Developing a Role for Small Satellites in the Canadian Forces

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ABSTRACT

Space-based capabilities are playing an ever-increasing role in support of military operations. The issue faced by many nations is evaluating how space-based capabilities best suit their own needs, and how to acquire these capabilities, either by indigenous development within the nation's resources, or through international leveraging with partners and allies.

Traditionally, many nations such as Canada have not had the resources to invest in indigenous military satellites. A significant reason for this is the high cost and long development time required to benefit from a satellite mission. In recent years, however, satellite technology has become more affordable, space-based capabilities are now within reach to an increasing number of military organizations – the challenge is to determine what space-based applications make sense to invest in. Just as important is also creating a positive environment such that new space-based proposals are accepted. This can be a significant obstacle as many have become apprehensive towards satellite programs when faced with the choice of funding space-based initiatives against more familiar technologies.

Defence Research and Development Canada (DRDC) is addressing these issues, defining the role of space-based capabilities, in concert with other terrestrial capabilities, to provide the Canadian Forces with an appropriate, effective suite of technologies that best meets national and deployed operational needs.

This paper will outline DRDC's efforts towards developing a sustainable small satellite program. Current research and development initiatives will be presented including two microsatellite demonstration missions currently underway. The benefit of partnership with the Canadian Space Agency (CSA) and other Allied programs will be reviewed along with the future possibilities of leveraging NATO collaborations. Finally, a discussion will be presented outlining a strategy to best influence positive change and acceptance within the Canadian Forces to adopt space-based technologies as a routine capability generator.

1.0 INTRODUCTION

Canadian defence research and development (R&D) has been involved in space from the very start of Canadian atmospheric and satellite research, beginning in the 1930s and contributing to the first Canadian satellite, Alouette. Defence R&D has, however, had significant ebbs and tides in its support to space over the years, largely reflecting the priorities of the Canadian military at the time. Although Canada has maintained expertise in niche technologies such as synthetic aperture radar (SAR), the Canadian military has had to rely upon commercial or allied military satellite systems due to the extreme resource commitments required to

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build and maintain an indigenous space capability. Over the last 12 years or so, opportunities have developed with technology and there is an increased awareness of space's role in support of military operations, both domestic and deployed. As such, we have seen a modest revitalization of space activities within the Canadian Forces (CF). This renewed interest has the potential to accelerate into many new mission areas previously unexplored within the CF. Defence R&D Canada (DRDC) is making efforts to ensure modern space technology is not only understood within the military, but also captured in potential capability development.

In order to adequately serve the CF, it must be understood from the onset that developing a space program for the CF is not a means unto itself. A space program can only exist if there is adequate justification for its use. With this in mind, DRDC aims to support the CF through its Space Thrust which focuses on capability development with both near and long-term objectives. The capabilities under review are driven by supporting policy such as the Department of National Defence's (DND) Defence Policy Statement [1] noting the need to recognize and meet threats far from the Canadian border, along with the a new CF Vision [2] that prioritizes the defence of Canada, North America and support to failed or failing states. These key policy directions then further drive operational requirements – to which space can significantly contribute. As an example, the Canadian government has recently placed added emphasis on the surveillance and defence of Canadian territorial boundaries, particularly the arctic. A former commander of the Canadian Forces Northern Area has unequivocally stated that "the most effective way to provide continuous surveillance of the Arctic is through the use of space-based assets." [3] The challenge is to determine how space-based assets can most effectively contribute to surveillance when combined with other terrestrial sensor systems that may not be as capable, but may be much less costly.

DRDC is playing a pivotal role in defining and promoting where space can be effectively used within the CF. DRDC's efforts are now being rewarded with an unprecedented number of activities directly related to the development and exploitation of space-based assets. This paper will outline current and near term activities for Space Systems development, focusing on two DRDC microsatellite programs underway. The future potential for small satellite capabilities within the CF and NATO will also be discussed in efforts to take advantage of an environment rich in potential, but as always, limited in resources.

2.0 DRDC'S SPACE THRUST

DRDC coordinates and conducts its R&D activities under an administrative Space Thrust. The Space Thrust directs its activities in accordance to C4ISR requirements identified by the R&D clients within the Canadian Forces. In efforts to best address the requirements passed down by military end-users, the Space Thrust balances its activities under two coordinated streams: space-based data exploitation and military space systems (see Figure 1). It must be noted that there is a significant amount of DRDC expertise that has been developed pertaining to space-based data exploitation, including SAR imagery and data exploitation, hyperspectral data exploitation and multi-sensor data fusion (much of which is in collaboration with NATO allies), however, this paper will not address the exploitation activities; the focus will be on the military space systems side of DRDC's Space Thrust R&D.

2.1 DRDC Space Systems' Applied Research Programs

The research and development activities pertaining to Space Systems must establish equilibrium between near- term objectives and longer term R&D investments while at the same time establishing a firm

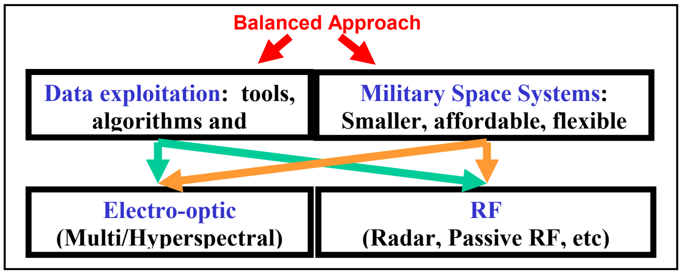

Figure 1: Balanced scope of DRDC's Space Thrust

foundation for a sustainable program without stretching available resources and expertise to thin. With this in mind, DRDC has made efforts to structure R&D activities that help enable an end-to-end space access through three major applied research projects:

- **Surveillance & Tracking of Space Objects**. This research project is an extension of niche expertise the Canadian military has established towards deep space surveillance. With an objective to increase Space Situational Awareness efforts in this domain include ground-based tracking telescopes as well as space-based sensors. DRDC space surveillance R&D supports two significant initiatives: SAPPHIRE - a Canadian Forces operational space-based surveillance telescope, and NEOSSat – a DRDC microsatellite demonstration mission. NEOSSat will be described in more detail below. SAPPHIRE, a 120 kg satellite intended for launch in 2010, will serve as a contributing sensor to the United States Space Surveillance Network (US SSN). R&D activities required to achieve mission success, for both SAPPHIRE and NEOSSat, include mission planning, optimization of task scheduling, data processing as well as coordination of data handling and distribution on the ground. To this end, a risk mitigation initiative for SAPPHIRE has been established for operations planning and US SSN compatibility. DRDC has established an autonomous network (referred to as the Concept Demonstrator, CD – Figure 3) of three ground-based sensors across Canada, controlled from DRDC Ottawa. The CD network serves a dual role of contributing much needed deep-space data to the US SSN as well as gaining the expertise and data functionality for SAPPHIRE to be tasked and report to the US SSN. In addition to the R&D in direct support of SAPPHIRE and NEOSSat, this project aims to increase DRDC's broader space situational awareness through the establishment of Space Common Operating Picture databases, as well as investigating opportunities to characterize aspects of microsatellite platforms to aid space surveillance techniques and applications.

- **Infrastructure for Ground Operations**. The objectives of this project aim to fill out the end-to-end space access goals required for space operations. The primary objectives include the development of ground station facilities for satellite operations and mission planning. A secondary objective, studying small launch vehicle technologies, is followed to understand and help react to future launch requirements. The foundation of this R&D project rests on the DRDC Satellite Ground Station site shown in Figure 2. This facility benefits from 9.1m, 4.6m and 1.2m antennas. The end-state capability of this facility will support both S-band and X-band telemetry and control (using CCSDS protocol) as well as mission payload operations on both the 9.1m and 4.6m metre antenna. The on-going development of this facility aims to conduct R&D iterations toward increased autonomous activities, mission planning and evaluation. These capabilities will help enable the expertise and infrastructure required for DND/DRDC satellite missions, as well as offer opportunities for trials and demonstrations with Allied space programs.

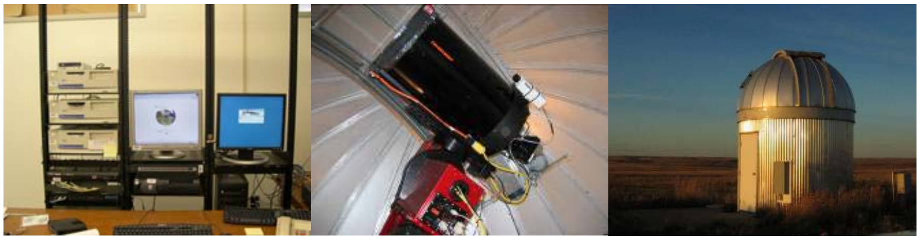

Figure 2: Elements of the Concept Demonstrator Telescope Tracking Network

Figure 3: DRDC Satellite Ground Station

- **Satellite Payloads and Systems**. This project loosely covers space segment interests with an objective to conduct research and development into mission concepts, payload applications and critical space technology enablers that best meet CF long term space requirements. Under this project, payload and mission concepts are identified and evaluated for the delivery of a required military capability. Interest in mission concepts range from Optical/Electro-optics, Passive RF, Stand-off Detection, Tactical Comms, InSAR and other concepts of opportunity. Technology outlook is also an important aspect towards understanding future opportunities and possibilities. To this end, DRDC has established close R&D collaboration with academia and the Canadian Space Agency in the development of nanosatellite technology and applications. With an appreciation of mission concepts and technology required to develop future military capabilities, efforts have also been made to identify key satellite systems in need of investment to attain or improve desired performance levels. Efforts to date have recognized attitude control on microsatellite platforms as an essential technology driver, and in coordination with Canadian industry (Dynacon Ltd), DRDC as invested in a Nano-High Precision Attitude Control System which includes miniaturized reaction wheels and the integration of a low-cost, low-power nano-star tracker.

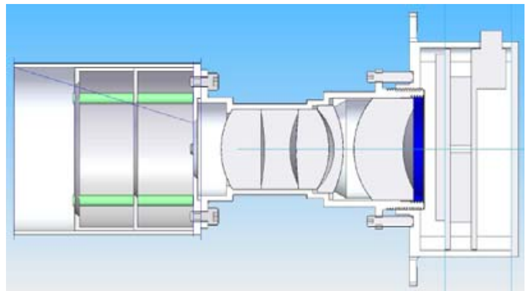

Figure 4: DRDC/Dynacon Nano-Star Tracker

2.2 DRDC Space Systems' Technology Demonstration Programs

The transition of technology from R&D to military operation often requires formal demonstration to validate and trial the capability in question. DRDC has established an internal program to fund and oversee this transition, the Technology Demonstration Program (TDP). By having such a program in place, the Space Systems activities have a venue to expand beyond concept and individual sub-system development. The TDP program affords DRDC the opportunity to demonstrate to the CF the benefits of a particular technology and serves as risk mitigation towards understanding the implications of acquiring and using this new technology as an operational capability.

Taking full advantage of this R&D program, DRDC has been able to initiate two microsatellite projects. These microsatellite projects have technology and programmatic merits, serving to demonstrate that a microsatellite platform can provide operational capability as well as improve upon the acquisition/programmatic challenges of satellite missions. Further rationale for employing this class of satellite is presented below and a detailed outline of these microsatellite projects shall be the prime focus from this point forward.

3.0 DRDC MICROSATELLITE PROGRAM

With recognition that the Canadian Forces is not likely able to support large satellite programs, attention is drawn to the possibilities of developing smaller satellite capabilities that will allow for more affordable, responsive and flexible capability generation. For this reason, the DRDC Space Thrust has made a focused effort towards defining and developing technology areas in small, micro and nano-satellite applications that can best serve the Canadian Forces. Attention needs to be drawn to the driving requirements that a small satellite program supports. Strong emphasis must be made to ensure end objectives are not the development of a satellite itself, but *the delivery of a capability, from space, on a small platform, where it makes the most sense to do so*. This is a strong theme that needs to be reinforced if small satellite programs are to be accepted, particularly by satellite-weary organizations.

To benefit from the small satellite platform, above all - microsatellites (generally accepted as spacecraft < 100kg), a new development approach must be accepted in contrast to traditional satellite programs. In fact, it is the novel development approach that makes microsatellite applications accessible to organizations that have otherwise been leery or unable to accept the burden of large satellite programs. The specifics of the small satellite development approach has been outlined and debated in many publications, but the overarching principles are clear. The prevailing rationale for microsatellites is to develop an affordable space-based capability. The majority of the microsatellite development principles serve this end, reducing cost. Such principles included small development teams, reduced documentation and specifications, focused requirements on a single application and the use of Commercial off The Shelf (COTS) technologies where appropriate. An additional aspect to microsatellite development, particularly important to the military, is the level of responsiveness in such a program. Rather than wait 10-15 years for a space-based capability via traditional missions, microsatellites offer rapid development potential with the most current technology. As a starting point, the first two DRDC microsatellite development schedules are three years with a near term goal to lower future microsatellite missions to two years. It is an interesting point to note that this development schedule is limited not by technology, but by the programmatic demands of government acquisition regulations.

Despite the cost reductions microsatellite principles allow, efforts to stand-up DRDC microsatellite projects solely through internal R&D funding would simply not be feasible due to the funding ceiling of the TDP program itself (approximately $5-6M CAD per project). Due credit must also be given to the Canadian Space Agency (CSA). The CSA also had initiatives for microsatellite programs in the interest of developing Canadian space industry in the microsatellite global market. As coincidence would have it, their allocated budget was not sufficient on its own either. An ideal inter-governmental partnership was then established, leveraging CSA and DRDC's funding, resources and expertise. This has lead to the creation of CSA's Multimission Microsatellite Bus, as well as two microsatellite missions. The two DRDC/CSA missions, NEOSSat and AIS/SMS, along with the CF's SAPPHIRE mission, have created an unprecedented level of space activity within the Canadian Department of National Defence.

3.1 Near Earth Orbit Surveillance Satellite (NEOSSat)

As the first DRDC-CSA joint microsatellite mission, NEOSSat has challenging objectives to satisfy DRDC and CSA interests. The NEOSSat mission, through the use of a single optical telescope payload, shall support two observing missions: NESS – Near-Earth Space Surveillance and HEOSS – High Earth Orbit Space Surveillance. Combining NESS and HEOSS – NEOSSat – each mission will share an equal portion of operational tasking.

The NESS mission satisfies CSA's scientific interests to investigate the orbits of Inner-Earth Orbit (IEO) objects and Aten-class asteroids; a task made difficult from Earth as these brands of asteroids and comets lay inside Earth's orbit requiring sensors to look toward the sun. Sky surveys are routinely conducted from terrestrial telescopes to map objects outside Earth's orbit, however, very little is known on the population of objects inside Earth's orbit. Recent public attention towards Earth impacting asteroids or comets has emphasised the importance of this mission, exploring the possibilities of an IEO or Aten asteroid crossing Earth's orbit with the potential of hitting the Earth in the future. From a scientific vantage point, these objects may also serve to help us better understand the formation of the solar system as they date back to the origins of the solar systems and may also contain a small quantity of pre-solar grains formed during even earlier times [4].

The DRDC mission, HEOSS, aims to obtain surveillance of space data by tracking Resident Space Objects (RSO) in deep space Earth orbits. RSO's range from active satellite and dead satellites to rocket bodies and debris left in orbit. The objective of HEOSS is to demonstrate that a microsatellite platform can be used to obtain space surveillance data that would be useful to the US SSN and, as a result, demonstrate that microsatellites can have operational roles of interest to the Canadian defence community. An additional objective accentuating the R&D aspect of this mission will be conducting advanced research in the field of space-based space surveillance which will demonstrate a new range of options for possible SAPPHIRE follow-on missions.

Requirement Type	HEOSS Requirement	NESS Requirement
Sensitivity	Mag 13.5 GEO satellite at 60"/s relative motion	Mag 19.5 star in 100s
Observing range	90-180° solar elongation	45-55° solar elongation, +/- 40° of ecliptic plane
Throughput	1 field every 5 minutes, with a goal of 1 field every 3 minutes	1 field every 5 minutes, with a goal of 1 field every 3 minutes
Field of view	> 30'	~ 50'
Resolution	> 1 pixel	Diffraction limited
Stability	1.7" rms	0.5" rms
Observing modes	SSM, TRM	SSM
Other	Strobing, subsampling	Goal to split 100s observation into 3 x 33s to minimize cosmic ray effects

Table 1: NEOSSat Mission Requirements

When combining the NESS and HEOSS missions to generate the necessary instrument and satellite bus requirements, some significant differences exist (see Table 1) [5]. The two missions have inherently different observing methods. NESS looks towards the sun within 45-55° helioecliptic longitude, staring at one location for relatively long exposure times, whereas HEOSS demands an anti-solar pointing direction to observe optimal phase angles (hence reflection) between the sun and given RSOs. HEOSS requires a fast slewing rate due to the relative position and transition between the microsatellite and individual target RSOs, and consequently has shorter exposure times before a target passes completely through the field of view. Incidentally, this takes into consideration that both NESS and HEOSS are imaging using a Sidereal Stare Mode (SSM) where the microsatellite slews to keep the background star field stationary, and any object moving between the satellite and star field is captured as a streak. HEOSS also has an addition observing goal, Track Rate Mode (TRM), where the satellite slews with the expected orbit of the target RSO to keep it focused as a point and the background star field is subsequently streaked, which further increases the demand on the attitude control system to meet slewing requirements.

The proposed NEOSSat spacecraft concept (Figure 5) following Phase A is based on the development of a Multi-Mission Microsatellite Bus (MMMB). The MMMB is an initiative coordinated through CSA to develop a microsatellite bus capable of multiple missions with minimal non-reoccurring costs. The current Phase A MMMB design is structured around a stacking tray concept over which exterior panels, solar cells, and deployables are attached.

NEOSSat is currently in the process of receiving bids for a Phase B/C/D contract for development and launch. The NEOSSat spacecraft will be approximately 60 kg, including its optical payload, consisting of a 15cm Rumak-Cassegrain reflecting telescope and 1024x1024 pixel astronomical grade CCD array. The total cost of the NEOSSat program is approximately $11M CAD, with an expected launch date in early 2009.

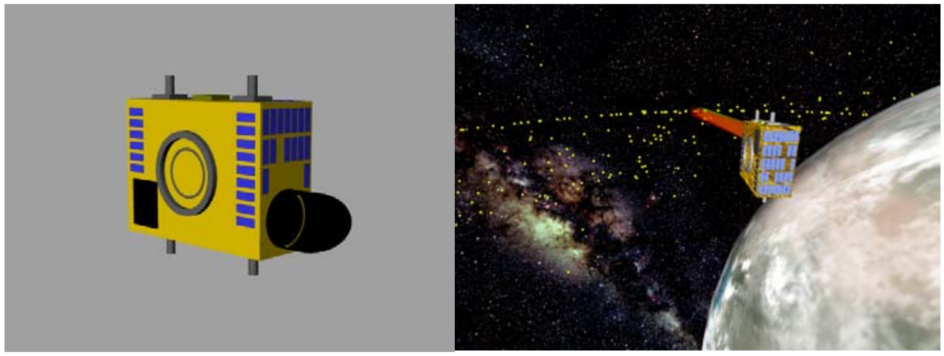

Figure 5: NEOSSat Phase A Concept Design

3.2 Automatic Identification System/Short Messaging System (AIS/SMS)

The second joint DRDC-CSA mission is a maritime surveillance mission that will collect and report AIS signals for integration into a Recognized Maritime Picture (RMP).

AIS is a maritime self-reporting network initiated by the International Maritime Organization through the United Nations. It is intended to improve safety at sea by having all ships greater than 300 tonnes continually transmit their location over VHF frequencies, and allow all AIS users to receive these signals from other ships in order to improve situational awareness. An AIS broadcast signal includes, among other things, the ship location, speed, rate of turn, bearing, cargo, etc. Being a VHF system, ground based receivers typically have a 20 to 40 nm detection range, useful around ports and choke points for maritime passageways. From a national surveillance perspective, DND is interested in expanding the detection of AIS signals past the maritime inner zone (50 nm), and integrating this data with other maritime ISR sensor data. The most efficient method to expand AIS coverage, and indeed provide global coverage, is a space-based platform.

In order to collect and process the AIS signal, a Short Messaging System (SMS) transponder will be used. The use of an SMS radio affords the flexibility not only to collect AIS, but to also send and receive data messaging as well. This concept thus allows two mission objectives. The primary objective will be to address maritime ISR deficiencies through the demonstration of a space-based AIS collection capability. A secondary objective will be to demonstrate SMS applications in support of CF activities and interests. SMS applications can include routine messaging, blue force tracking, and a myriad of autonomous sensor data relay possibilities (acoustic monitoring, chemical detection, soil moisture density, etc).

Although the AIS signal itself is fairly simple, the task of receiving and processing the signal in space is somewhat complicated as AIS was never designed with space-based reception in mind. The signal space is coordinated between ships in a localized area through a Self-Organized Time Division Multiple Access (TDMA) protocol at VHF frequencies of 161.975 and 162.025 MHz, GMSK/FM modulated at a baud rate of 9600 bps . As such, a ship's AIS radio reserves a particular time slot to report on, and other ships' AIS systems plan their transmissions accordingly. Once a particular ship is out of line of sight radio range, its time slot then opens up for others uses. This creates multiple AIS cells across large areas where time slots are coordinated internal to a single cell, but reused across cells. This is an efficient way to coordinate messaging terrestrially, however as elevation rises, and the line of sight increases, multiple cells come into view. An AIS cell would average approximately 200 nm miles base the baud rate of 9600bps. From a spacecraft perspective, vast numbers of AIS cells would be visible. This means there could potentially be large number of visible ships reusing the same time slot, resulting in colliding messages that could be lost.

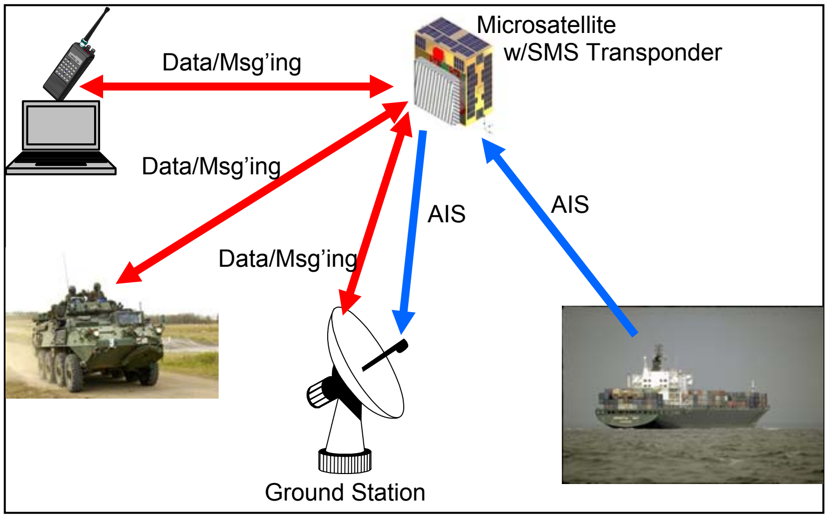

Figure 6: AIS/SMS Mission Concept (Microsatellite design not accurately portrayed)

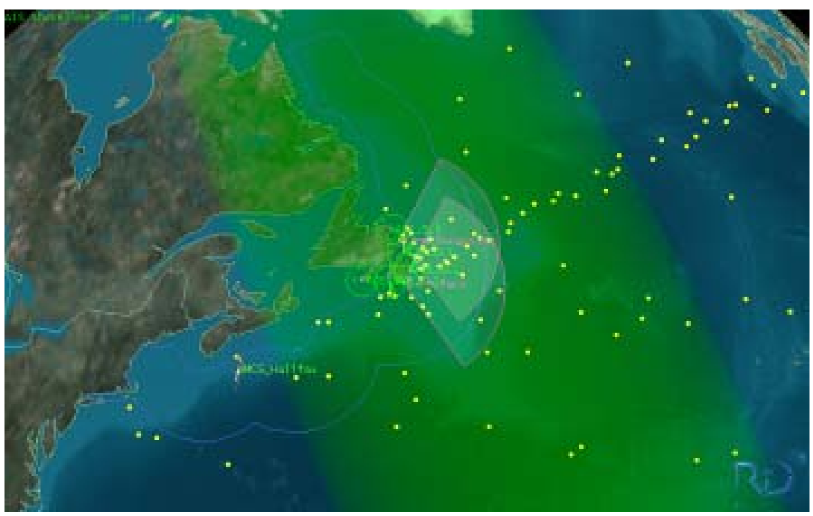

Figure 7: Example of a notional swath coverage of for space-based AIS sensor (green) in comparison to ground based AIS receivers (green circles) and High Frequency Surface Wave Radar (pink cones). Simulated maritime traffic shown as yellow dots.

In fact a DRDC study conducted with COM DEV Ltd [6] shows that the message collision frequency would be detrimental enough that over a 15 minute viewing interval (typical of a LEO orbit pass), the probability of detection of 1000 uniformly distributed ships would be 70%. This in itself may be adequate, but the probability of detection curve rapidly diminishes. For 1200 ships the detection rate falls to 30%, and for 1500 ships – 14%. Stated another way, if a ship reports every 6 seconds, it would take approximately 50 minutes of continual viewing to report on 1200 ships. In order to capture all 1200 ships from a LEO orbit, it is obvious that a constellation of sensors is required, or signal processing techniques must be employed to discriminate between incoming signals sharing the same time slots.

It is worthwhile to point out that shipping densities worldwide are expected to increase. Expected shipping traffic along Canada's east coast alone in 2006 is estimated to be 1450 ships, and this is a modest shipping environment when compared to other high traffic locations in northern Europe and Indonesia.

The problem is compounded yet again when other factors are taken into consideration such as land mobile transmitting interference, ionospheric effects, sea scattering multi-path and Doppler shifts. The Faraday rotation of the signal through the ionosphere can also be a significant factor in changing the signal's polarization; a factor to be considered when estimating the performance of an intended receiving antenna.

There does exist several space-based AIS initiatives currently in development and it is believed that these initiatives will have modest signal processing techniques on board to help improve the signal detection rate, however, it is also clear that many ships may pass undetected. As mentioned, a constellation can further reduce this problem with increased persistent observation. In the situation of DRDC and indeed, the same situation the CF finds itself, only a signal spacecraft will likely finds its way past program approval. This means that an individual spacecraft has to be optimized to collect and discriminate as many signals as possible in order to attain high probability of detection requirements. On a traditional satellite platform this may not be so much of an issue through the use of large antenna arrays, however, on a microsatellite limited in power and surface area, this is a significant challenge.

The DRDC-CSA AIS/SMS mission aims to tackle this problem, through innovative antenna design, processing techniques, and collection schemes. On-board data processing will need to be re-programmable to allow for raw signal collection and reporting, and then migrate to variable programmable processes to optimize collection once the signal space is better understood. The intended orbit for the AIS/SMS mission will also aim to be optimized with Radarsat 2 by minimizing separation time between satellites to best coordinate timely fusion of AIS data with Radarsat 2 imagery.

In regards to SMS applications, exploitation plans are being coordinated to benefit from both hand-held mobile terminals and autonomous sensors passing message to and from the AIS/SMS microsatellite. It is estimated that a typical sensor would only be required to be 1kg in size with a transmit power of 1W. Depending on the data rate, the microsatellite could support anywhere between 10's – 1000's of sensors. It is likely that if an allocated frequency is to be shared with other users, the data rate may have to be on the order of 1 kbps for this demonstration mission to avoid interfering with others. At this data rate, the system would be capable of transmitting approximately 50 messages per minute (each message is 160 characters in length).

The DRDC-CSA AIS/SMS mission is currently entering a formal Phase A and a contract is expected to be awarded by end-September. The program itself is expected to cost $12M CAD, with a launch in late 2009. The development schedule for this project are being timed such that it is close enough to NEOSSat to allow for concurrent bus development/buys, but staggered enough from the NEOSSat project to be able to benefit from lessons learned in the first microsatellite program.

4.0 FUTURE DIRECTION

DRDC has organized its Space Systems activities within the Space Thrust to establish a solid foundation to trial and demonstrate space-based capabilities that will transition to military operations. Recent DRDC endeavours in establishing microsatellite programs and developing satellite ground station capabilities have been greatly rewarded but there are still significant challenges ahead. The path for space-based demonstration technologies transitioning to operations continues to have considerable hurdles, and if these hurdles are not cleared, present efforts may be in vain. There is a need within the CF to clear many misconceptions towards satellite programs and proactively inform many of the potential of small satellite. It should be clearly acknowledged that small satellites do not solve all space related requirements, and may often have to be used in conjunction with larger missions; however, there are opportunities for small satellite capabilities to address military needs, whether limited as a single mission, as part of a constellation, or augmenting larger satellite missions.

To gain wide-spread acceptance within government, these opportunities must not only be advocated, but there must also be demonstration. There will be much attention place towards the utility of DRDC's two microsatellite missions. It is hoped that these demonstrations will deliver the reinforcement required to sooth concerns regarding satellite missions and in fact create an active interest to pursue additional small satellite programs. There must also exist open dialogue towards the benefits and limitations of small satellite capabilities. By virtue of using an affordable space platform, there will be limitations regarding performance and any proposal to approve a small satellite program must acknowledge these, while at the same time presenting a solid case for investment when considering alternative options. If expectations are not managed in this way, a disservice will be conducted towards small satellite initiatives, possibly fostering the negative satellite stereotypes that have had to be overcome in the first place.

As the Canadian military remains a modest, if not relatively small organization, it would not be prudent to believe it could stand up significant space-based military capabilities on its own. The CF will have to continue to foster the positive relationships it has with government agencies such as the Canadian Space Agency. There will also come a time when either DRDC or the CF in general will have to partner with international Allies to create an affordable space-based capability that serves military interest across borders. The AIS mission is a prime example. Although the DRDC/CSA mission is optimizing its single platform as best as it is able, the mission would greatly benefit from the coordination of additional space-based assets to reduce revisit time.

A large potential exists in the small satellite domain to establish collaborative partnerships. Very few nations can afford traditional, large satellite programs; they can neither afford to develop and support constellations. It is very possible on the other hand that several nations may be able to afford single, focused small satellite missions that can leverage other nation's programs. This may be through coordinated development of identical sensor flown independently but shared as a virtual constellation, or it may exist as a suite of different sensors of opportunity that can be used to enhance individual capability through cross-cueing and data fusion. The prime example that ought to be used as a benchmark for this type of international collaboration is Surrey Satellite Technology Ltd's Disaster Monitoring Constellation, a coordinated small remote sensing satellite constellation developed between five governments: Algeria, Nigeria, Turkey, Britain and China.

DRDC has developed partnerships with several nations such as the US, UK, Germany and Norway to share and collaborate on space-based technology. As NATO looks toward space as a capability generator, it is easy to see that international collaboration must play a significant role as well. These relationships must be taken full advantage of to advocate any space-based solution that has been shown to be appropriate and affordable to meet capability requirements. Individual organizations may have difficulty on their own establishing satellite programs, however, with the backing and encouragement of an organized coalition perhaps further synergy can be created.

5.0 SUMMARY

Defence R&D Canada is positioning itself to help influence small satellite technologies as a capability generator for the Canadian Forces. Through DRDC's Space Thrust, coordinated R&D projects and demonstration programs have been established to help deliver end-to-end space access to the CF. These initiatives include:

- Applied Research Programs
  - Satellite Payloads and Systems
  - Infrastructure for Ground Operations
  - Surveillance and Tracking of Space Objects
- Technology Demonstration Programs
  - High Earth Orbit Space Surveillance (HEOSS) – NEOSSat microsatellite mission
  - Space-based AIS/SMS microsatellite mission

Additional research initiatives such as Ground Movement and Tracking Indicator (GMTI) with Radarsat 2 and a wide range of radar, RF and electro-optic data exploitation projects should also share greater credit towards Space Systems development.

Through these initiatives, DRDC hopes to build the foundation for a sustainable small satellite R&D program that serves to identify and development space-based military capabilities. Significant partnership has been established across inter-governmental departments to ensure the success of current programs. Preliminary discussion on future programs have been initiated with international Allies, however, large potential exists to expand and promote small satellite initiatives across NATO. Through collaboration significantly more nations may be able to contribute towards developing NATO space-based capabilities. DRDC is eager to share it's lessons learned regarding the development of a small satellite program and excited to grow with the acceptance of demonstrated technologies and increased international leveraging.

Through current and future space R&D initiatives, DRDC strives to establish itself in the small satellite world with an end state focused towards:

- Being world-class developers/experts in small/microsat technologies for military applications
- Influencing and adopting affordable, responsive technology
- Continued Technology Watch
- Sustainability
- International in scope
- Active promotion of the technology and potential within CF

6.0 REFERENCES

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