USE-CASES – The Arctic Region

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This document lists the use cases to be used as part of the “The Arctic Region” thematic call. It aims at developing sustainable services leveraging space assets and technology in consort to address key challenges and opportunities to develop operational solutions. The use cases presented result from engagements between the European Space Agency (ESA) and stakeholders with varied interests in the Arctic Region, as well as internal research and public reports. These include pan-Arctic fora, coastguards, research institutes, energy operators, risk management providers, and satellite operators. The objective of this initiative is to support European industry in studying, developing and demonstrating, operational services to address current and emerging challenges in the Arctic, by notably utilising satellite technology and data.

When writing the initial proposal (APQ/APQ+ proposal), the applicant will make clear which use case(s) their solution will address, if chosen from those listed here.

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Use case n. 1 Environmental Protection

Increased maritime and offshore activity in the Arctic region is heightening the risk of environmental pollution, in the form of oil spills, air pollutants, underwater radiated noise, and others, with the potential for severe disturbance to fragile marine ecosystems and Arctic communities. Detection of oil spills from vessels, offshore platforms, and pipelines in the Arctic region present novel challenges relative to those in non-Arctic regions. This is owing to the obstructive presence of sea ice and snow, cloudy conditions, and the perpetual darkness of the polar winter forcing reliance on radar and other non-visual techniques during those periods. Many marine mammals rely on acoustics to communicate and navigate dark or ice-covered waters. Underwater radiated noise from increased vessel traffic and offshore activity risks disorienting marine mammals, impacting their ability to forage and find mates. Persistent or violent noise events can even displace marine life from their habitats, interfere with migration, and exacerbate other ecosystem stressors. Other pollutants such as persistent organic pollutant (POPs) and microplastics are transported to the Arctic via ocean currents and rivers, while also being produced by local sources such as industrial sites, infrastructure and shipping, alongside black carbon, heavy metals, and beyond. Permafrost thaw further increases pollution risks through the mobilisation of legacy contaminants, such as mercury, into soils and water systems.

This focus area invites innovative ideas for operational, deployable and scalable services that use satellite communications, Earth observation and/or positioning (combined with complementary technologies) to support pollution detection, monitoring, assessment and response in the Arctic. Proposed services may address one or more of the following areas:

- Operational oil spill detection and monitoring, effective in ice-affected waters, cloudy conditions and Arctic lighting conditions year-round, to support rapid response and mitigation activities.
- Environmental monitoring systems for marine, coastal and land pollution (air, surface and underwater), to support planning, compliance and ecosystem protection.

Use case n.2 Aquaculture and Fishery Resilience

Several of the Arctic States engage in coastal aquaculture and operate fisheries at sea, with Norway being the world's largest producer and exporter of Atlantic salmon, amongst other seafood. As such, sub-Arctic waters, like the Barents Sea, contribute disproportionately (by economic value) to global seafood production, via output from Norway, Canada, Russia, and to a lesser extent the other Arctic States. Climate-driven changes in global fish stocks are restructuring marine ecosystems, with species migrating poleward, into deeper waters, between EEZs (Exclusive Economic Zones), and from national jurisdictions towards the high seas. Warming seas and heatwaves can increase the prevalence of sea lice outbreaks, infectious disease, algal blooms, and jellyfish invasions, threatening produce quality and even crashing fisheries where shorter-lived species are farmed. Marine predators (such as tuna) entering new ecosystems may upend food chains, threatening species that have nowhere left to migrate. These biological stressors and shifting distributions may present risks and challenges for sustainable fishery management, with outsized consequences for the nations that rely heavily on their seafood industry for sustenance, employment and national income.

While the Central Arctic Ocean Fisheries Agreement (effective 2021) bans unregulated commercial fishing in the "central Arctic" until 2037 (to enable scientific research on ecosystem understanding), there is a need to support the adaptation and resilience of aquaculture and fishery operations in sub-Arctic waters today.

This focus area invites innovative ideas for operational services that use satellite communications, Earth observation and/or positioning (combined with complementary technologies) to support day-to-day decision-making and risk management by aquaculture operators, fisheries, insurers, and regulators:

- Operational, early warning, alerting and predictive services for marine heatwaves and extreme climate events, enabling aquaculture and fisheries operators to take timely mitigation actions (e.g. stock relocation, oxygenating water, lowering submersible pens to cooler depths).
- Monitoring and alert services for jellyfish invasions, algal blooms, infectious disease outbreaks, providing geo-located risk indications and forecasting to support operational planning and loss mitigation.
- Actionable climate projections in coastal areas, to support risk management and seasonal outlooks for aquaculture stakeholders.
- Monitoring for and predicting the connection between changes in environmental parameters (such as sea temperature, pH, salinity…)—at the sea surface and at depth—and disease outbreaks to support operational decision-making.

Use case n. 3 Critical Infrastructure Protection

The Arctic landmass hosts diverse, and often remote, infrastructure and assets that are vulnerable to both intentional human threats and unintentional, climate-driven threats. These span transportation infrastructure (roads, bridges, and airstrips), buildings and settlements, utilities (power and telecommunication networks) and sensing and monitoring systems essential for safety, navigation and domain awareness. Increasing temperatures in the Arctic region catalyse permafrost thawing, upon which much of such infrastructure is situated, destabilising such structures and threatening their failure. Subsequent accelerated coastal dynamics increase erosion at coastlines, threatening local communities and the infrastructure that serves them. Extreme weather events, such as wildfires, inland and coastal flooding, have significant socio-economic consequences in the region and are anticipated to become more prevalent into the future. Further, uncooperative UAS/drone platforms and GNSS jamming from nearby military exercises can disrupt commercial operations (in aviation, ports, surveyance…).

This focus area invites innovative ideas for operational services that use satellite communications, Earth observation and/or positioning (combined with complementary technologies) to support protection, monitoring and resilience of critical infrastructure and assets in the Arctic. Proposals should focus on non-aggressive protective and resilience-enhancing services with clearly identified users and operational outputs, rather than offensive security activities.

- Structural integrity monitoring of critical infrastructure, with prediction and detection of deterioration and failure risk.

- Advance pan-Arctic geohazard (permafrost thaw, coastal erosion, thermokarst) mapping at improved spatial and temporal resolution to support engineering design, emergency alerting and/or risk assessments, associated with changing permafrost conditions and prospective impacts on infrastructure.
- Persistent detection and alerting services for non-aggressive threats and anomalies affecting critical infrastructure (e.g. GNSS interference, anomalous activity near assets, uncooperative UAS/drone platforms), providing timely situational awareness and forensic evidence to relevant civil or defence authorities.

Use case n.4 Search and Rescue

Melting sea ice in the Arctic is both lengthening the navigation season and opening new maritime trade routes in the region. This expanded accessibility is increasing commercial, passenger and specialized maritime traffic. This is resulting in a heightened risk of accidents and search-and-rescue (SAR) incidents in a sparse region with limited and unevenly distributed SAR assets, surveillance, communications, and general infrastructure. A limited number of large-scale permanent hubs exist to support maritime or aviation operations and are generally concentrated about a few primary gateways across the coastlines of the Arctic states (such as Murmansk, Longyearbyen, Tromsø, and Nuuk). Smaller Arctic ports are more prevalent, though highly seasonal, equipped only to host smaller vessels and aerial platforms, with limited medical support capabilities, and with less robust connectivity infrastructure compared to the larger Arctic hubs. Additionally, following detection of an incident, SAR operations are made harder by the vast distances and associated transit times of support capabilities, the polar night, and the harsh environmental conditions compromising the efforts of responders and the technologies at their disposal. Beyond practical constraints, coordination amongst the eight Arctic nations

Use case n.5 Ice Charting, Collision Avoidance and Navigation

The threat of errant ice bodies in the Arctic is becoming more prevalent, as higher air and water temperatures catalyse iceberg calving at the boundaries of ice and ocean water. Such threats present a collision risk to vessel operators navigating through the region, as well as energy operators concerned by potential floating iceberg impacts with their offshore platforms. For offshore oil platforms, close encounters with free-floating ice can threaten a halt in production, while bottom-scouring icebergs may cause damage to the network of pipelines installed at the ocean floor, resulting in significant operational and/or damage costs. At present, various solutions are used to detect, track and circumvent such obstacles. For oil platforms, these include local radar tracking systems with detection ranges of 10s of kilometres from the platform, as well as satellite SAR (Synthetic Aperture Radar) imagery in tip-and-cue systems, i.e. use of coarse resolution imagery (e.g. Sentinel-1) for initial detection followed by higher resolution to zone in on the target and feed trajectory models. Aerial or vessel-based patrols also provide ice monitoring and surveillance. Vessel operators use a combination of satellite SAR imagery, radar, sonar and human observation to inform detections and charting, supported by satellite-AIS (Automatic Identification System) data fusion to filter for other vessels. Beyond collision avoidance, vessel operators require precise, up-to-date information on the location of ice edges, ice type, concentration, nearby vessels, and various parameters critical for deciding on safe speeds/routes through pack ice. This enables to avoid accidents, but also to find paths of least resistance (e.g. in the case of icebreakers) to save fuel.

While these solutions offer some level of support and risk management to stakeholders, emerging satellite technology and data capabilities could offer a means to improve sea ice mapping and free-floating iceberg detection and tracking. In addition to improvements in chart resolution and iceberg detection, there is a need for downstream services that address operational limitations faced by ice information providers and users. These include reducing end-to-end latency from existing satellite data streams, enabling more frequent updates in dynamic or high-risk areas, and exploiting complementary use of available SAR frequencies and acquisition modes to balance wide-area coverage with high-resolution monitoring. Services that integrate and harmonise multi-source satellite data with in-situ observations and modelling outputs, while clearly conveying confidence and limitations, can significantly enhance the usability, resilience and operational value of ice charts. This focus area invites innovative ideas for services that use satellite communications, Earth observation and/or positioning (combined with complementary technologies) to support these needs. Proposals may address one or more of the following areas:

- Improve the temporal and spatial resolution and availability of sea ice charts in the Arctic (and Antarctic) region to capture rapid changes at very high latitudes, marginal ice zones, and obscured narrow navigable channels, in support of vessel navigation in varied weather conditions.
- Advance the timeliness of detection and tracking latency of free-floating icebergs that pose a threat to vessels or offshore infrastructure.
- Advance the predictive capability of free-floating iceberg trajectory models to support offshore infrastructure operators.

Use case n.6 Maritime Security

Melting Arctic sea ice is opening shorter, seasonally navigable shipping lanes, like the Northern Sea Route and the Northwest Passage, but these new trade routes come with significant security and geopolitical risks. Additionally, the Arctic is estimated to host a significant proportion of the world's undiscovered oil and natural gas resources, as well as vast mineral deposits and rare earth elements. As new routes and previously unreachable fields and deposits open, interest from state and commercial actors may increase, leading to strategic competition for resource access. Increased maritime activity may then coincide with opportunistic unlawful activity,illegal, unreported and unregulated (IUU) fishing, smuggling, grey-zone operations, shadow-fleet activity, and other international law violations. These may manifest as so-called "dark vessels" operating in restricted zones to exploit fishing opportunities, conduct undersea surveillance, or smuggle illicit goods undetected. Other potential concerns include sanction-evasion tactics, covert vessels probing state defence capabilities, or actions that test coastal-state jurisdictions in disputed straits. In view of this, there is scope for innovative solutions that support improved maritime situational awareness and security.

This focus area invites innovative ideas for services that use satellite communications, Earth observation and/or positioning (combined with complementary technologies) to support maritime stakeholders with enhanced security. Proposals may address one or more of the following areas:

- Advance maritime domain awareness and “dark vessel” detection and monitoring using satellite Earth observation, autonomous platforms, in-situ sensing, or combinations thereof.
- Threat and anomaly alerting services for risks to offshore energy, subsea telecommunications and maritime assets (e.g., proximity anomalies, GNSS interference indicators, cyber-resilience telemetry backhauled via satellite), providing timely situational awareness and forensic evidence to civil or defence authorities.