# REQUIREMENTS DOCUMENT

# for

# MULTI-APERTURE SAR STUDY

**Revision A**

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# 1    Introduction

This Requirements Document contains the requirements specific to Other Government Departments (OGDs) that were established as part of the RADARSAT Next Generation (RNG) Option Study.

This document is intended to be used as an input for the Multi-Aperture SAR Study to help identify options with the highest benefits and must not be interpreted as formal requirements from the OGDs.

# 2    Requirements

## 2.1 High-Level DND Requirements

**[DND0001] Persistent Surveillance Capability:** The system must provide a reliable, minimum system availability of 90% (TBC), operational surveillance capability over the land and maritime areas of interest to DND.

*Rationale:*

- Fundamental requirement defining the operational objectives from which all other requirements are derived.

*Comments:*

- Scope of the system capabilities is restricted to land and maritime applications.

**[DND0100] Canadian Domestic Maritime Area.** This area must include Canada's surrounding waters out to 1200 nautical miles from Canadian territory, including maritime approaches to Canada at lower latitudes than Canada.

**Priority Classification for [DND0100]**

| Reqmts | Classification | POC Comments |
|--------|----------------|--------------|
| 0-1200 NM | ESSENTIAL | |

*Rationale:*

- DND and OGDs have requirements to track incoming ships in that area.

*Comments:*

- The area will be covered on a daily basis by RCM from latitude 42° N and above but not always with the ship detection mode.

**[DND0110] Canadian Expeditionary Naval Task Group Maritime Area**. This region must include two areas with a radius of 250 nautical miles, anywhere in the world.

**Priority Classification for [DND0110]**

| ESSENTIAL |
| --- |

*Rationale:*

- This requirement is to support Canadian naval operations abroad.

*Comments:*

- The locations of the areas are not fixed and may vary on a daily basis.

**[DND0120] Continental North American Maritime Area.** This area must be an extension of Canadian domestic maritime area around continental USA out to 1200 nautical miles from land, including Atlantic, Pacific and Arctic oceans, Gulf of Mexico, Caribbean Sea, Alaskan panhandle, islands of Bahamas, Barbados to coastlines of Venezuela and Colombia, but excluding Hawaii.

**Priority Classification for [DND0120]**

| Reqmts | Classification | POC Comments |
| --- | --- | --- |
| 0-1200 NM | ESSENTIAL | |

*Rationale:*

- The area is of joint interest to DND and US DoD.

*Comments:*

- A map of the area is provided in Annex A.

**[DND0130] UK-Norway Maritime Area.** This region must include waters up to 1200 nautical miles around North Atlantic countries such as UK and Norway, including the Strait of Gibraltar, the White Sea and the Mediterranean Sea.

**Priority Classification for [DND0130]**

| Reqmts | Classification | POC Comments |
| --- | --- | --- |
| 0-1200 NM | DESIRABLE | |

*Rationale:*

- The area is of joint interest to DND and NATO partners.

*Comments:*

- A map of the area is provided in Annex A

**[DND0140] Canada-Australia Coalition Maritime Area.** This area must include waters around Australia, up to 1200 nautical miles from land.

**Priority Classification for [DND0140]**

| Reqmts | Classification | POC Comments |
|--------|----------------|--------------|
| 0-1200 NM | DESIRABLE | |

*Rationale:*

- The area is of joint interest to DND and Australia's Department of Defence.

*Comments:*

- A map of the area is provided in Annex A.

**[DND0200] Persistent Vessel Detection.** As a goal, the system should detect, classify, identify and track all vessels, day and night, in all weather conditions, in near real-time.

**Priority Classification for [DND0200]**

DESIRABLE

With the following priority of effort:
1. **Canadian domestic maritime area**
2. **Canadian Expeditionary Naval Task Group maritime area.**
3. **Continental North American maritime area.**
4. **UK-Norway and Canada-Australia Coalition maritime area.**

*Rationale:*

- The requirement provides guidance on the general use of the system with respect to ship detection.

*Comments:*

- The exact intent of [DND0200] is made clear by several requirements below.

**[DND0210] SAR Coverage Rate.** Complete SAR coverage must be provided at least four times daily.

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**Priority Classification for [DND0210]**

ESSENTIAL
</div>

- 3 times daily (SAR) - Canadian domestic maritime + Continental North American Maritime Area with a capability for 4 times a day access;

- 4 times daily (SAR) - Canadian Expeditionary Naval Task Group maritime area

<div align="center">

DESIRABLE
</div>

- 4 times daily (SAR) - Canadian domestic maritime + Continental North American Maritime Area

<div align="center">

OPTIONAL
</div>

- 1 time daily (SAR) - UK-Norway and Canada-Australia Coalition maritime area.

*Rationale:*

- States that collection of AIS and SAR data is looked for.

- Precise how much persistence is desired.

*Comments:*

- Concept of operation is similar to RCM. AIS data provides ship identification and classification for cooperative targets.

- SAR provides confirmation of AIS data and detection of non-cooperative targets. SAR is used for detection mostly, classification and identification using SAR data could be performed by the system but no performance requirements are given.

- About equally spaced temporal coverage in average is implicit in the requirement. Four contacts a day occurring very close in time is not considered meeting the requirement.

- The priority is collection of data over Continental North America. Relaxation of the coverage over other areas is possible.

- Access means the system can potentially image the area without necessarily taking an image. Coverage means that actual acquisition must happen.

- AIS coverage is 4 times daily, priorities only concern SAR data.

- Potential conflict between Naval Expeditionary Task Group and other areas can be ignored at this stage.

**[DND0220] SAR Vessel Detection Performance.** The system must detect vessels of lengths 25 meters or larger with a 90% probability, in all weather conditions up to and including sea state 5, with sufficient swath to meet the coverage rate specified above.

**Priority Classification for [DND0220]**

| ESSENTIAL |
| --- |

*Rationale:*

- Quantify the required performance for SAR ship detection.

*Comments:*

- Probability of false-alarm is $2.5 \ 10^{-9}$ over a resolution cell of 50 m x 50 m.

- A ship and sea clutter model provided by DRDC/CSA must be used to verify design compliance to this requirement.


**[DND0230] AIS Signal Detection.** Class A vessel AIS messages must be received and discriminated with a 90% probability.  As a goal, the same requirement should apply to Class B messages.

**Priority Classification for [DND0230]**

| Reqmts | Classification | POC Comments |
| --- | --- | --- |
| Class A | ESSENTIAL | |
| Class B | OPTIONAL | |

*Rationale:*

- Quantify the desired performance for AIS ship detection.

*Comments:*

- The requirement must interpreted in line with coverage, i.e. each time an area is covered there is minimum probability of 90% that all ships over that area are detected using their AIS message.

- In areas of high ship density near shorelines, the availability of AIS data from shore stations should be taken into account.

**[DND0240] AIS Coverage Area.** As a goal, AIS coverage should be worldwide. Minimum requirement is that areas specified above must be covered.

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**Priority Classification for [DND0240]**
</div>

| Reqmts | Classification | POC Comments |
|---|---|---|
| Area specified in POC Comments | ESSENTIAL | Canadian domestic maritime area from 50 to 1200nm. Canadian Expeditionary Naval Task Group maritime area. Continental North American maritime area from 50 to 1200nm. |
| | DESIRABLE | UK-Norway and Canada-Australia Coalition maritime area. |
| Worldwide | OPTIONAL | Worldwide |

*Rationale:*

- Provides a goal for AIS.

*Comments:*

- Comments made on [DND0230] also apply.

**[DND0250] SAR/AIS Data Latency.** The system must provide near real-time data latency (<15 minutes) from SAR illumination of vessels and AIS data reception onboard space segment to publication of ship contact report. This requirement is limited to Canadian domestic maritime area.

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**Priority Classification for [DND0250]**

ESSENTIAL
</div>

*Rationale:*

- Precise the meaning and application of near real time.

*Comments:*

- The requirement includes a possible delay between SAR illumination and beginning of down-link at a ground station (or data relay). The solution for the data links must be sized such that the 15 minutes requirement is met.

- No requirement is imposed in other AOI. There is an indirect requirement that data collected in AOI should not create a backlog that could affect the performance over Canadian Domestic Area.

- Small areas at the edge of coverage may be non-compliant. System design should not strive to ensure 100% compliance.

**[DND0300] Tactical Land Reconnaissance.** The system must be able to monitor 100 small targets worldwide (i.e. buildings, bridges, camps, port, airfield facilities) to detect coherent changes.

**Priority Classification for [DND0300]**

| Reqmts | Classification | POC Comments |
|---|---|---|
| Ellipse 8km x 5km | ESSENTIAL | |
| Ellipse 10km x 8km | DESIRABLE | |
| Square 10km x 10km | OPTIONAL | |

*Rationale:*

- Defines number and sizes of areas for which high resolution observations are required. Coherent changes should be provided.

*Comments:*

- Phase coherent change is meant here.

- Other system characteristics will be determined when trade off between resolution, revisit, SNR, etc has been established. Tentatively, resolution of 1 m and CCD period better than 4 days should be assumed.

**[DND0310] Operational Land Reconnaissance.** The system must be able to monitor 20 areas 100km x 100km worldwide to provide imagery and detect coherent changes.

**Priority Classification for [DND0310]**

| Reqmts | Classification | POC Comments |
|---|---|---|
| Detect 1 cm changes in decorrelation | ESSENTIAL | The 1/5 of a wavelength requirement caused some confusion. In an attempt to simplify what the user needs, the requirement is now expressed in terms of a directly measurable requirement, such as 1 cm. Therefore, CCD shall identify changes in decorrelation of 1 cm or better. |

*Rationale:*

- Defines requirement for large areas to be monitored for coherent change detection.

*Comments:*

- Other system characteristics are to be determined when trade off between resolution, revisit, SNR, etc has been established. Tentatively, resolution should be 5 m and CCD period better than 4 days. Multiple acquisitions could be used to cover the 100 km area if it can be done in less than 24 hours.

- Performance requirement applying to coherent detection is that if nothing in the environment changes between two acquisitions (rain, snow, vegetation change, etc) then the system must be able to detect a change in a resolution cell corresponding to a displacement of 1 cm (in horizontal or vertical direction) with a 90% confidence level.

- The system must be able to detect changes due to vehicle tracks, human activities, etc which may affect sub-parts of a pixel.

**[DND0400] High-Resolution Imagery.** The system must provide a beam mode with a resolution of 0.5 meter or better with a worldwide access to monitor 100 small targets.

**Priority Classification for [DND0400]**

| Reqmts | Classification | POC Comments |
|---|---|---|
| Ellipse 8km x 5km | ESSENTIAL | |
| Ellipse 10km x 8km | DESIRABLE | |
| Square 10km x 10km | OPTIONAL | |
| Scene density: 3 in 2500 km$^2$ | ESSENTIAL | |
| Scene density: 4 in 2500 km$^2$ | DESIRABLE | |

*Rationale:*

- States the needs for high-resolution radar imagery.

*Comments:*

- Ground Resolution (in azimuth and range direction) is covered by this requirement.
- The mode is expected to support CCD. There is no requirement for a minimum CCD period at this point. However, it would be useful to identify the resulting CCD period for each options.

**[DND0410] Moving Target Indication.** The system must be able to determine the velocity and the direction of objects moving on land or water.

**Priority Classification for [DND0410]**

| ESSENTIAL |
|---|

*Rationale:*

- Capability has been demonstrated by RADARSAT-2 and will be supported in part by RCM. MTI is providing high value military intelligence.

*Comments:*

- This requirement applies to the radar data. AIS heading and velocity information is covered by other requirements.

- The wording 'must be able' means that the system is capable but the capability is not required in a systematic manner nor the capacity must be available on every spacecraft.

**[DND0500] Global Revisit.** A 12-hour average revisit time must be provided worldwide.

**Priority Classification for [DND0500]**

ESSENTIAL

*Rationale:*

- Operational requirement to support operations worldwide.

*Comments:*

- No detailed required is given to control the statistics on revisit. Expectation is that if an area is visited twice in a day, the two revisits are spaced by 12 hours $\pm$ 2 hours.

- This requirements applies to [DND0400] and [DND0410].

**[DND0600] Time-Sensitive Tasking.** It must be possible to receive, process and execute changes to the collection plan in real-time, the only time constraint being the location of the ground stations.

**Priority Classification for [DND0600]**

ESSENTIAL

*Rationale:*

- Essential capability for military operations that will be improved in RNG Options.

*Comments:*

- The wording ''the only time constraint being the location of the ground stations'', means there can be a delay when a satellite is not in view of the stations to upload the new acquisition plan. Other aspects of the acquisition plan must be executed in real time.
- The study on time-sensitive tasking should consider the possibility of radar mode changes.

**[DND0610] Emergency Override.** The system must have a non-routine capability to override any orders for emergency or security purposes.

**Priority Classification for [DND0610]**

ESSENTIAL

*Rationale:*

- Essential capability for military operations.

*Comments:*

- This capability is already present in RCM.

**[DND0620] Data Download to Deployed Ground Stations.** It must be possible to download SAR and AIS data to ground stations deployed while conducting expeditionary operations.

| Priority Classification for [DND0620] |
|:---:|
| ESSENTIAL |

*Rationale:*

- Essential capability for military operations.

*Comments:*

- This capability is already present in RCM.
- Assumption about the deployable ground stations is that they can be transported in a container.

**[DND0630] System Protection Measures.** The system must provide a robust protection of commands and data links in accordance with GoC security policies.

| Priority Classification for [DND0630] |
|:---:|
| **ESSENTIAL** |

*Rationale:*

- The system data links must be ruggedized for military use.

*Comments:*

- CSEC and DFAIT will provide guidance for the exact means to be used to protect data links.

**[DND0640] Unrestricted Data Policy.** It must be possible to share any data and product, with any partner or coalition, without restriction.

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**Priority Classification for [DND0640]**

**ESSENTIAL**

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*Rationale:*

- Requirement to support exchange of data with Allies and OGDs.

*Comments:*

- The statement will be reflected in the data policy and operating license. ''Without restriction'' means that the system design should allow exchanging data easily.

## 2.2 High-Level AAFC Requirements

This section provides high-level requirements relating to Agriculture and Agri-Foods Canada (AAFC).

**[AAFC0100] Surface Soil Moisture Estimates Threshold.** It must be possible to estimate surface soil moisture over the entire agriculture region of Canada on a weekly basis with a data latency of 24 hours, a resolution of ≤30m, 4-look (TBC), an NESZ of performance levels comparable to RADARSAT-2, an absolute radiometric accuracy of 1 dB (0.5dB preferred), and HH and VV polarizations (CP may be good compromise).

*Rationale:*

- ≤30m, 4-look (TBC) resolution is required to identify field level soil moisture.
- Very good NESZ is needed for soil moisture as smooth bare soils have low signal.

*Comments:*

- Research on the use of compact polarimetric data for soil moisture applications is ongoing. If results show promise, there would be interest in a compact polarimetric mode for L, C and X-band frequencies.
- Image acquisition should be avoided during early morning pass.
- L-Band is ideal to provide soil moisture at deeper depths, to minimize effects of roughness on radar signal and to permit determination of moisture under some vegetation canopies.

**[AAFC0110] Surface Soil Moisture Estimates Goal.** It must be possible to estimate surface soil moisture over the entire agriculture region of Canada on a daily basis with a data latency of 24 hours, a resolution of ≤30m, 4-look (TBC), an NESZ of performance levels comparable to RADARSAT-2, an absolute radiometric accuracy of 1 dB (0.5dB preferred), and HH and VV polarizations (CP may be good compromise).

*Rationale:*

- See AAFC0100.

*Comments:*

- See AAFC0100.

**[AAFC0200] Crop classification and acreage estimation.** It must be possible to perform crop classification and acreage estimation over the entire agriculture region of Canada on a bi-weekly (once every two weeks) basis with a data latency of 1 week, a resolution of ≤30m, 4-look (TBC), an NESZ of performance levels comparable to RADARSAT-2, a relative radiometric accuracy of 1 dB (0.5dB preferred), and VV and VH polarizations (CP may be good compromise).

*Rationale:*

- ≤30m, 4-look (TBC) resolution is needed to identify crops as field level.

*Comments:*

- Ideally, X, C and L-Band are needed as higher frequencies provide better classification for low biomass crops while low frequencies are needed for higher biomass crops; SAR only crop classification benefits significantly from multi-frequency data access.
- Research on the use of compact polarimetric data for crop classification applications is ongoing. If results show promise, there would be interest in a compact polarimetric mode for L, C and X-band frequencies.
- Image acquisition should be avoided during early morning pass.

**[AAFC0300] Crop condition and productivity.** It must be possible to estimate crop condition and productivity over the entire agriculture region of Canada on a weekly basis with a data latency of 1 week, a resolution of ≤10m, 4-look (TBC), an NESZ of performance levels comparable to RADARSAT-2, an absolute radiometric accuracy of 1 dB (0.5dB preferred), and VV and VH polarizations (CP may be good compromise).

*Rationale:*

- ≤10m, 4-look (TBC) resolution is needed to identify within field crop conditions.

*Comments:*

- Ideally, X, C and L-Band are needed; X-Band has proven sensitive to upper canopy including volume of grain development; lower frequencies are sensitive to entire canopy and provide information on crop parameters indicative of productivity such as Leaf Area Index.
- Research on the use of compact polarimetric data for crop condition assessment is ongoing. If results show promise, there would be interest in a compact polarimetric mode for L, C and X-band frequencies.
- Image acquisition should be avoided during early morning pass.

**[AAFC0400] Monitoring soil tillage.** It must be possible to monitor soil tillage over the entire agriculture region of Canada on a weekly basis with a data latency of 1 week, a resolution of ≤30m, 4-look (TBC), an NESZ of performance levels comparable to RADARSAT-2, a relative radiometric accuracy of 1 dB (0.5dB preferred), and VV and VH or HH and HV polarizations (CP may be good compromise).

*Rationale:*

- ≤30m, 4-look (TBC) resolution is needed to identify tillage at field level.
- Very good NESZ is needed as smooth soils have low signal.

*Comments:*

- Ideally, X, C and L-Band are needed as sensitivity to roughness is frequency dependent; higher frequencies capture small changes in roughness caused for example by conservation implements such as chisels while conventional implements like moldboard ploughs create very rough conditions and lower frequency data are required to identify these land management practices.

- Research on the use of compact polarimetric data for tillage monitoring is ongoing. If results show promise, there would be interest in a compact polarimetric mode for L, C and X-band frequencies.

- Image acquisition should be avoided during early morning pass.

## 2.3 High-Level EC Requirements

This section provides high-level requirements relating to Environment Canada (EC) and EC Canadian Ice Services (CIS).

**[EC0100] Ice Monitoring for NAIS (North American Ice Service).** It must be possible to monitor ice over all Canadian waters, METAREAS, Inland Lakes, Arctic and Antarctic hemispheres on a twice daily basis with a data latency of 30 minutes, a resolution of ≤50m for wide swath (500km or better) and a high resolution of 3-50m at reduced swath, an NESZ noise floor of -25dB or better, and HH/HV & VV/HH polarizations with compact polarimetry and interferometric capabilities.

*Rationale:*

- Low noise floor required in order to detect smooth new ice.

*Comments:*

- The ice and iceberg monitoring requirements contributed by all NAIS partners (CIS, NIC, IIP); strong requirement for C-band continuity with L- and Ku band compliment.

**[EC0200] Iceberg Monitoring for NAIS.** It must be possible to monitor icebergs and ice islands larger than 10m within all Canadian waters, and METAREAS on a twice daily basis with a data latency of 30 minutes, swath width of 300km or greater, an NESZ noise floor of -25dB, and HH/HV & VV/HH polarizations with compact polarimetry and interferometric capabilities.

*Rationale:*

- There is a requirement for accurate and robust ship/iceberg discrimination.

*Comments:*

- The ice and iceberg monitoring requirements contributed by all NAIS partners (CIS, NIC, IIP); Strong requirement for C-band continuity with L- and Ku band compliment.

**[EC0300] Oil Spill Monitoring for NAIS.** It must be possible to monitor oil spills with a minimum width of 100m (length of oil spill will be in the kms range) as well as detect ships of minimum length 50m within the same surveillance swath over all Canadian waters and METAREAS on a twice daily basis with a data latency of 15 minutes, a swath width of 300km or larger, a noise floor and swath position that is suitable for the detection of both oil and ships at wind speeds 2-10m/s, an oil clutter to noise ratio of 6 dB over the entire swath, and HH/HV and VV/HH polarizations with compact polarimetry capabilities.

*Comments:*

- Requirement for concurrent AIS information on same swath.

- Requirement for concurrent estimates of surface wind on same swath.

**[EC0400] Data Policy to Permit Sharing with Partners (NAIS and others).** Requirement for free and open data policy.

NOTE: The following requirements, [EC0500] through [EC1100], represent goal requirements for EC.

**[EC0500] Derive Ice Thickness and Associated Stage of Development from SAR.** It should be possible to derive ice thickness with an accuracy of +/- 5 cm for level ice up to 50 cm thickness and +/- 20 cm beyond, over the same regions as listed in [EC0100].

*Rationale:*

- Deriving ice thickness from SAR is currently a science gap.

*Comments:*

- Desire for system to provide thickness or supply appropriate data to derive this ice parameter.

**[EC0600] Improve Detection of Ice Roughness Features (ridges, rubble fields).** It should be possible to calculate the area coverage of ridges to within an accuracy of +/- 10%, as well as to estimate the average ridge heights to within an accuracy of +/- 20cm, within an area of approximately 2 km; this requirement covers the same regions as listed in [EC0100].

*Comments:*

- Requirement is for the detection of small ridges ie. higher resolution imagery but at large swaths.

**[EC0700] Determine Ice Strength from SAR.** It should be possible to determine ice strength from SAR over the same regions as listed in [EC0100].

**[EC0800] Determine Ice Pressure from SAR.** It should be possible to detect moderate or severe ice pressure 90% of the time, over the same regions as listed in [EC0100] on a twice-daily basis.

*Rationale:*

- Higher temporal frequency should enable the derivation of ice pressure information.

**[EC0900] Determine Snow Cover on Ice from SAR.** It should be possible to derive snow depth to accuracy within +/- 20%, over the same regions as listed in [EC0100].

*Rationale:*

- Identification of wet snow areas in SAR is an important aspect of navigation.

**[EC1000] Improved Automated Classification.** It should be possible to provide highly accurate automated classification (>95%).

**[EC1100] Improved Ship / Iceberg discrimination.** It should be possible to have iceberg/ship discrimination capabilities that are better than RCM capabilities as per the iceberg requirements listed in [EC0200].

## Acronyms and Abbreviations

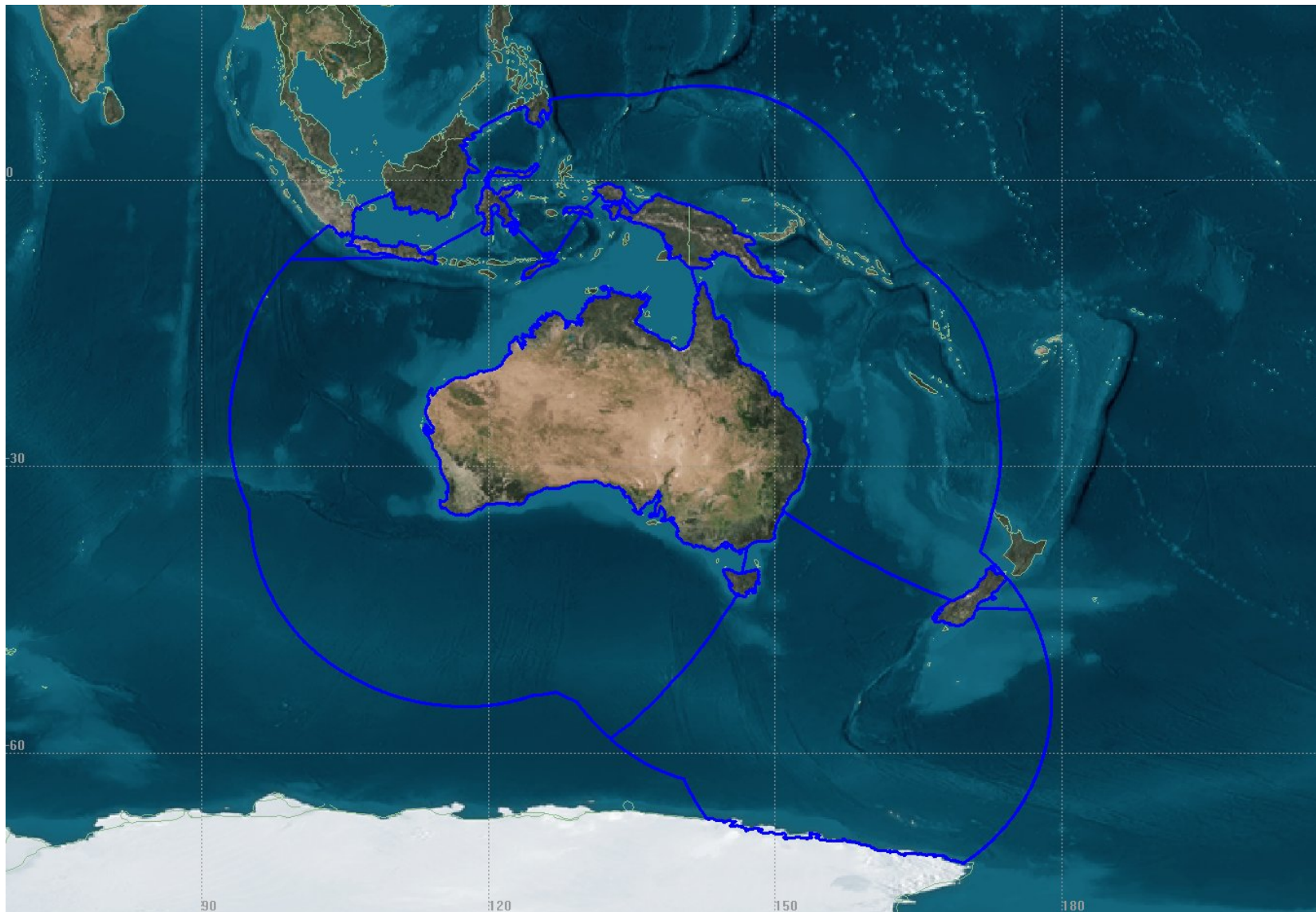| | |
|---|---|
| AAFC | Agriculture and Agri-Foods Canada |
| AIS | Automatic Identification System |
| AOI | Area of Interest |
| AOR | Area of Responsibility |
| CCD | Coherent Change Detection |
| CF | Canadian Forces |
| CSA | Canadian Space Agency |
| DFAIT | Department of Foreign Affairs and International Trade |
| DND | Department of National Defence |
| DRDC | Defence Research and Development Canada |
| EC | Environment Canada |
| GMTI | Ground Motion Target Indication |
| GPS | Global Positioning System |
| km | Kilometres |
| MDA | Maritime Domain Awareness |
| NRCAN | Natural Resources Canada |
| OGD | Other Government Department |
| PM | Project Manager |
| RCM | Radarsat Constellation Mission |
| SAR | Synthetic Aperture Radar |
| TBC | To be confirmed |
| TBD | To be determined |

## Annex A –DND Areas of Interest
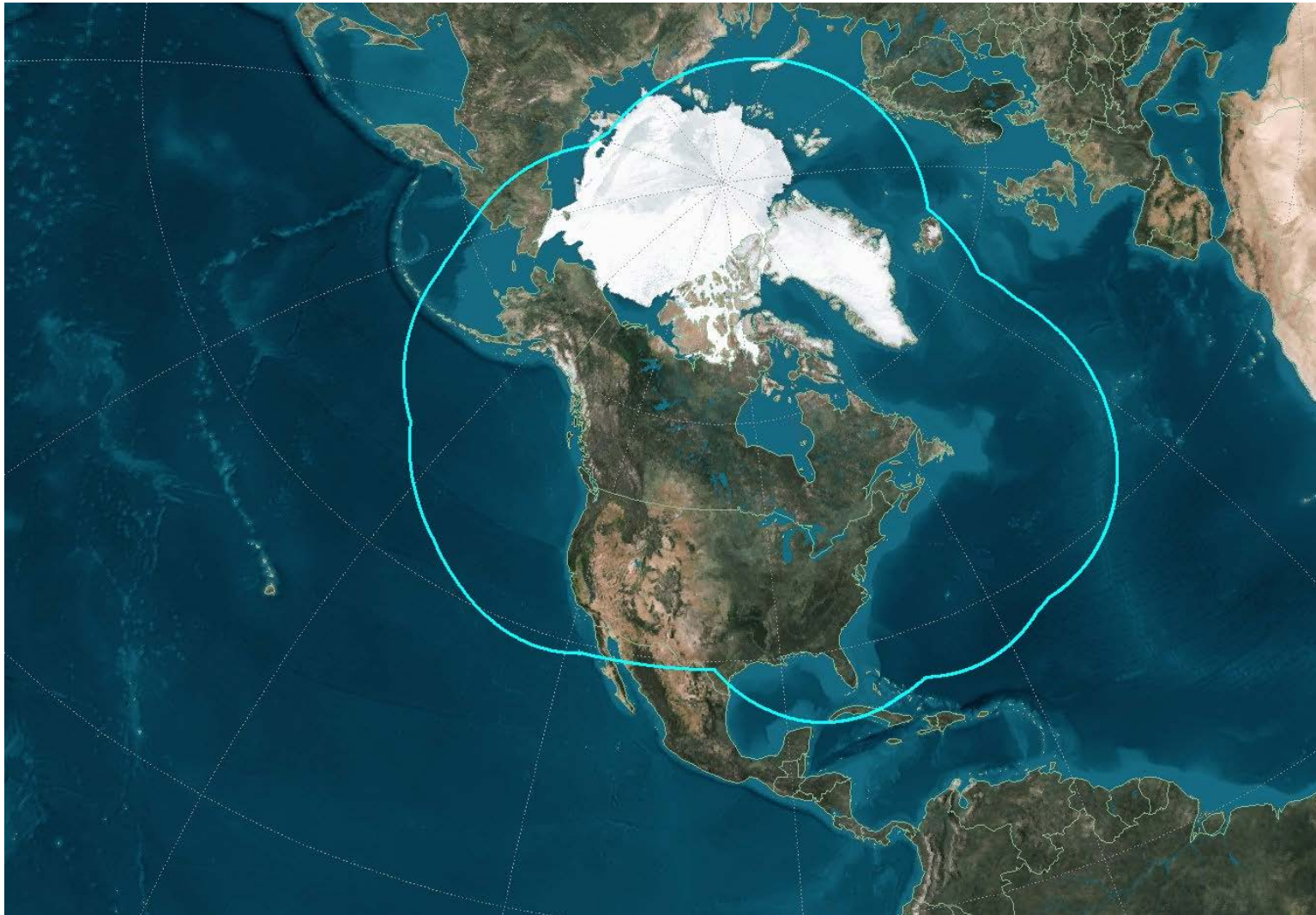


DND0100: Canadian Domestic Maritime Area
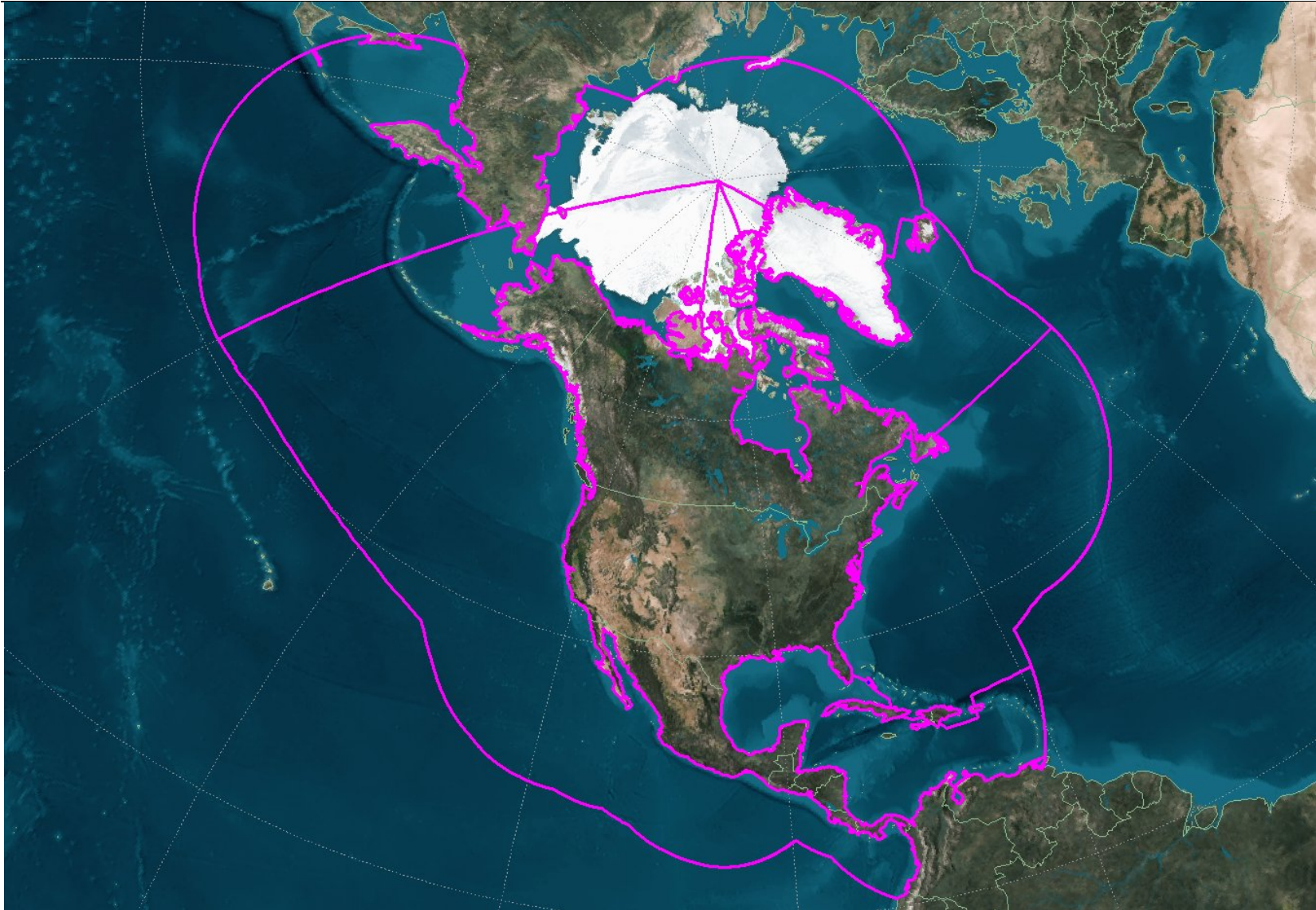
DND0120: Continental North American Maritime Area

DND0130: UK-Norway Maritime Area

DND0140: Canada-Australia Coalition Maritime Area.