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A system concept for persistent, unmanned, local-area Arctic surveillance

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ABSTRACT

This paper describes a system concept for persistent (up to 365 days, 24/7), unmanned, local-area surveillance of maritime surface and sub-surface objects, as well as air objects, in the Canadian Arctic. The system concept is based on unmanned, remotely controlled and monitored Local-Area Arctic Surveillance Systems (LAASS) that could be deployed at one or more maritime chokepoints, at locations in the Canadian Arctic Archipelago. The LAASS would be operated over a satellite communications channel from a Southern Control Centre (SCC) located in the south of Canada. Surveillance information for each detected platform and environmental reports for the local operating area would be compiled semi-automatically, from the integration of data transmitted from multiple above-water and underwater sensors and self-reporting systems, and be disseminated, in near real-time, to defence, security, and public safety clients. The system concept is comprised of a surveillance concept – which includes environmental and geographic factors, platform types under potential surveillance, end-user information requirements, contributions of individual sensor types to surveillance, and the role of local-area surveillance within the broader context of Arctic Domain Awareness – and a system operating concept. The system operating concept describes the system capabilities and operating modes required to achieve the surveillance concept. Consideration is given to the interplay between the automation level, the quality and timeliness of the resulting information productions, the allocation of processing functions between the SCC and the LAASS, and transmitted data volumes.

Keywords: surveillance, Arctic, unmanned, remote operation, Maritime Domain Awareness

1. INTRODUCTION

The surveillance of Canada's Arctic territory, including its airspace and waters, has been articulated as a capability important to the defence of Canada, to the protection against threats to public safety and security, and to the exercise of Arctic sovereignty[1,2]. In part, this has been viewed as a response to the challenges and opportunities presented by reductions of Arctic ice coverage, which are making Arctic waters more accessible for shipping, tourism, and resource exploration[3]. Internationally, other nations have established initiatives to monitor their Arctic maritime jurisdictions, an example being Norway's BarentsWatch system[4].

This paper presents a system concept for persistent (up to 365 days, 24/7), unmanned, local-area surveillance of maritime surface and sub-surface objects, as well as air objects, in the Canadian Arctic. The system concept is based on unmanned, remotely controlled and monitored Local-Area Arctic Surveillance Systems (LAASS) that could be deployed at one or more maritime chokepoints at locations in the Canadian Arctic Archipelago. The LAASS would be operated over a satellite communication channel from a Southern Control Centre (SCC) located in the south of Canada. Surveillance information for each detected platform and environmental reports for the local operating area would be compiled semi-automatically, from the integration of data transmitted from multiple above-water and underwater sensors and self-reporting systems, and be disseminated, in near real-time, to defence, security, and public safety clients. Potential sensors and self-reporting systems considered in this paper include radar, radar intercept receiver, underwater acoustic arrays, electro-optical/infrared camera system, Automatic Identification System (AIS), Automatic Dependent Surveillance - Broadcast (ADS-B), and a meteorological sensor system. The LAASS includes a Habitat System, to provide power, safety, security and physical structures. The system concept is being used in support of the specification of functional requirements for a concept demonstration system for Arctic surveillance, currently under development by Defence R&D Canada as part of the Northern Watch project.

The system concept is comprised of a surveillance concept and a system operating concept. These are the topics of sections 2 and 3, respectively. The surveillance concept considers high-level surveillance requirements for persistent, unmanned, local-area Arctic surveillance, while the system operating concept considers system capabilities and operating modes required to achieve the surveillance concept.

2. SURVEILLANCE CONCEPT

The concept for local-area Arctic surveillance centers on monitoring maritime surface and sub-surface traffic passing through maritime chokepoints in the Arctic Archipelago[5]. Local-area surveillance, which can provide persistent, 24/7 coverage of a specific location, complements the mobile, but more intermittent, coverage provided by wide-area surveillance assets. Of the many waterways separating the islands that comprise Canada's Arctic Archipelago, the Northwest Passage (NWP) is the most important. It consists of several alternative East-West routes[6] as depicted in Figure 1. Reductions in ice coverage have resulted in more of the Northwest Passage being accessible to a broader range of vessels over longer periods of time.

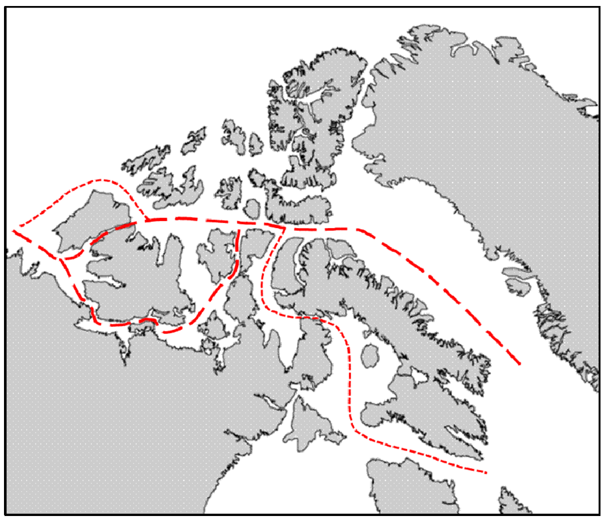

Figure 1. The Canadian Arctic Archipelago and routes through the Northwest Passage (with primary and secondary routes indicated by red lines with longer and shorter dashes, respectively).

Below, the following aspects of the surveillance concept are described in greater detail: supported surveillance functions; platform types under potential surveillance; client information requirements; information integration and the contribution of individual sensors to surveillance; geographic and environmental factors; and, the role of local-area surveillance within the broader context of Arctic Domain Awareness.

Supported surveillance functions

Local-area surveillance will be required to detect, track, and classify man-made platforms within a defined coverage area, based on the following definitions:

- Detect: determine the presence of platforms within the surveillance area based on one or more measured characteristics;
- Track: estimate platforms' current and/or predicted position and velocity; and,
- Classify: determine platform type, based on a set of distinguishing features. Classification may range from general (for example, maritime surface platform) to specific (a unique vessel). Classification at the level of a unique platform is termed identification.

In addition to surveillance information, local-area surveillance can be used to measure environmental conditions at each operating site. Environmental information may be used in support of the modeling and analysis of sensor performance;

or, to support the planning process in the event of the deployment of physical assets, such as aircraft or ships, to the local area.

Platform types under surveillance

Local-area surveillance will be directed primarily at surface or sub-surface platforms transiting through a maritime chokepoint. As a secondary capability, the local-area surveillance site may be equipped for air surveillance in order to extend the surveillance coverage provided by other sources. The surveillance concept is limited to the detection of man-made platforms, although it may be necessary to discriminate between man-made and naturally-occurring detections, such as might occur in the case of biological or ice-related acoustic sources.

Maritime surface vessels transiting or operating within the NWP include: Coast Guard icebreakers; tug/supply vessels; passenger/cruise ships; research and exploration vessels; military vessels; and pleasure craft, including private yachts and sailboats. The first transit of the NWP by a bulk carrier, Nordic Orion, was recorded in September 2013[7]. While in absolute terms the volume of vessel traffic transiting the NWP is low, the relative numbers have continued to increase. For example, the number of transits per year has increased from 4 in the 1980s to 20-30 in the years from 2009-2013[8].

Waller et al.[5] make the distinction between vessel types that are or are not required to self-report while in Arctic waters, on the basis of international or national regulations. These reporting (also termed 'cooperative") vessels include: commercial vessels over 300 gt, vessels engaged in towing or carrying dangerous cargos, and passenger vessels. Recently, safety and security concerns have been raised over increasing numbers of pleasure craft operating in Arctic waters, for which reporting is voluntary[9].

Client information requirements

In order for surveillance to be effective, its information products must enhance situational awareness and support the follow-on decision making and action of operational clients. This implies that both the type and quality of the information products match client information and decision requirements. Local-area surveillance information may be utilized for defence, security & safety purposes, with responsibilities spread within and between multiple government departments.

Surveillance system information quality can be described in terms of Measures of Performance (MOPs) and Measures of Effectiveness (MOEs)[10]. Applicable MOPs include probabilities of detection, false alarm, and correct classification, RMS errors for position and velocity, and latency. These can be calculated at the system level or for individual sensors. MOEs are designed to measure the impact of local-area surveillance on end-user decisions and actions, and are normally applied within the context of specified missions and tasks. A low false alarm rate can be expected to be an important measure of information quality because of the resources (a ship or aircraft) required to respond to an alarm.

The differing missions of defence, safety, and security translate into differing surveillance information requirements, with, for example, different emphasis on specific platform types, and different information quality requirements. As an example, the monitoring of pleasure craft can be expected to be a higher priority for safety and security, from perspectives such as maritime search and rescue or undeclared landings, but a lower priority from a defence perspective.

Sensor types and information integration

Because no single sensor is capable of providing data that supports all surveillance functions across all platform types and domains, it is necessary to exploit data from multiple sensors and information sources. Platforms may be detected, tracked and classified, based on sensing a range of acoustic, electromagnetic, and chemical characteristics and emissions, and by cooperative self-reporting schemes. Information collected from self-reporting systems, such as AIS and ADS-B, may require verification by independent sources in order to be fully trusted. By integrating information from multiple sensors and information sources it should be possible to create a higher quality information product that:

- has a higher probability of successfully detecting, tracking, and classifying platform types of interest within the surveillance region;
- has a lower probability of false alarm or mis-classification;
- mitigates environmental factors that limit single-sensor performance such as range, topography, and atmospheric or oceanographic conditions;

- provides a more complete description of platform types of interest and their activities; and,
- provides a higher degree of confidence based on the use of corroborating information from multiple sources.

Potential sensors that have been considered for demonstration purposes as part of the Northern Watch project include radar, radar intercept receiver, electro-optical/infrared, underwater acoustic arrays, AIS, ADS-B, and a meteorological sensor system. A high-level description of each sensor is provided in Table 1; sensors are discussed in more detail in Forand et al.[11] and Heard et al.[12]

Table 1. Sensors considered for use within the Northern Watch project. The platforms types and surveillance capabilities supported by each sensor are summarized.

Sensor	**Description**
AIS receiver	Self-reporting system providing tracking, classification, and identification information for vessels. AIS is required for commercial vessels and may be carried by smaller pleasure craft for safety purposes
Rutter Radar	X band navigation radar providing detection and tracking for maritime surface platforms and a limited capability for aircraft. Radar video images may be of benefit for classification (based on radar return size) and environmental monitoring (ice detection and precipitation).
CANDISS EO/IR	Multi-sensor system that provides: imagery and video for classification and (possible) identification of maritime surface platforms, from wide and narrow field-of-view visible light, narrow field-of-view active laser imager and IR camera; and tracking information for maritime surface platforms from laser rangefinder
Radar intercept	Provides detection, bearings-only tracking and broad classification of maritime surface platforms based on X and S band radar emissions
Underwater surveillance system (UWSS)	Underwater acoustic arrays providing detection, tracking (bearings only or cross-fixes) and information for classification of maritime surface and sub-surface platforms, with some capability for detection of aircraft
ADS-B receiver	Self-reporting system providing tracking, classification and identification information for aircraft. Use of ADS-B is currently voluntary in Canadian airspace and tends to be installed only on commercial aircraft.
Meteorological system	System providing weather data

From Table 1, it can be seen that the degree to which each sensor supports detection, tracking, and classification varies substantially, especially when considered against the range of different platform types. Cooperative, self-reporting, surface vessels should be detected, tracked and classified by multiple sources. AIS will provide the most accurate vessel position and velocity, as well as classification to the level of a unique vessel. In turn, AIS position information may be confirmed by position reports from radar or UWSS and bearing reports from radar intercept or UWSS; and AIS classification may be confirmed by imagery, with the possibility of identification at close ranges, or by supporting broad classification information provided by radar intercept and UWSS.

Conversely, the detection and tracking of smaller vessels that are not required to operate AIS, such as pleasure craft, may be limited to radar, radar intercept and UWSS sensors. Image-based detection and tracking based on EO/IR motion detection and/or thermal emissions, while not supported by the EO/IR system in Table 1, could provide an additional detection and tracking capability. The detection and tracking of small vessels can be expected to be range and platform dependent because of smaller size (and hence smaller radar cross section), lower likelihood of operating navigation radar (and hence being detected by radar intercept), and lower acoustic emissions (for example, if under sail). For smaller vessels not operating AIS, the primary means of classification is expected to be EO/IR imagery.

Of the sensors considered in Table 1, the UWSS provides a unique capability in sensing the sub-surface domain. As UWSS is capable of detecting acoustic emissions from sub-surface, surface, and air platforms, the use of complementary information provided by other above-water sensors and self-reporting systems may be required to aid in the interpretation of acoustic data.

Geographic and environmental factors

The remoteness, lack of local infrastructure, and the extreme environmental conditions characterizing the Canadian Arctic Archipelago will impact the installation, operation and sustainment of local-area chokepoint surveillance systems. Potential surveillance sites are likely to be accessible only by air or ship, and with no local shipping infrastructure and very limited port facilities in the Arctic, installation and re-supply resources generally must be sourced from Southern Canada. Poor weather can make access to sites difficult, particularly outside summer months, so that in the case of critical equipment failures weeks may be required to deploy on-site technical support. As a consequence, the surveillance concept assumes unmanned operation of LAASS facilities with scheduled re-supply and maintenance during the summer months.

Satellite communications in the Arctic are also challenging, with geostationary satellites having limited coverage. Future communications capabilities, such as Canada's potential Polar Communications and Weather mission[13] may offer a long-term solution for communications.

The contribution of local-area-surveillance to Arctic Domain Awareness

Local-area chokepoint surveillance systems will complement other sources of self-reported, space-based and air-based wide-area Arctic surveillance information that include:

- NORDREG reports – ship self-reports required under the Northern Canada Vessel Traffic Services Zone Regulations[14]. NORDREG reports principally apply to vessels of 300 gt or more and require that reports be made in specific circumstances or at least once per day;
- Long Range Identification and Tracking (LRIT) – satellite-based ship self-reporting system used as a complement to shore-based AIS[15]. LRIT applies to SOLAS Class vessels and requires self-reports be transmitted at least four times daily;
- Satellite-based AIS – reception of AIS self-reports from low-earth orbiting satellites[16];
- Radarsat – spaced-based synthetic aperture radar that can detect ships of 25 m length or greater[17]. The next-generation Radarsat Constellation system, scheduled for launch in 2018, will provide an improved capability for Arctic surveillance, with several passes per day over the Northwest Passage[18]; and
- Surveillance aircraft – for example, surveillance flights operated by Transport Canada.

Information provided by other surveillance assets may be used to cue local-area surveillance systems and could potentially be used to adjust sensor operating parameters in order to maximize surveillance performance, by providing a priori knowledge of platform type. One potential cueing mechanism has been described by Isenor et al[19].

The primary contribution that local-area surveillance can make to Arctic Domain Awareness is persistence, with performance that can be optimized for a specific location. Persistence also can be viewed from the perspective of the time period over which different platform classes can possibly be present in the surveillance area. The persistent surveillance of vessels having no ice rating can be achieved if the system operates over the restricted time period when a chokepoint is not ice-covered; however, persistent surveillance of the sub-surface domain will require year-round surveillance coverage. Local-area surveillance will play an important role in the surveillance of non-reporting platforms, such as pleasure craft. It can also confirm self-reports made by reporting platforms and complement data provided by wide-area surveillance. The number and placement of local-area surveillance sites, as well as the specific selection of local-area surveillance sensors, will need to take into account overall Arctic Domain Awareness effectiveness using the entire array of available surveillance resources.

3. SYSTEM OPERATING CONCEPT

This section presents an operating concept for a local-area Arctic surveillance system. The system operating concept takes into consideration the sensor capabilities required to support unmanned operation, the sensor and telemetry data types to be transmitted between the LAASS and SCC; and, options for the management of that data in a bandwidth-constrained communications environment. A data model is presented for an integrated surveillance information product, as well as options for dissemination of information products. As a baseline, the operating concept for the production of surveillance information products and for remote monitoring and control of the LAASS assumes a semi-automated process, with manning of the SCC occurring on a periodic basis or on-demand, in response to system alarms or the detection of events of interest.

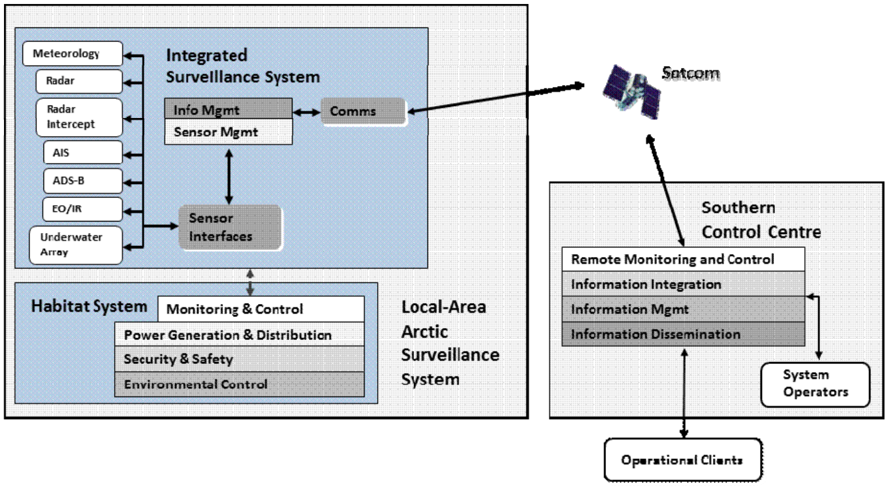

Figure 2. High-level schematic of the LAASS and SCC

A high-level block diagram of the LASSS and SCC is shown in Figure 2. The Arctic-deployed components of the LAASS consist of the Integrated Surveillance System (ISS), which includes sensors, sensor and data management functions, and communications, and the Habitat system, which includes the physical structure to house the ISS as well as sub-systems for power, environmental control, safety, and security. While the Habitat System is an integral part of the LAASS, this paper's discussion of the infrastructure services provided by the Habitat System is limited to their interaction with system capabilities for conducting surveillance.

In order to meet the objective for 24/7, 365 day operation in an Arctic environment, the system hardware and software must meet high standards for reliability and survivability.

Transmitted data types

Data transmissions between the LAASS and the SCC will consist primarily of sensor data, status information from the ISS and the Habitat System and control information from SCC remote operation. These may be supplemented by data used for system maintenance, such as file transfers for updates to system software. Possible transmitted sensor data types, based on the Northern Watch sensor set, are summarized in Table 2. Sensor data fall into the general categories of report data, imagery and samples of raw or partially processed sensor data. Report data can contain information related to kinematics (position, velocity, bearing, or bearing rate), attributes (such as radar emitter parameters), or classification. Report data are in many cases associated with a track number, or a platform identifier such as an AIS Maritime Mobile Service Identity (MMSI) number, and are typically of small size in comparison with imagery data or raw data.

Unmanned and remote operation of the LAASS

The system operating concept is motivated by the objective that the LAASS be capable of 24/7 operation, unmanned by on-site operators. The ISS and the Habitat System that comprise the LAASS will be monitored and controlled remotely, from the SCC. In turn, monitoring and control operations are assumed to be performed either at periodic intervals or in response to system-generated alarms. This will reduce the requirement for manning the SCC or allow a small number of operators to monitor and control multiple LAASS installed at different locations. Under normal conditions, personnel would be dispatched to the Arctic only during the summer months, to perform routine maintenance and replenishment of consumable items, principally fuel. Personnel would also need to be dispatched in response to critical system failures that could not be resolved remotely from the SCC.

In order to support unmanned operation of the LAASS, and periodic manning of the SCC, ISS sensors and self-reporting systems should automatically produce data outputs, without requiring the presence of a remote operator in-the-loop in order to obtain acceptable performance. If the Northern Watch sensors from Table 1 are considered as an example, some of the following challenges can be identified:

- As a baseline for unmanned operation, EO/IR sensors require automating aiming and assignment of imaging parameters, such as focus and zoom, based on position cues provided by AIS or radar. The full exploitation of EO/IR for surveillance purpose requires an automatic detection and tracking capability, such as provided through the use of automated image analysis.
- Operator involvement may be necessary, in some cases, for the adjustment of sensor operating parameters in response to changing environmental conditions. This may require operator access to more bandwidth-intensive data, in real-time. As an example, in order to assess the impact of adjusting radar system operating parameters, such as range modes or auto-acquisition zones, the operator may require access to images of the radar PPI display.

Table 2. Summary of transmitted sensor data types, based on the Northern Watch sensor set.

Sensor	**Data Output**	**Description**
AIS	Position Report	Message types 1,3 and 18. Includes: position and velocity; ship MMSI number
	Ship Static Data Report	Message types 5 and 24. Includes: MMSI and International Maritime Organisation (IMO) numbers; call sign; ship name, type, & cargo; dimensions; draught; destination & time of arrival
ADS-B	Extended Squitter Report	Includes position and velocity data; aircraft (ICAO) address, call sign, country
Radar	Track Report	Position and velocity estimates
	Plot Report	Range and bearing measurements
	Radar Image	Digitized image of one radar sweep
Radar Intercept	Bearing Report	Bearing measurement
	Classification Report	Radar type and radar emitter parameters
CANDISS EO/IR	EO/IR Image	Images from wide field-of-view (FOV) visible light, narrow FOV visible light, narrow FOV active laser imager, or IR camera
	EO/IR Video	Video from wide FOV visible light, narrow FOV visible light, narrow FOV active laser imager, or IR camera
	Laser Rangefinder Position Report	Range and bearing measurement
UWSS	Bearing Report	Narrowband or broadband bearing measurements
	Cross-fix Report	Position and velocity estimates based on array cross-fixes
	Acoustic Image	Acoustics spectrogram
	Acoustic Data Sample	Time-series data; Beam-map data
Meteor-ological	Basic Meteorology Report	Solar irradiance, atmospheric pressure, air temperature, relative humidity, wind speed & direction
	Optical Measurement Report	Visibility, precipitation rate & type, cloud cover fraction, cloud base
	Meteorology Image	Low resolution, wide-angle image

A second requirement is that ISS and Habitat systems be capable of automatically reporting the utilization of resources and the operating status for key functions. Low-priority alerts and high-priority alarms will be generated in response to abnormal operating conditions. All status information will be logged at the SCC for potential review by the operator. The operator (or watch-stander) will be informed of alarms automatically, so that the problem can be promptly attended to. The failure of the primary power system would be an example of an alarm condition.

A minimum set of control capabilities includes the ability to power-on, power-off, and re-start all system components; and to change system component operating parameters. Both remote monitoring and control are facilitated by system components that are network accessible, and allow for remote login and/or web-based configuration.

Production of surveillance information products

The process of producing information products from local-area surveillance can be viewed as producing a local-area Common Operating Picture (COP) of the surveillance coverage area. This requires system capabilities for picture compilation in support of building the COP; database and display capabilities to store and visualize the COP; and information dissemination capabilities to provide the information products in a format useable by clients. The surveillance information produced for each platform detected within the coverage region should include:

- a single system track, describing the location (in latitude, longitude, and altitude or, in the case of a bearings-only track, in bearing) and velocity (in course, speed, and rate of ascent/descent, or, in the case of a bearings-only track, in bearing rate) of each platform as a function of time, over the period of time it is within the surveillance region;
- platform classification, to the highest level of precision possible, given the collected sensor data;
- sensors and self-reporting systems reporting on the platform (and, potentially, a confidence level in the detection based on the number and type of sensors reporting on the platform); and
- links to supporting data from individual sensors and self-reporting systems, such as: AIS reports; ADS-B reports; visible light or infrared imagery; emitter characteristics; radar images; and acoustic spectrograms.

Building the COP requires picture compilation functions for: data association; classification of detected platforms (given data provided by individual reporting sensors); position and velocity estimation (including dead reckoning); and for track management tasks such as removal of spurious tracks. The aim of data association is to determine whether specific sensor and self-reporting system tracks originate from the same platform and hence should be linked to the same system track. This also includes the joining together of intermittent or broken tracks generated by a single sensor (for example, broken radar tracks caused by blind zones or atmospheric propagation).

The initial focus on formats for disseminated data has been on military formats, such as OTH-Gold. However further consideration should be given to more recent information exchange frameworks such as the National Information Exchange Model (NIEM)[20], which supports the maritime domain and is being widely used within the public safety and security communities[21].

The operating concept for producing surveillance information, and the allocation of system functions to the LAASS or the SCC, both depend on the level of automation, or conversely, the level of operator interaction assumed in the process. The options under consideration are manual operation by the operator; semi-automated operation, whereby the operator's task is to monitor and approve the output of automated processing; and automated operation, in which the operator's role is reduced to monitoring and, if necessary, overriding automated processing. Using the data association and classification functions as examples:

- Data association: With the exception of UWSS, the track data produced by sensors and self-reporting systems are relatively simple (for example, one simultaneous track per detected platform can be expected for AIS, ADS-B and in most cases, for radar) and are amenable to automated processing using established data association algorithms such as chi-squared tests[22]. UWSS is a somewhat more complex source for data association[23], with the possibility of many acoustic bearings originating from the same platform. This complexity can be reduced somewhat if another source of position data, such as AIS or radar, is available for association[24]; otherwise, semi-automation may be required.
- Classification: Of the NW sensors and self-reporting systems, only AIS and ADS-B provide a direct output of platform type (and, in fact, identify the unique platform), but of course, both are self-reporting, and hence less trusted, sources. The remaining sensors provide data that can be used in support of classification, given the appropriate analysis. However, none of these sensors themselves provide an automated output of platform type. As such, the analysis of classification-related data from individual sensors, such as imagery from the EO/IR system, and the assignment of a classification to the system track, is for now assigned as a manual function for the operator.

It is recommended that functions requiring semi-automated or manual operation by an operator be performed locally in the SCC rather than remotely from the LAASS, to avoid user interface lags caused by satellite communications.

Automated functions can be hosted at either location. Installation of automated functions in the LAASS has the potential of reducing satellite bandwidth requirements, on the basis that processed outputs are more compact than raw input data. The biggest gains from assigning processing to the LAASS are expected to come from functions, such as image-based classification, that require access to high-volume data types; conversely; less significant gains may be expected from hosting track-based data association in the LAASS.

As a baseline, the operating concept for production of surveillance information is to use a semi-automated process, with automated processing for functions that have technically mature solutions, such as data association, and manual processing for functions for which automated solutions are lacking The operator will monitor the picture compilation process and review information products prior to dissemination to clients. It is expected that over time, as automation matures and the level of confidence in its performance increases, the release of information products for dissemination will become automated. Initially, all surveillance information production functions will be hosted in the SCC.

Given any particular level of automation, the assumption of minimum, periodic manning of the SCC must be taken into account. Automated processing may minimize delays in the dissemination of information products caused by periodic manning; however, depending on the capability of automation relative to that of the operator, automated processing may lead to a decrease in quality (for example, an increase in false alarm rate). To support periodic manning there will be a requirement for user interfaces and operator aids that support the review of the current situation, the summarization of detections made since the last inspection of the system, and the replay and/or reprocessing of historical data.

Management of bandwidth

Networked connectivity between the LAASS and the SCC is assumed to be provided over satellite communications. To increase the overall reliability of communications the system should include a primary and a backup, lower-bandwidth, secondary, communications service. The LAASS will maintain a cache of transmittable data, in the case of a communications interruption or a bandwidth reduction.

Satellite communications bandwidth must be allocated to satisfy the requirements for surveillance and environmental data from sensors and the requirements for the remote monitoring and control of the LAASS. As data volumes may exceed the available channel capacity, several measures are considered to manage bandwidth requirements. These include: the decimation of report data from sensors to a lower data rate sufficient to support the production of surveillance information products; for bandwidth-intensive data types, such as imagery or raw acoustic data, the automatic transmission of summary or indexing information, supplemented by the selective retrieval of complete data samples from local storage in the ISS by the operator; the background transfer of data during periods of low bandwidth demand; and, the enforcement of pre-determined bandwidth limits on individual functions.

There may also be a need for bandwidth to be adaptively re-allocated between functions in order to support the handling of alarm conditions. As an example, the switch-over from primary to secondary communications should trigger a change to a low-bandwidth mode of operation for monitoring and control and for transmission of surveillance data, in order to facilitate troubleshooting of the LAASS primary communications channel hardware.

4. CONCLUSIONS

Surveillance of Canada's Arctic Archipelago is assuming greater importance across the defence, security and safety communities, with the opening of Arctic waterways to increased shipping, tourism, and resource exploitation. Local-area surveillance of maritime chokepoints is but one of several approaches to Arctic surveillance, which also include increasing requirements for self-reporting and space-based wide-area surveillance sensors. Through the deployment of a mix of above-water and underwater sensing techniques, local-area surveillance, which has the principal advantage of persistence, should have the potential to play an important role in the surveillance of non-reporting platforms.

This paper has presented a system concept for chokepoint surveillance based on unmanned, remotely controlled and monitored, Local-Area Arctic Surveillance Systems that would be operated over a satellite communication channel from a Southern Control Centre located in the south of Canada. Some key aspects of the system concept include: the role of potential sensors in local-area surveillance, together with sensor capabilities necessary for unmanned, remote operation; a model for surveillance information products based on the production of an integrated system track, and the process for building those products, which can be viewed as building a local-area COP; trade-offs related to the level of automation; and proposed techniques for managing communications bandwidth. The system concept is being used in support of the specification of functional requirements for a concept demonstration system for Arctic surveillance, currently under development by Defence R&D Canada.

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