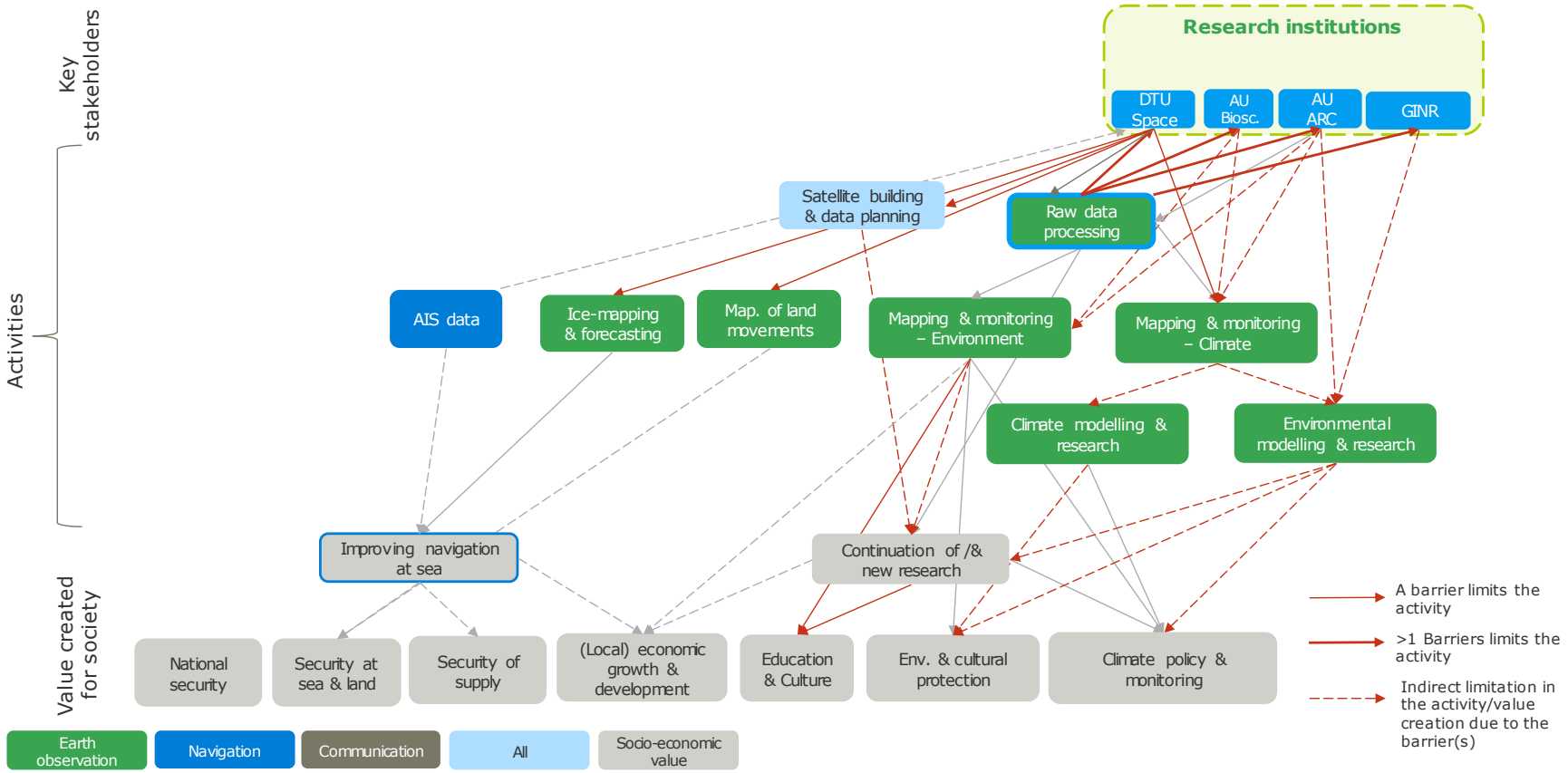
The consequence of value creation for society span from affecting the level of national and local security provided to the quality and scope of research and hence policy development and education.

Barriers expressed by research institutes

The barriers expressed by research institute stakeholders are most frequently related to the cost associated with obtaining data of a certain quality and coverage, followed by barriers in relation to resources and expertise available in order to obtain and analyse space-generated data.

In the figure below, the red arrows illustrate how these barriers transform into limitations for activities and in the end in value creation for society. An overview of the barriers can be seen in Table 6-3.

Figure 6.6 Mapping of how the indicated barriers limit value-creation – Research institutes



Source: Ramboll, based on the barriers stated by 15 of the stakeholders interviewed in phase 1 and 2.

Note: When the activity involves all three focus areas (Earth observation, Navigation and Communication) it is marked instead as the light-blue box "All".

As seen from the figure, the barriers (red arrows) expressed by research institute stakeholders are mainly centred around access to/use of raw and processed data. The barriers experienced by these stakeholders result in a wide range of indirect activity limitations as illustrated by the dotted red lines. The consequences of these barriers transform into a potential less-than-optimal knowledge base for the development of climate and environmental protection policies and education. In addition, the limitations also affect the mapping and modelling used for navigational activities by the private and public sector. This can potentially limit the services provided for limiting risks at sea.

A summary of the barriers expressed by the research institutes are provided in the table below:

Table 6-3: Summary of barriers expressed by the research institute stakeholders

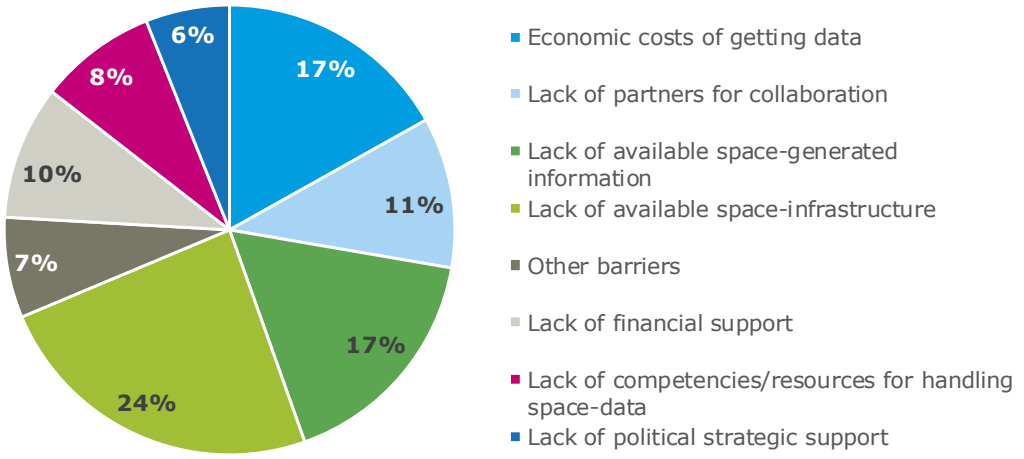
Stakeholder	Barriers expressed		
DTU Space	Inadequate communication infrastructure	Access to data (complex to access foreign satellite data for better data quality)	Price for accessing commercial data
Aarhus University Department of Bioscience	Price for accessing commercial data	Lack of expertise in handling and analysing space-generated data	
Aarhus University Arctic Research Centre	Lack of expertise in handling and analysing space-generated data	Lack of knowledge of what data is available and how it could be used	Lack of resources available for data handling
Greenland Institute of Natural Resources	Inadequate geographical coverage	Inadequate data availability	

The barriers mentioned in relation to available resources and expertise could indicate the existence of a complex data structure[49]. Combined with the barrier of lack of knowledge in how and where to use space-generated data, this illustrates that there might be a need for increased awareness on practical application of such data and how to structure it in the best possible way. In the survey, the respondents were asked to which extent they experienced a set of predefined barriers. They were also able to specify if they experienced other barriers than the ones mentioned. Replies from the interviews were not categorised in the same closed-question framework, yet several of the answers relate to the same categories as in the survey and are therefore included in the statistical analysis.

A summary of the barriers which the respondents experience in relation to their space-related activities in the Arctic is shown in the figure below:

[49] This aligns with the potentials for further value creation expressed by the stakeholders in section 0 where data hubs and collaboration on data use are some of the most frequently mentioned areas for improvement.

Figure 6.7 Barriers to space-related activities in the Arctic

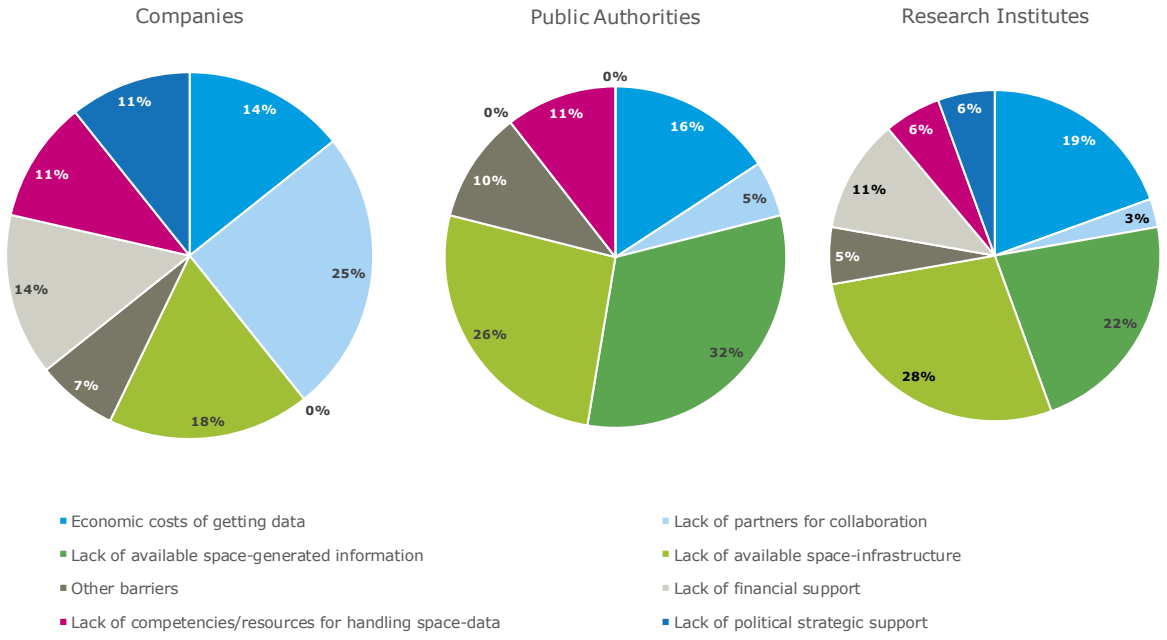


Source: Ramboll. N = 48 (of which 36 are respondents from the survey and 12 are respondents from the interviews).

The figure shows that across all stakeholder types, the three barriers most frequently named are: lack of space-infrastructure (24%), the economic cost of obtaining adequately detailed space-generated data and its availability (17% respectively).

When segmenting the answers into stakeholder types, a distinctive variation in which barriers are experienced most often is established:

Figure 6.8 Expressed barriers divided into response frequency per stakeholder type



Source: Ramboll, N = 48 (of which 36 are respondents from the survey and 12 are respondents from the interviews).

For public authorities, the barrier most frequently mentioned is lack of available space-generated information (32%), followed by lack of available space infrastructure (26%). For the research institutes, these are also the most often mentioned barriers but in reverse order. This means that for research institutes, lack of available space infrastructure (28%) is the most frequent barrier, followed by lack of available space-generated information. For both types of stakeholders, the third most frequently mentioned barrier is the economic cost of obtaining data (19% for research institutes and 16% for public authorities).

For companies, the barrier most frequently mentioned is lack of partners for collaboration (25%), followed by an expressed lack of available space infrastructure (18%). Lack of financial support and the economic cost of obtaining data is both mentioned the third most frequently by these stakeholders (14% respectively).

The top three mentioned barriers per type of stakeholder is listed in order in the table below:

Table 6-4: Top three most often expressed barriers, by stakeholder type

Top	Companies	Public authorities	Research institutes
1	Lack of partners for collaboration	Lack of available space-generated information	Lack of available space infrastructure
2	Lack of available space infrastructure	Lack of available space infrastructure	Lack of available space-generated information
3	Economic costs of obtaining data/lack of economic support	Economic costs of obtaining data	Economic costs of obtaining data

From the survey and interview responses, both the economic costs of obtaining data as well as inadequate availability of information are mentioned as top three barriers for all types of stakeholders. During some of the interviews, it was elaborated that while free data exists, it is often not of adequate quality (i.e. there are data gaps and/or the frequency by which it can be accessed is too low), thus necessitating that additional data is bought to close these gaps.

In summary, the existence of barriers limits the scope of activities provided by the stakeholders, which in the end results in less-than-optimal value creation compared to what could be the potential if these barriers did not exist. In particular, the stakeholders interviewed expressed that the reduction and/or removal of these barriers would assist in more search and rescue missions, faster response in case of oil spill, expanding the field of research and improving national security and enforcement of sovereignty, especially in a time where the Arctic is seeing a yearly increase in marine traffic.

6.4 Potentials for strengthening and establishing new activities

As mentioned, the upstream and downstream space data and infrastructure use in the Arctic see several barriers, as well as multiple stakeholders acting in collaboration as well as individually. However, these activities also support several valuable services for society. Therefore, we have assessed if there are untapped potentials which could act to either reduce limitations to or establish new activities in the Arctic for the stakeholders in the Kingdom of Denmark.

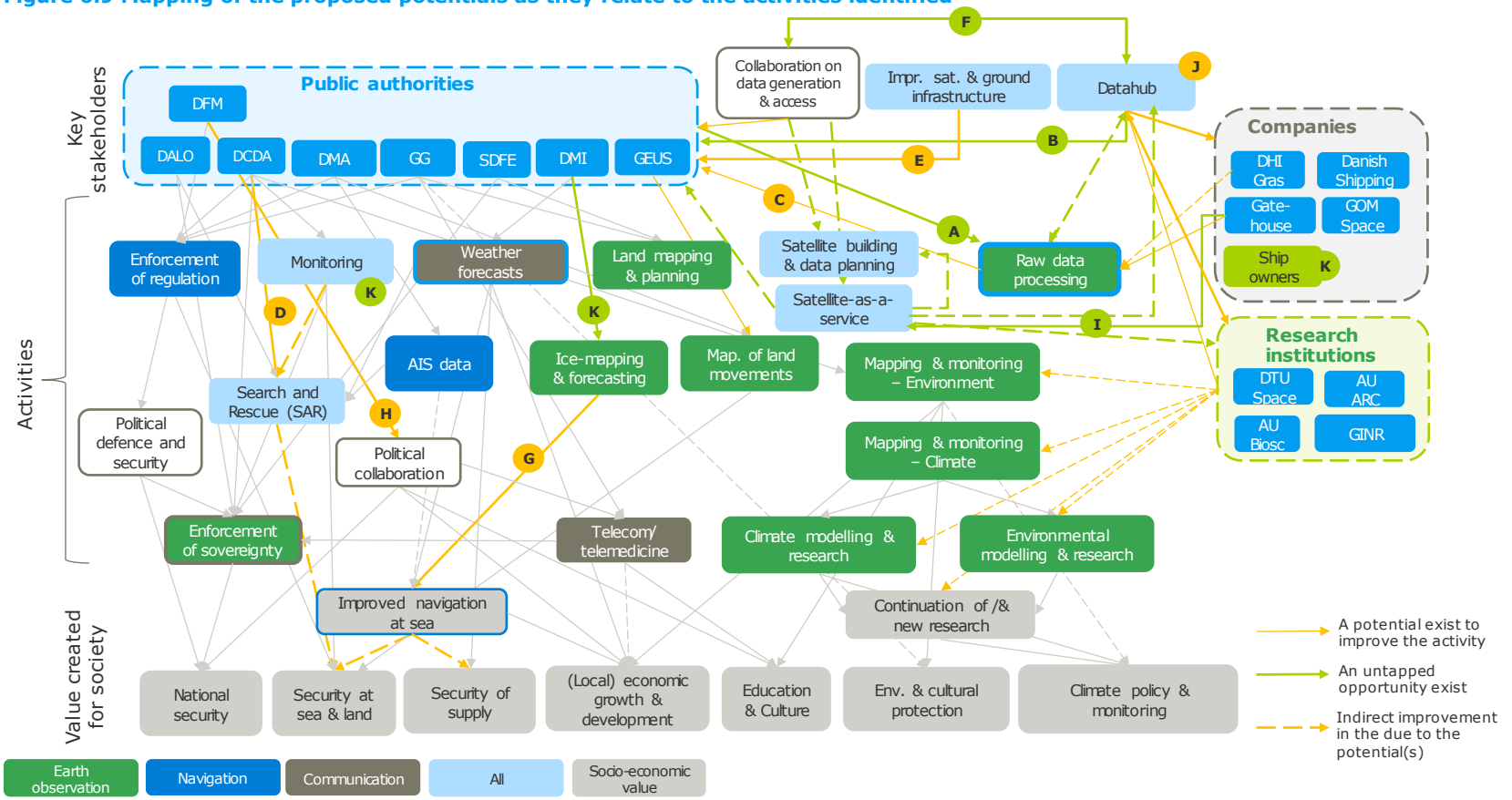
In the interviews in phase 1 and phase 2, the stakeholders were asked to identify untapped potentials for improving their Arctic activities using space-generated data and/or infrastructure.

The most frequently mentioned potentials were to establish data hubs (for researchers as well as general use) and to improve collaboration among stakeholders in accessing and analysing data. Lastly, there is a potential value for society in addressing the complexity currently inherent in accessing and using satellite data. A data hub could support it, as could an earlier introduction of the uses of satellite data in complementary university subjects to raise awareness.

Both stakeholders with frequent collaboration and stakeholders with low collaboration highlight access to information as an untapped potential. In particular, stakeholders with frequent collaboration see a potential for streamlining their existing activities further, thereby gaining more value from the collaboration. Stakeholders with low levels of collaboration see a potential in better access to data, which eases the access to information and knowledge about the potential for using space-related data in the Arctic.

How the indicated (untapped) potentials mentioned by the interviewees relate to the mapped activities is shown in Figure 6.9 below, with clarification on the relations (by letters) in Table 6-5.

Figure 6.9 Mapping of the proposed potentials as they relate to the activities identified

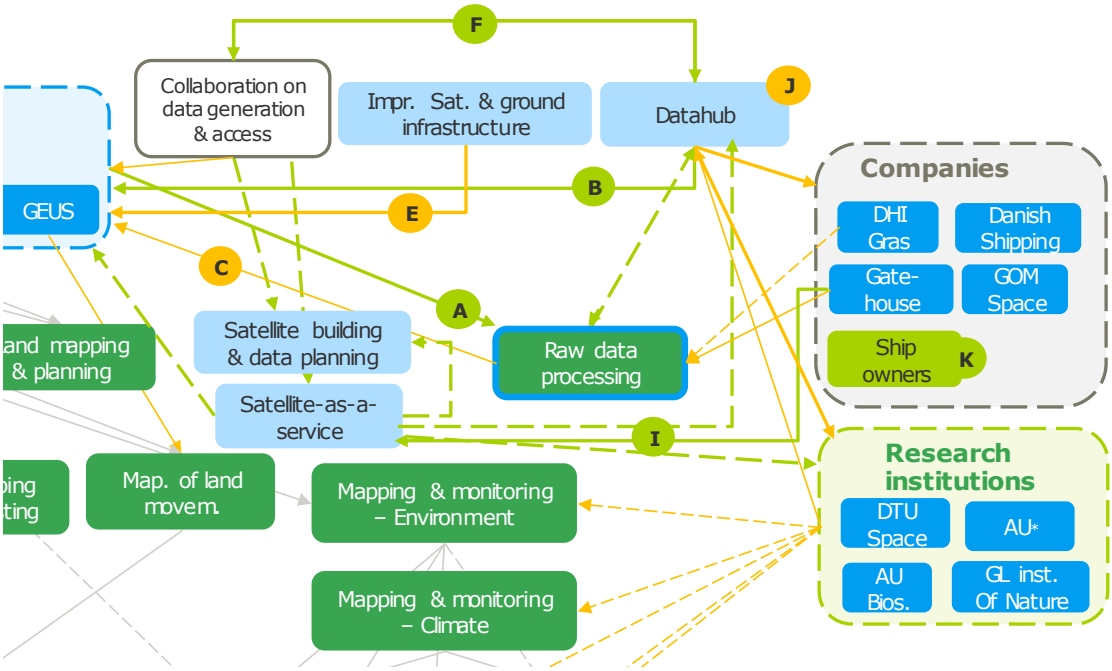


Source: Ramboll. Based on responses from 14 of the stakeholder interviews in both Phase 1 and 2. The map has been revised into a simpler version than presented in Figure 6.1 to allow for a clearer picture of the mapped potentials. Since the improvement in data access and collaboration has the potential to affect (either directly or indirectly) most of the activities mapped, only the most direct potentials have been given an orange or green colour (see the explanation of the colours in the picture).

Note: When the activity involves all three focus areas (Earth observation, Navigation and Communication) it is marked instead as the light-blue box "All".

The mapping of the indicated potentials in the figure show that most of the potentials, across all stakeholders, are centred around the establishment of a data hub supported by collaboration on the access to and use of data as well as engagement in "Satellite-as-a-service". A snapshot of the upper right corner is provided for easy of reading in the figure below, followed by a discussion of the three main potentials identified.

Figure 6.10 Snapshot of the mapping in Figure 6.9



Note: In the figure above, the green lines symbolise an untapped potential. The orange lines represent a potential to improve existing activities. The solid lines illustrate a direct link whereas the dotted lines symbolise an indirect link, i.e. an improvement in another link/activity which the stakeholder is involved in may support new activities/links for the stakeholder. When the activity involves all three focus areas (Earth observation, Navigation and Communication) it is marked instead as the light-blue box "All".

Establishment of a datahub

One of the most frequently mentioned potentials by the interviewed stakeholders is the facilitation of data sharing, for instance through a datahub. The datahub could improve the possibility to share of data, create awareness of possibilities for data use and could potentially enable a better, "re-use" and "re-selling" of (raw) data.

A number of direct and indirect benefits to the stakeholders as well as to society could arise from such a datahub. The first of these is better access to data and better knowledge of data use for all stakeholders. This is illustrated through the orange arrows leading from the "Datahub" to the stakeholder groupings in the figure above. In addition, this improved access and knowledge of other stakeholders' use of data could inspire new ways of using data and hence new types of activities and value creation. This is illustrated through the light green arrows in the figure above, where solid lines indicate a direct contribution and dotted lines a potential indirect contribution.

A second potential benefit of the datahub is resource efficiency, because the datahub would enable stakeholders to see the analyses already initiated or undertaken. This could reduce duplications of what is already available as well as allowing for increased collaboration. This could in turn pool analysis efforts and financial resources.

Lastly, another potential benefit from the datahub is that it could provide a better overview of the possibilities for using space related data, an overview currently missing today. In addition, a datahub could provide the stakeholders with an overview of other stakeholders' focus areas and provide inspiration for further collaborations.

The stakeholders frequently mention the lack of information as a barrier for further activities and thereby value creation. Both stakeholders who are highly and less engaged in networks and collaboration mentioned this. A datahub could serve to fill this information gap and contribute to break down this barrier.

Collaboration on data generation and use

The establishment of a datahub is closely connected with the next identified potential – better collaboration on generating and using data. A datahub could potentially act as a driver for fulfilling this potential. On the other hand, it is also dependent on better collaboration to deliver on its full potential. This is illustrated as the solid green arrow, marked "F", in the snapshot figure above.

There is also potential in enabling collaboration with the purpose of pooling financial budgets. This could allow access to better quality data. Moreover, better collaboration could enable better coordination of re-selling or re-use of data. Such collaboration has the potential to reduce the barriers on price as well as quality, which could both improve the quality of existing activities as well as potentially support the development of new products and services.

An important enabler of the link between collaboration and the datahub, is to ensure adequate human capital; i.e. ensuring there are enough people to handle the related tasks and creating awareness of the opportunities of the uses of space-generated data and space infrastructure in complementary fields.

"Satellite-as-a-service"

Another mentioned untapped potential is "satellite-as-a-service". This refers to the concept where a user interested in specific satellite data can request specific missions to available satellites, to fulfil this need. Such a setup could potentially reduce the barrier of low geographical coverage and data quality. However, it could potentially also increase the price of the data delivered.

"Satellite-as-a-service" has value-creating potential, which would benefit from improved stakeholder collaboration and the establish of a datahub as described above. This is indicated by the green dotted arrows from the potential in the snapshot figure above.

The uptake of such a service could also act as a driver for increased upstream activities and more specific satellite infrastructure needs and requests. This potential is illustrated with a green

dotted line from the proposed potential to "satellite building and data planning" in the snapshot figure above.

An overview of the mentioned potentials is listed in the table below, along with the reference letter used in the figure and which barrier the potential might be able to address:

Table 6-5 List of indicated potentials

Stakeholder	Potential (s)	Could reduce the barrier(s):
GateHouse	**I: "Satellite-as-a-service"** –could improve knowledge of which missions are where and send request for specific missions.	Data delay-times and inadequate geographical coverage and data access
Danish Shipping	**K: Ships as upstream data suppliers** –enabling ships to stream data gathered on their ships.	Data of inadequate detail
DHI Gras	**J: Increase the amount of freely available data** – Lowering the barrier for entry creates increased interest and hence use by other/new stakeholders.	F: Price for and ease of data access
Joint Arctic Command	**A: Same-grade data "re-use"** – Create a structure where data, of the same grade, can be used between stakeholders without having to be downgraded for the next user. **B: A single collectively accessible solution gathering satellite and drone-generated data** **C: Increase in the use of commercial stakeholders** **D: Operative supervision satellites** – used for Search and Rescue (SAR) investigations.	C: Low geographic coverage, speed of access and detail level
Danish Maritime Authority	**E: Increase the amount of available space and related ground infrastructure** **G: Improved detail level of air photos** – could increase the use onboard ships and reduce risk.	E: Inadequate geographical coverage
The Danish Agency for Data Supply and Efficiency	**F: Joint purchasing of data access of higher quality**	F: Price for and ease of data access
Danish Meteorological Institute	**B/F: Common data hub** – could reduce the complexity of data use and hence engage additional stakeholders such as municipalities etc.	Reduce barriers due to complexity in handling data and in resources needed for handling and using data
Danish Defence Acquisition and Logistics Organisation	**Improve the access to real-time data** – could improve services related to search and rescue and the enforcement of Danish sovereignty through a timelier response to incidents. **Improve collaboration between public and private stakeholders** **E: Ground station on Greenland** – for handling services and data which are needed locally. B/F: Sharing and "re-use" of data – such as purchased real-time data which can be re-used by stakeholders where real-time is not essential.	Data gaps and delayed data access

Stakeholder	Potential (s)	Could reduce the barrier(s):
Geological Survey of Denmark and Greenland	**Improve available resources** –could improve natural area protection and support a more widespread adoption of sustainable fishery approaches.	
Danish Foreign Ministry	**H: Improve the communication of "best practice cases"** – could show the benefit and value of improving stakeholder and cross-country collaboration to more efficiently provided space-related services and products. H: Improve knowledge of possibilities of space-based IT solutions – could support a wider uptake and use of E-learning and Telemedicine.	
DTU Space	**J: Gathering satellites in one common system** –could a) provide security on the future availability of data, b) improve the detail level of timeseries and c) make data collection more efficient. These will collectively work to improve the business case for new stakeholders to enter the market.	
University of Aarhus Department of Bioscience	**J: Common data hub** – where data used by other stakeholders such as researchers could be stored. This could improve collaboration on different research topics and potentially enable stakeholders to pool funding and reduce overlapping data handling efforts.	
University of Aarhus Arctic Research Centre	**Expand the knowledge of the opportunities in/the use of satellite data and infrastructure in complementary research areas** –could lead to more stakeholders wanting/being able to make use of space-generated data and space infrastructure, both in the private and public sector.	Lack of expertise in handling and analysing data
Greenland Institute of Natural Resources	**(F): Make data more easily accessible and easy to understand for non-experts**	

Source: Ramboll

From the answers provided, it is clear that for only a few the potentials are related to single stakeholder activities, but for the majority of stakeholders the potentials are related to activities combining resources, data and technologies and collaborating in using these more effectively and knowingly.

7. ANALYSIS METHOD

This section provides a description of the methodological approach used for mapping the stakeholders in the Kingdom of Denmark with activities in the Arctic. The analysis is structured around two main thematic phases:

Phase 1: Stakeholder mapping: This phase identifies central stakeholders, their area of activities and patterns of collaboration and networking. This phase was undertaken using a combination of desk research, interviews and a survey.

Phase 2: Identifying barriers and potentials: This phase identifies barriers and value creation of the mapped stakeholders as well as any untapped potentials related to these. This phase builds on the stakeholder mapping of Phase 1, combined with information gathered from interviews and the Phase 1 survey.

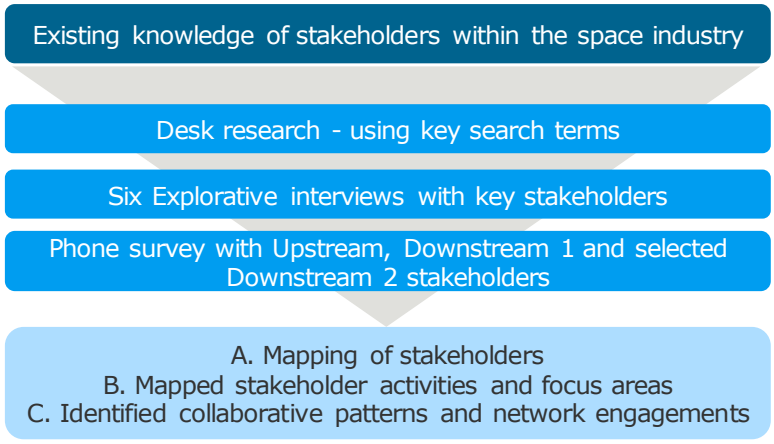
The steps and approaches in completing each of the two phases are described in the two sections below.

7.1 Method for Phase 1 – Stakeholder mapping

The first phase was designed to provide both a mapping of central stakeholders, their activities, collaborative patterns and network engagement as well as providing an offset for the analysis in Phase 2.

The general steps comprising Phase 1 are illustrated in the figure below:

Figure 7.1 Methodological steps of Phase 1



The first step of the Phase 1 analysis was to examine existing knowledge of potentially relevant stakeholders identified as part of the analysis "Statistik om Rumerhvervet". 165 companies were identified in the analysis as having space-related activities. These companies were then screened for their relevancy, i.e. companies with more than 20% of their revenue from space-related activities were included in the further analysis. Of the 165 listed companies, 105 met this requirement and were extracted for further analysis.

Next, the list of extracted stakeholders was further narrowed down, when it was covered which of the 105 stakeholders having activities in the Arctic. Concretely, we carried out an Internet search on the company name combined with the text string "'arctic" or "arktisk". Where necessary, this was followed up with a screening of the stakeholder's websites. Among the 105 initially extracted companies, 37 were identified as having Arctic activities.

To identify additional central stakeholders, a systematic Internet search was undertaken. The search was based on a list of 117 key search terms, of which 51 were selected by the Danish Ministry of Higher Education and Science. Additional terms were added by Ramboll based on prior sector knowledge and source material. The desk research provided a total of an additional 68 relevant stakeholders with significant space-related activities in the Arctic.

With the central stakeholders mapped, the next step in the analysis was to gather information about collaboration and network engagement of these stakeholders. This knowledge was gathered a) in parallel to the search on key terms mentioned above, b) through six explorative interviews with selected key stakeholders from the full list, approved by SFU and c) through a phone survey.

The stakeholders selected for the explorative interview were the following:

- GOMspace
- Danish Maritime Authority
- Joint Arctic Commando
- Government of Greenland
- DTU Space
- The Danish Agency for Data Supply and Efficiency

The interviews were conducted based on an interview guide with questions related to the stakeholder's activities, collaborations and network engagements, with additional questions as to barriers.

Following the interviews, a phone survey was conducted for the upstream and downstream 1 stakeholders as well as a few selected key downstream 2 stakeholders, totalling 92 stakeholders. Of these, 37 completed the interview, 21 indicated that they did not have any activities in the Arctic/related to space, and 34 refused to participate or did not respond. The purpose of the phone interview was to gather information on the stakeholder's activities, collaborative patterns, network engagements as well as value creation and barriers experienced in the use of space-generated data and space infrastructure.

The results from Phase 1 are presented and discussed in section 5.

7.2 Method for Phase 2 – Identifying barriers and potentials

Phase 2 of the analysis focused on mapping socio-economic value creation, barriers and value-creating untapped potentials resulting from the use of space-generated data and space infrastructure identified by key representative stakeholders.

All information for this was gathered mainly through semi-structured in-depth interviews with 10 selected key stakeholders. The interviewed stakeholders in Phase 2 were:

- Danish Meteorological Institute (DMI)
- University of Aarhus Arctic Research Centre
- Greenland Institute of Natural Resources
- DHI Gras
- Geological Survey of Denmark and Greenland (GEUS)
- GateHouse
- Danish Defence Acquisition and Logistics Organisation
- University of Aarhus Department of Bioscience
- Danish Shipping
- Danish Foreign Ministry

The interviews were conducted based on an interview guide with semi-structured questions. The interview guide was divided into three main parts; i) knowledge gathering as to interrelations between the stakeholder's activities and value creation for society, ii) stakeholder-experienced barriers in relation to undertaking these activities and iii) any untapped potentials in the use of space-generated data and space infrastructure that could further existing (or create new) activities.

The results of the interviews were supplemented with responses provided from the phone survey and described in section 6.

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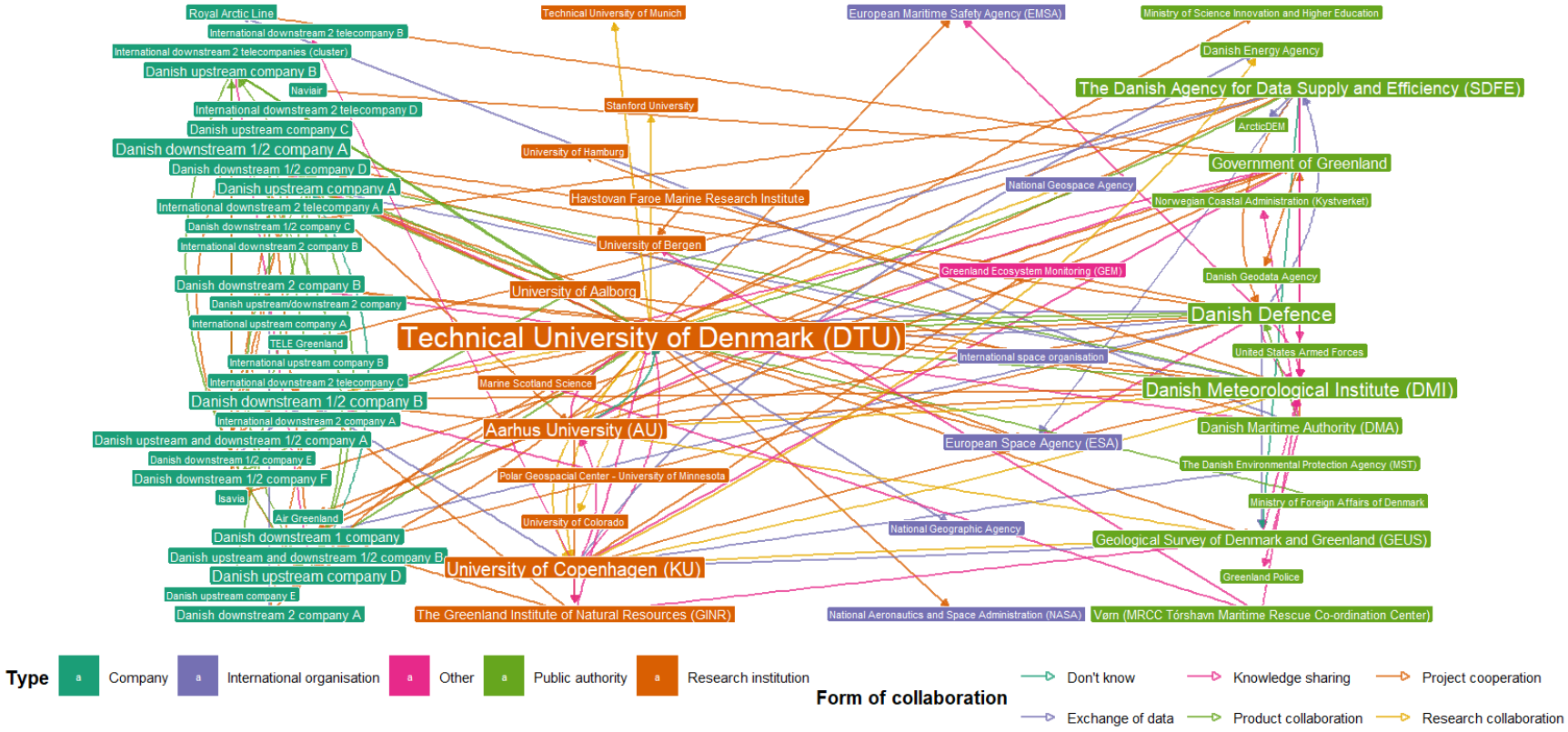
9. APPENDIX

9.1 Table overview of international networks and membership of central Danish stakeholders

Stakeholders	Intergovernmental networks			Research networks					
	ESA	Nordic Council	AMAP	GEM	INTAROS	ESA CCI	Ice Arc	PROMICE	ASP
Total	**8**	**3**	**6**	**7**	**5**	**4**	**4**	**3**	**3**
DTU (8)	X	X	X	X	X	X	X	X	
AU (4)			X	X	X				X
AAU (3)			X	X					
KU (5)	X			X	X	X			X
GINR (4)				X	X		X		X
FAMRI (1)			X						
GEUS (5)				X	X	X	X	X	
DMI (5)	X		X	X		X	X		
SDFE (1)	X								
Government of Greenland (1)			X						
DCDA (1)	X								
SFU (1)	X								
DMA (1)		X							
Sternula (1)	X								
Asiaq (4)	X			X		X		X	
Orbicon Arctic (1)		X							

Source: Ramboll

9.2 All stakeholder collaborations



Source: Ramboll

9.3 Table overview of national networks and membership of central national stakeholders

Stakeholders	Research networks				Defence networks			Other networks		
	Forum for Arctic Research	Villum Research Institution	Nuuk Basic	ISAAFFIK	Censec	DI FAD	Defend Arctic	Arctic Space Partnership	Mariot	Informal EMSA network
Total	**11**	**3**	**4**	**12**	**7**	**5**	**2**	**17**	**7**	**5**
DTU (5)	X			X	X			X		X
AU (6)	X	X	X	X				X	X	
AAU (5)	X			X			X	X	X	
KU (4)	X		X	X				X		
SDU (3)	X			X		X				
GINR (3)	X		X	X						
GEUS (2)				X				X		
DMI (4)	X			X				X	X	
SDFE (2)								X		X
Government of Greenland (4)	X	X		X				X		
DALO (1)										X
DCDA (4)	X	X		X				X		X
SFU (3)	X			X				X		
Danish Geodata Agency (1)										X
DMA (1)								X		
Sternula (1)									X	

Stakeholders	Research networks				Defence networks				Other networks	
	Forum for Arctic Research	Villum Research Institution	Nuuk Basic	ISAAFFIK	Censec	DI FAD	Defend Arctic	Arctic Space Partnership	Mariot	Informal EMSA network
GomSpace (4)	X				X	X		X		
Terma (3)					x	X		X		
Radiolab (2)					X			X		
Asiaq (3)		X	X	X						
GateHouse (3)						X		X	X	
Space Inventor (4)					X		X	X	X	
DHI Gras								X		
Scandinavian Avionics (2)					X	X				
Satlab (2)					X				X	
Harnvig Arctic and Maritime (1)					X					

Source: Ramboll