D11- Executive summary

Arctic Mission System Study

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ABSTRACT

The Arctic Mission System Study were two parallel studies conducted by consortia led by OHB Sweden and Thales Alenia Space under contracts to ESA. The scope of the studies were to identify needs in the Arctic region that could be met with mission architecture containing space elements, to propose such mission architectures, to define the elements of one of the architectures to some detail and to propose a plan to implement it.

78 needs, mainly in five domains, were identified by the consortia working closely with stakeholders. The needs were scored, prioritised and ranked based on criteria such as number of users affected, societal impact, economic value to the region, current and future gap in fulfilment and matching to industrial capabilities in the Nordic countries. The final downselection produced the recommendation for implementing an Arctic Weather Monitoring Satellite Constellation, AWeSat.

This executive summary gives an overview of how the study was performed and the intermediate and final results.

1. INTRODUCTION

This executive summary report summarizes the final results from ESA study (RFQ/3-15368/18/NL/GLC) referred to as the Arctic Mission System Study (AMSS). The purpose of this document is to concisely summarize the findings of the study for non-experts in the field.

1.1 CONTEXT

This study answers the needs for the Agency to take steps to support sustainable development, better knowledge of the environment and economic development of specific areas while ensuring the protection of the corresponding valued ecosystems, such as the Arctic. Based on the outcome of one of ESA's preliminary Arctic studies and workshops with industry and delegations, an industrial system study was initiated named "Arctic Mission System Study" which received funding from the Preparation Element of the Discovery, Preparation and Technology Development Programme under the ESA Basic Activities.
The system study shall address the prioritisation and consolidation of needs and interests into a set of mission requirements, and to elaborate end-to-end concepts for mission architectures based on the identified needs and requirements.

1.2 WORK LOGIC

The study activities have been organized in three main tasks:

1. **Task 1:** Analysis of user needs and interests over the Arctic Region. Identification and prioritisation of the needs and establishment of a preliminary set of requirements for the Arctic Mission System of system.
2. **Task 2:** Identification of options for mission architecture concepts. Analysis of existing or planned assets and gap to cover the Task 1 identified needs.
3. **Task 3:** Preliminary assessment of the selected mission architecture concept. Including analysis, trade-off of options.

1.3 CONSORTIA

Two Consortia, led by OHB Sweden and Thales Alenia Space France (TAS-F) respectively, were selected to perform two studies in parallel. The first consortium was constituted of OHB Sweden (leader), KSAT, Space Norway, CLS and Polar View. For the second half of the study, Omnisys Instruments were brought in to the consortium to provide payload expertise. The second consortium was constituted of Thales Alenia Space France (leader), FMI, NERSC, UPC, SatConsul, GomSpace, Space Norway and KSAT. After completing task 1 and task 2 in parallel it was decided at the Gap Analysis Review (GAR) that both consortia should focus on studying the design of the mission elements of a single mission architecture. Thus, in task 3, the OHB Sweden consortium focused on the design of the spacecraft element of the mission architecture and the TAS-F consortium focused on the design of the ground segment, the data management segment and the orbit, launch and system (spacecraft and constellation) management elements.

2. RESULTS

2.1 TASK 1: ANALYSIS OF NEEDS AND INTERESTS OVER THE ARCTIC REGION.

The first part of this study identified the needs and interests to survey the Arctic Region. All user needs and interests have been collected using the selected consortium partners' extensive end-user and end-end-user networks, e.g. arctic communities, meteorological institutes, coast guard organisations, offshore/maritime sector, fishing agencies, ministries and intergovernmental organisations (ECMWF/Eumetsat). The needs were assessed by means of calling for the users to state the needs they could identify in an open questionnaire sent to representatives for the identified groups and through a survey. All Nordic countries' needs were used in this analysis. i.e. Denmark, Finland, Norway, Sweden and Estoni[1]a, but also representatives from Iceland, Germany, Canada and Saami were consulted in this study. From this study, both consortia identified a large list of needs (60) which could be grouped into several categories as presented in Table 1.

Table 1: Categorized Arctic needs

Sustainable Management of Fisheries	Climate services	Earth Observation Science
Environmental monitoring (e.g. Oil slick detection, oil in ice etc.)	Animal tracking	Communication
Sea Ice Characterization and detection	MetOcean data collection	Navigation
Ground motion monitoring	Economic interests	Governmental and public interests (e.g. Vessel detection)

In order to extract the main Arctic Mission system application domain form the large number of needs, a prioritization exercise has been performed based in three phases. First, the industry consortium has prioritized all received needs using three Key Performance Indicators (as defined by ESA): Amount of users, economic revenue and strategic value for the Arctic region. In the second phase, these results from the consortium were shared with all end-users which responded by their prioritization. Lastly, a ranking was performed based on: needs which could be covered by a common architecture, needs from Nordic industry, needs requiring new instrumentation and needs in line with the consortium area of expertise.

Down selection of needs

The down selection of needs thanks to the prioritisation exercise led to the identification of two prioritised applications to be covered by the Arctic Mission System by the consortia:

- Polar weather forecasting and real time reporting
- Sea Ice Detection and Characterization,

and another two applications that were to be studied at a higher level of abstraction:

- Arctic Data Center
- Broadband Telecommunication

[1] The terms end-users and end-end-users were introduced in the Requirements Prioritisation Review to distinguish between end-users, that use the data produced by the system to produce higher level data products, and the end-end-users that use the data produced by the system or data products based on the same data other enterprises.

The TAS-F consortium was instructed to focus High Earth Orbit solutions to prioritised applications while the OHB Sweden consortium was instructed to focus on solutions based on small satellites.

2.2 TASK 2: IDENTIFICATION OF EXISTING ASSETS AND GAP FILLER ELEMENTS FOR ARCTIC MISSION ARCHITECTURE

The second phase of the study consisted of assessing existing or planned assets to meet these most promising needs and consequently analysed the expected gaps and their possible gap fillers using an architecture as proposed by the consortium.
The TAS-F consortium focussed on studying the feasibility of a large HEO platform whilst the OHB Consortium focused on a solution with small satellites, addressing augmentable constellation concepts.

Assets and gap analysis

It has been concluded that the telecommunication services needs could be covered by commercial missions. Also, the selected Norwegian mission “Arctic Broadband Satellite Mission” is foreseen to provide relevant communication services on the Arctic Region. The need for an Arctic Data Center has been considered as to be part of the under development DIAS for ESA and therefore should not be considered as a gap in the following years.
On the remaining two application domains, Polar Weather and Sea Ice monitoring, the main constrains which have been highlighted is the need for high temporal resolution.
Some High Priority Copernicus Mission studies are on-going and the associated measurement together with the emerging commercial initiatives, such as Iceye, are expected to answer the Sea Ice monitoring needs. Finally, the Nordic perspective and benefits of having a global weather system improvement finally made the decision in favour of the Polar weather monitoring need.

Nordic met-offices (i.e. SMHI and Met-No) and ECMWF emphasised their key needs of shorter re-visit times and short delivery latency. The currently most used meteorological satellites in geostationary orbits are not suitable for covering the arctic region due to the bad view angle at higher (and, correspondingly, at lower) latitudes. Alternatives like satellites in sun-synchronous (near-polar) low-earth-orbits provide global coverage (including polar regions) but are not sufficiently present and as such result in long revisit times. In order to solve this problem, a constellation of multiple satellites is proposed.

Preliminary Arctic Mission Architectures

Based on this conclusion both consortia proposed a different solution to cover the need for weather monitoring.

- **OHB Sweden:** Constellation of small Low Earth Orbit satellites carrying a Passive Microwave Radiometer (PMR), providing full Arctic Region Coverage with a fine temporal resolution.
- **TAS-F:** A pair of High Elliptical Orbit satellites the same instrument as from MeteoSat 3rd Gen Imaging mission (Flexible Combined Instrument (FCI)). This solution would allow to provide the same measurement in the Arctic region as those on the rest of the globe.

The first solution of OHB Sweden using a PMR small satellite constellation was selected to be further analysed in the third and last phase of the study as the second solution from TAS-F is already being analysed in the frame of another ESA study.

2.3 TASK 3: PRELIMINARY ASSESSMENT OF ARCTIC MISSION CONCEPTS

The third and last phase of study has been performed with the objectives to define a baseline for the system definition, to perform a preliminary design of the missing elements of the system and to come up with a development roadmap of such a proposed mission.
The proposed system improves the arctic weather forecasting by increasing coverage, decreasing the latency of weather measurements in the arctic region and provides real time reporting using a constellation of small satellites carrying Passive Microwave Radiometers (PMR) in highly inclined (near polar) orbits. Furthermore, these measurements will also improve weather monitoring on a global scale.
The Arctic Weather Satellite System (AWeSat) architecture is designed to complement existing data sources (surface based and in geostationary and polar orbits) in providing data for assimilation into existing weather forecast systems. AWeSat consists of the elements summarised in Table 2.

Table 2: AWeSat architecture solution summary

Spacecraft Payload	Spacecraft Platform	Constellation	Launch	Ground segment	Application
Scanning PMR	Small Satellite	16 satellites	Dedicated	Centralised & Decentralised	Input to existing forecast models
- Oxygen - Water	- 100kg - COTS - Downlink: ▪ Continuous stream ▪ Full earth download	- 4 planes - 4 satellites per plane - (Near) polar - Full Arctic coverage - Low revisit time	- 4 satellites per launch - Sharing with other missions	- Three Arctic ground stations - Access to real-time data	- Existing applications - Meteo offices

Development roadmap

Figure 1 illustrates the overall development roadmap proposed for the entire operational constellation as proposed in this study. First, a single prototype called ProtAWeSat will is proposed to be developed, launched and evaluated in step 1. After successful evaluation by end users of data collected on orbit, the full constellation with all related AWeSat elements (ground, operations, maintenance etc) can be developed for full operational purpose in step 2. Every satellite has a design lifetime of 5 years resulting in a necessary extension period (step 3).

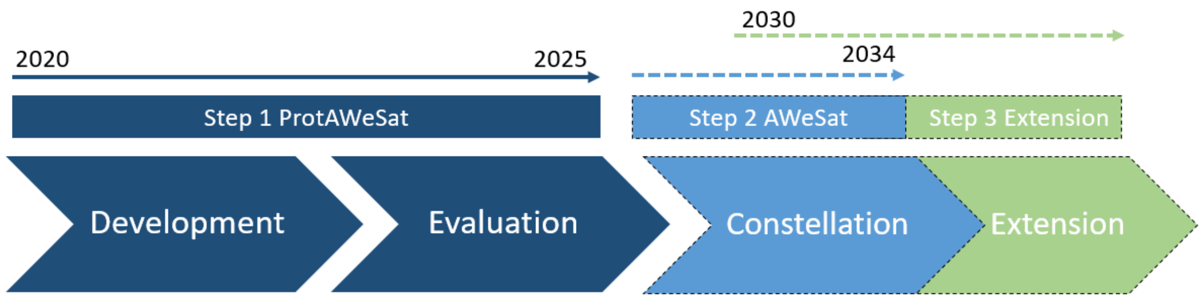

Figure 1: AWeSat development roadmap

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