Public Works and Government Services Canada

Travaux publics et Services gouvernementaux Canada

RETURN BIDS TO:
RETOURNER LES SOUMISSIONS À:

Bid Receiving
PWGSC
33 City Centre Drive
Suite 480C
Mississauga
Ontario
L5B 2N5
Bid Fax: (905) 615-2095

SOLICITATION AMENDMENT
MODIFICATION DE L'INVITATION

The referenced document is hereby revised; unless otherwise indicated, all other terms and conditions of the Solicitation remain the same.

Ce document est par la présente révisé; sauf indication contraire, les modalités de l'invitation demeurent les mêmes.

Comments - Commentaires

Vendor/Firm Name and Address
Raison sociale et adresse du fournisseur/de l'entrepreneur

Issuing Office - Bureau de distribution

Public Works and Government Services Canada
Ontario Region
33 City Centre Drive
Suite 480
Mississauga
Ontario
L5B 2N5

Title - Sujet Weather Radar NetworkModernization	
Solicitation No. - N° de l'invitation K3D33-141144/A	**Amendment No. - N° modif.** 001
Client Reference No. - N° de référence du client K3D33-141144	**Date** 2014-09-08
GETS Reference No. - N° de référence de SEAG PW-$TOR-018-6639	
File No. - N° de dossier TOR-4-37044 (018)	**CCC No./N° CCC - FMS No./N° VME**
Solicitation Closes - L'invitation prend fin **at - à** 02:00 PM **on - le** 2014-10-15	**Time Zone** **Fuseau horaire** Eastern Daylight Saving Time EDT
F.O.B. - F.A.B. **Plant-Usine:** ☐ **Destination:** ☑ **Other-Autre:** ☐	
Address Enquiries to: - Adresser toutes questions à: Pan, Long	**Buyer Id - Id de l'acheteur** tor018
Telephone No. - N° de téléphone (905) 615-2076 ( )	**FAX No. - N° de FAX** (905) 615-2060
Destination - of Goods, Services, and Construction: **Destination - des biens, services et construction:**	

Instructions: See Herein

Instructions: Voir aux présentes

Delivery Required - Livraison exigée	**Delivery Offered - Livraison proposée**
Vendor/Firm Name and Address **Raison sociale et adresse du fournisseur/de l'entrepreneur** **Telephone No. - N° de téléphone** **Facsimile No. - N° de télécopieur**	
Name and title of person authorized to sign on behalf of Vendor/Firm (type or print) **Nom et titre de la personne autorisée à signer au nom du fournisseur/ de l'entrepreneur (taper ou écrire en caractères d'imprimerie)** **Signature**	**Date**

Canada

AMENDMENT NO. 1

Amendment No.1 includes the following information:

- Annex A – Context and Considerations

  - Appendix 1 - Needs Index and Gap Analysis
  - Appendix 2 - Scientific and Technical Considerations

- Annex B – Industry Engagement Process

- Annex C Industry Day and One-on-One Meetings Schedule

- Annex D Engagement Rules (Mandatory Form)

Please see attached documents.

IMPORTANT NOTE:

Registration is mandatory if you wish to participate in the Engagement Process and the related One0on-one meetings. Please sign and return Annex D – Engagement Rules (Mandatory Form) and provide the required information described in Annex C – Industry Day and One-on-One Meetings Schedule.

ANNEX A to Letter of Intent:

Modernization of Environment Canada’s Weather Radar Network

Context and Considerations Document

Executive Summary:

This specific procurement action forms part of the overall strategy for modernizing Canada's Weather Radar Network (CWRN). This multi-year modernization is being undertaken as follows:

1. Assess conditions and stabilize existing network (2012-2015)
2. Develop and assess network design options (2011-2015)
3. Replace the aging Montreal area radar (McGill) (2013-2016)
4. Design and implement the upgrade to dual-polarization of the 10 most modern radars in the network (2012-2017)
5. **Replace the 19 obsolete radars and infrastructure and add 1 new radar to northern Alberta (2014-2023)**
6. **Harmonize operations across the entire network to the replacement radars as standard (2019-2023)**
7. **Modernize Integrated Logistic Support and Life-Cycle Management (2012-2023)**
8. **Development of modern products and tools for technicians, meteorologists, and general users (2014-2023)**
9. Establishment of a test and development program, including a test and repair facility and radar systems to support that work.

This Letter of Intent deals with activity numbers 5 through 7 and parts of activity number 8.

Table of Contents

LIST OF ACRONYMS

ADM	Assistant Deputy Minister
AHP	Analytical Hierarchy Process
APU	Auxiliary Power Units
AR5	The IPCC 5th Assessment Report
BITE	Built-in Test Equipment
BOM	Australian Bureau of Meteorology
CanESM2	The Second Generation Earth System Model
CaPA	Canadian Precipitation Analysis
C-C	Clausius-Clapeyron
CGCM4	The Fourth Generation Canadian General Circulation Model
CMAC	Canadian Meteorological Aviation Centre
CMC	Canadian Meteorological Center
COTS	Commercial off the Shelf
CRD	Climate Research Division
CSB	Corporate Services Branch
CWRN	Canadian Weather Radar Network
DA	Data Assimilation
DND	National Defence and the Canadian Armed Force
DP	Dual-Polarization
EC	Environment Canada
EEC	Enterprise Electronics Corporation
EER	Environmental Emergency Response
FTE	Full Time Equivalent (employee)
GCM	Global Climate Model
GIS	Geographic Information System
GMAP	Gaussian Model Adaptive Processing
GTA	Greater Toronto Area
HQ	Headquarters
HVAC	Heating, Ventilation and Air Conditioning
IM/IT	Information Management/Information Technology
IPCC	Intergovernmental Panel on Climate Change
K_{DP}	Specific Differential Phase
LFH	Land Falling Hurricanes
MAR	Montreal Area Radar
MF	Météo France
MOIP	Meteorologist Internship Program
MSC	Meteorological Service of Canada

NexRAD	The U.S. Next Generation Weather Radar
NHMS	National Hydrological and Meteorological Services
NI	Needs Index
NOAA	National Oceanographic and Atmospheric Administration
NRP	Canadian National Radar Program
NWP	Numerical Weather Prediction
O&M	Operation and Maintenance
OSH	Occupational Health and Safety
PC	Pulse Compression
PRF	Pulse Repetition Frequency
PWGSC	Public Works and Government Services Canada
PY	Person Year
QC	Quality Control
QMS	Quality Management System
QPE	Quantitative Precipitation Estimate
R&D	Research and Development
RES	Real Estate Services
RFP	Request for Proposal
RUAD	Radar and Upper Air Division
S&T	Science and Technology
SPC	Storm Prediction Center
SPP	Strategies, Planning & Performance
SSC	Shared Services Canada
SSIA	Sub-system Integrated Approach
SSW	Summer Severe Weather
STB	Science and Technology Branch
STS	Severe Thunder Storm
TB	Treasury Board
TTAC	Technology Transfer Advisory Committee
UPS	Uninterrupted Power Supplies
URP	Unified Radar Processing
VCP	Volume Coverage Pattern
WEM	Weather and Environmental Monitoring
WEO	Weather and Environmental Operations
WG1	Working Group 1 (IPCC)
WMO	World Meteorological Organization
WSW	Winter Severe Weather
Z_{DR}	Differential Reflectivity

1. INTRODUCTION

This document provides the background information and describes the strategy for the modernization of the Canadian Weather Radar Network (CWRN). It describes our considerations and some of the preferred options. It presents the first step of the network optimization, with focus on user needs, technology and network design considerations. It also takes into consideration future applications and existing and emerging technologies that could reduce the operating costs of the radar.

The development of network design options involved the creation of user requirements, , gap analysis and cost-benefit analysis, the need to re-furbish existing radars, to have reliable radar data, to maximize coverage while minimizing costs and operational impacts.

In this analysis, “benefit” is in reference to the public interests, the Departmental program needs, integrated climate risk assessment, as well as the user requirements for coverage, radar utility and spatial/temporal resolutions.

The document consists of seven sections and 2 appendices:

1	Introduction
2	Context and Background
3	Procurement Intentions
4	Goals for Functionality
5	Goals for Operations
6	Summary of Considerations (technical, scientific, operational)
7	Input sought from Industry
Appendix 1	Needs Index and Gap Analysis
Appendix 2	Scientific and Technical Considerations (detail)

Various options have been considered for the strategic network design including the mix of radar types (C, S and X). A notional solution of mixed network of S, C and (in the future) X-Band radars was accepted. The decision on the final mix of radars in the network will be determined, in part, by the results of this industry engagement and any subsequent RFP process. Note that at this time X-band is out of scope as we do not intend to increase the number of radar sites beyond the one mentioned in the Executive Summary (Northern Alberta).

2. CONTEXT AND BACKGROUND

Radar network planning activities commenced in late 2011. Understanding user requirements was the first step of the strategic planning and design process. An objective approach was applied to optimize the radar network. Primary considerations were given to meteorological factors in conjunction with:

- Current and future program needs;
- Social and economic factors;
- Radar technologies; and,
- Cost-benefit analyses.

2.1 Main Drivers and Considerations

The main drivers for the network design are user needs, which translate into the security, safety, and economic wellbeing of Canadians. Detection and prediction of weather phenomenon are primary components of the meteorological service of EC, for which, weather radar is one of the primary tools used by meteorologists for detecting and monitoring severe and hazardous weather phenomena in order to provide adequate advanced warning.

Radar networks and their design are updated about every 15 to 25 years. Therefore, the design needs also to be driven by anticipated requirements and progress in scientific and technology developments. Hence, flexibility and adaptability needs to be built into the implementation plan in order to provide the best value for Canadians.

Additionally, the last significant upgrade of the CWRN took place in the late 1990s and at that time 19 existing radars were refurbished and 11 new systems purchased. The refurbished radars are now beyond their useful life, are unsuitable for upgrade and have become difficult and costly to support. In Figure 1 below, the obsolete systems have been circled.

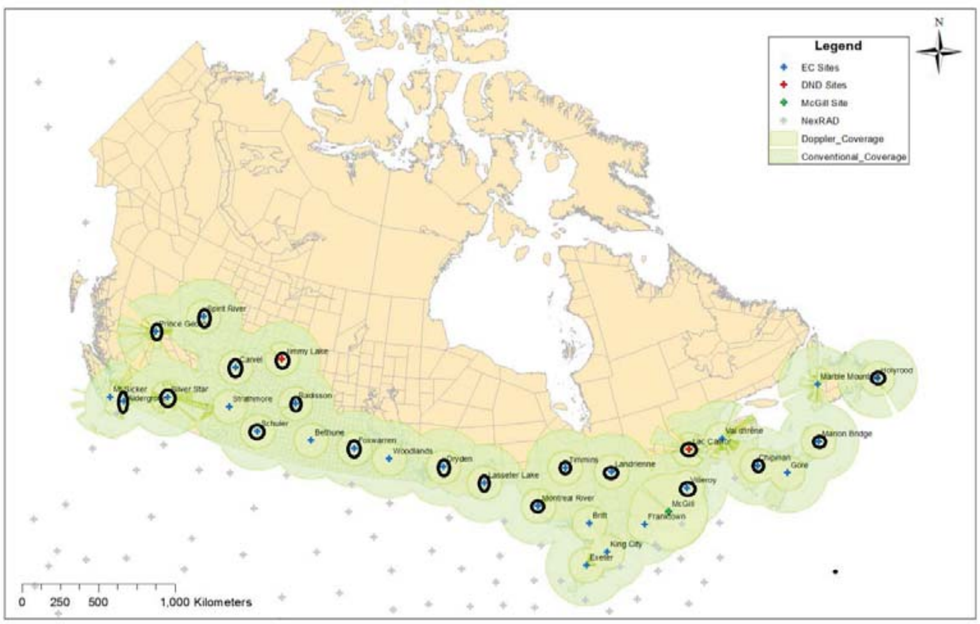

Figure 1 Environment Canada's current Weather Radar Network

2.2 Risk-based Assessment for Radar Coverage

Canada is large, with significant differences in its regional geography and seasonal conditions, resulting in a wide range of hazardous weather conditions: from ice storms, snow squalls and blizzards in the cold season, to severe thunderstorms, tornadoes and hurricanes in the warm season, as well as windstorms year-round (Table 1, Figure 2). Major weather disasters have occurred from coast to coast in Canada. Damage to homes, properties and businesses, as well as disruption and damage to electrical, communication and transportation systems can result from these storms.

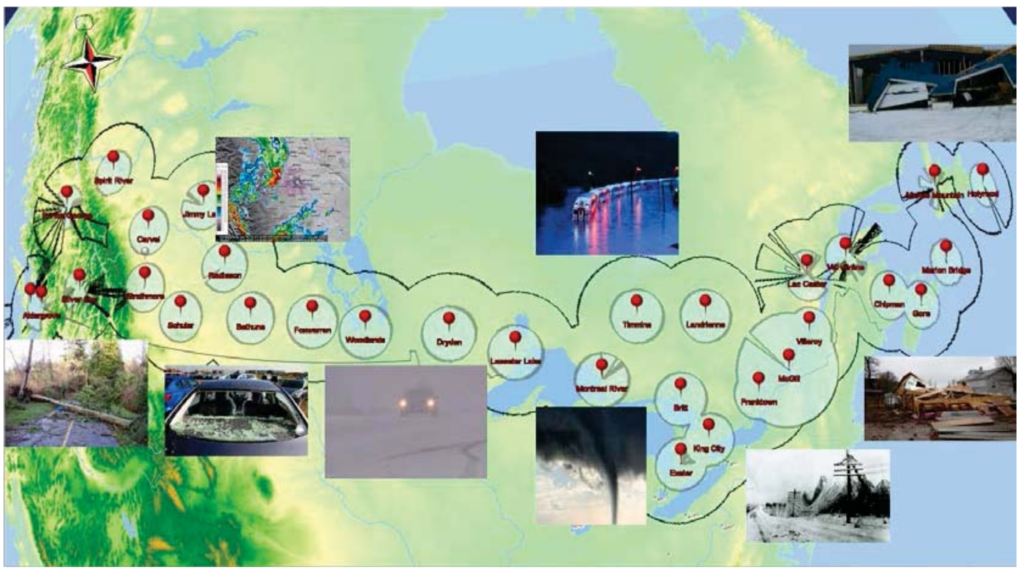

Figure 2 Canada's Diverse Weather Regimes

Table 1 Regional Weather Characteristics

Area / Region	Main Weather Characteristics
Southern Ontario	Tornado alley, severe thunderstorm, squall lines, heavy rainfall
Southern Prairies	Hail alley, tornado, severe thunderstorms, heavy rainfall
Atlantic Region	Land falling Hurricanes
Montreal and - Saint Lawrence river valley	Nor'easters, severe thunderstorm, squall lines, heavy rainfall
The Great Lakes and other large lakes	Low level snow squalls

The social and economic impact from these weather disasters can be tremendous. For example:

- The 1998 Ice Storm impacted about 25% of Canada's population in Ontario, Quebec, New Brunswick and Nova Scotia as well as 7 states in the Northeastern U.S. Total economic losses estimated at $5.4 billion ($ in 2000).
- The deadly Pine Lake tornado in central Alberta in July 2000 took 12 lives when it struck a campground and trailer park. On August 20, 2009, 18 tornadoes crossed southern Ontario, a record number of tornadoes observed on one day in Canada.
- The Summer 2013 flooding resulted from a severe thunderstorm in the Greater Toronto Area (GTA) region was the most expensive natural disaster in Ontario history with estimated insurance cost of $850 million.
- In September 2003, Hurricane Juan made landfall near Halifax, Nova Scotia as one of the most powerful and damaging hurricanes to ever affect the region.
- The devastating Vancouver windstorms in 2006 resulted in extreme damage to trees in Stanley Park and to the seawall.
- Localized shallow snow squalls can result in “white out” conditions posing hazardous driving condition. On Feb 27, 2014, a lake effect snow squall resulted in a 50 car pileup.

2.3 Needs Analysis

To objectively and quantitatively identify and prioritize the radar coverage gaps, a risk-based analysis was conducted. The goal of this analysis was to use available data to conduct spatial analyses to quantify the user needs, to characterize potential radar sites, and to perform radar coverage and blockage analysis. A Needs Index (NI) was created based on the ranking and weighing of significance of high impact weather risks, social economic values and infrastructures factors. For more information, see Appendix 1 of this document.

The Needs Index was calculated and used to characterize and prioritize the existing CWRN radar sites as well as to validate and prioritize user-perceived radar coverage gaps. Snowsquall-prone areas and hurricane landfall data were overlaid on this map as well. (Figure 3)

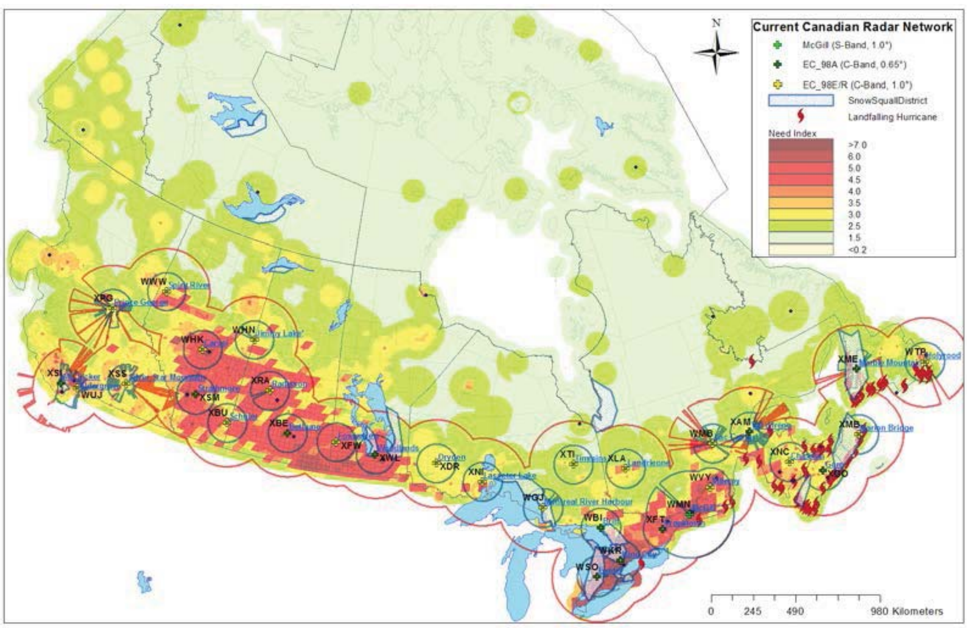

Figure 3 Spatial distribution of the Needs Index with equally weighed impact of severe weather, social and infrastructure groups.

2.4 Gap Analysis

Applying the Needs Index, a gap analysis was conducted to validate and prioritize user-perceived radar coverage gaps. Gap areas were prioritized based on the NI values, the existing combined radar coverage from the CWRN, and the U.S. NexRAD along the border areas.

Figure 4 demonstrates the ranked gap areas for general radar coverage requirements (assumed radius = 250km) and areas with Doppler coverage needs (radius = 110km). Results suggested that, the top 5 gap areas for general radar coverage are: The Pas, Port Hardy, Fort McMurray, Yarmouth and Prince Rupert. For Doppler coverage, the top 5 gap areas are: Wainwright, Halliburton, Swift Current, Bruce Peninsula and Sundre.

The Government of Canada does not want to add new radar sites at this time (except the one identified in Northern Alberta – near #3 on the left hand map below in Figure 4). Therefore, through our current modernization, we are intending to fill as many high-priority gaps as possible by applying new technology and data gathering and processing techniques.

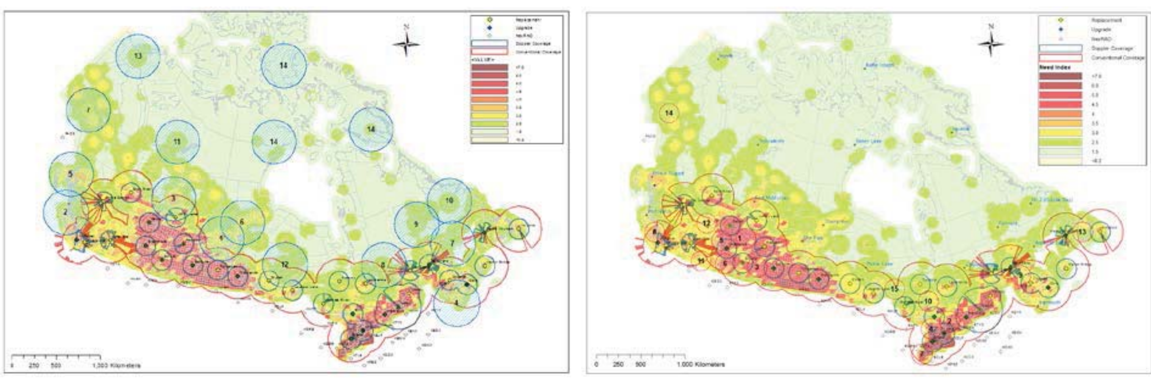

Figure 4 Prioritized weather radar gap areas for general radar coverage (left) and Doppler coverage (right).

2.5 Future Projections and Radar Network

Because the Government of Canada does not want to add new radar sites at this time, this gap analysis will serve as our long-term vision for moving forward over the coming decades. As we move forward with the current Modernization Plan, we will periodically review the Needs Index and Gap Analysis, investigate technologies that may help fill those gaps, and seek funding for further network enhancements as appropriate.

Additionally, future reviews of the radar network strategic design will take into account potential risks and impacts arising from a changing climate in Canada and consequently, how the radar network would be used in future applications, such as data assimilation, hydrology, wind-shear nowcasting, etc.

Finally, the weather radar network should not be used in isolation. With the rapid advancement of satellite technologies and growing telecommunication capabilities, radar, together with other observational networks, will be increasingly used in an integrated fashion for local and short-time applications, to regional and national applications for severe weather warning, data assimilation, hydrology, and climate applications.

3. PROCUREMENT INTENTIONS

To meet the evolving radar data requirements and Environment Canada's mandate, EC is interested in procuring twenty (20) state-of-the-art dual-polarized Doppler weather radar systems. Each system will include; tower, radome, antenna with pedestal, transmitter, receiver, signal processor, radar control system and anything else to ensure function and serviceability. Services shall include, but not be limited to; site preparation, installation, testing, technical training, documentation, and Integrated Logistic Support.

3.1 Project Management (PM)

PM services will be required throughout the duration of the project. The PM services will include (but are not limited to), establishment of a formal project plan; tracking, documentation and reporting of project progress, expenses and deliverables against the plan, etc. The expectation is that PM services shall be delivered following one of the common international standards (for example: PMI, PRINCE2, ISO)

3.2 Site Infrastructure

The majority of the installations will take place at existing radar sites. It is anticipated that little of the current infrastructure (tower, shelters, foundations) will be suitable for the new equipment. All infrastructure must meet applicable Canadian Standards.

3.3 Radar Systems

The antenna and pedestal must operate continuously through 360 degrees of azimuth and varying degrees of elevation (scanning strategy to be determined) within a temperature range of -40C to +40C and a relative humidity of 10 to 100%.

The radome and any other protective system must not significantly impede the operation of the radar and must protect the sensitive systems from harsh climatic conditions; including high winds, freezing rain, snow-loading, etc.

All cabling, waveguides, computers, processors, transmitter and receiver components must also be appropriate for Canadian conditions and meet all applicable standards.

3.4 Integrated Logistics Support

The requirements for integrated logistics support include but are not limited to; information and documentation, as well as the support services required for training, life-cycle management, and inventory management.

4. GOALS FOR FUNCTIONALITY

Given the gap analysis, some fundamental needs could be addressed by simply updating our current Doppler network and changing the scan strategy. However, given the obsolete condition of 2/3 of the network and the emergence of operational dual-polarization technology, this is a good time to optimize the network and prepare for the next 25 years. This includes extending the type and quality of the data by adding dual-polarization to the network for echo classification (rain vs snow, vs ground clutter, etc.,)attenuation correction and rainfall estimation using Specific Differential Phase ($_{KDP}$) and improved calibration through maintenance and calibration processes and also using the self-consistency dual-polarization technique.

It should be noted that the prime requirement of the radar data is still for understanding severe weather and issuing warnings, particularly of rapidly developing situations. However, quantitative precipitation estimates have long been a goal of weather radar. While accurate estimates are needed more than ever for severe weather warnings and hydrological applications, they have been elusive.

Data Assimilation is a future area that requires quantitative information. Some systems do not require the use of the reflectivity (that may be attenuated) but use the radial velocity that is attenuation free. Hence, the quantitative use of weather radar can still be viewed as a pressing need requiring additional scientific and technological development.

Specifically, the requirements can be summarized as following:

- Qualitative use for forecasters (Primary) and decision-makers (Secondary)
  - Detection – e.g. low level snow squalls, storms at long range
  - Need extended Doppler coverage horizontally (~180km), vertically (~12-15 elevation angles) for better warnings
  - Need rapid scan (5-6 min) for timely warnings and Data Assimilation for nowcasting
  - Convective severe weather warnings (patterns/understanding)
  - Fault tolerant

- Quantitative use for precipitation analysis, Data Assimilation and Hydrology (Emerging)
  - Severe Weather Algorithms
  - Need good quality wind data upstream of critical areas and within 100 km of radar for data assimilation
  - Need good quality data (attenuation compensated, target type) for precipitation estimation
  - Not fault tolerant

A case has been made that 0.65° beam width radars are needed for low level snow squall detection and for data quality - related to beam filling to longer ranges. Experience has shown that C-Band radars are good enough for qualitative use both for Doppler applications and for quantitative use if attenuation and K_{DP} techniques can routinely be demonstrated across the breadth of the Canadian climate regimes.

If the CWRN had spacing between sites of 200km rather than 300km, or the useful Doppler range could be extended beyond 160+km and attenuation can be corrected, staying with an all C-band network may have been a clearly preferred approach.

S-Band is also "proven technology". It is used very successfully in the U.S. and at Montreal/McGill in Canada. It has a better range-velocity trade-off and less attenuation. Estimates indicate that the setup of a 1.0^{o} beam S-Band is about 25-30% more costly than a 0.65^{o} C-Band. The trade-offs are complex and discussed in Appendix 2 of this document.

5. GOALS FOR OPERATIONS

The monitoring renewal project will address key issues with EC's foundational monitoring infrastructure and its long-term sustainability. One of the key requirements is to implement a network that can be maintained in a cost-efficient way.

Technological ideas on how to reduce operating and maintenance cost generally revolve around more robust equipment, redundant components, better information, better depot and sparing management which the result of fewer maintenance issues and visits at the expense of greater initial capital costs.

For example, Built-in Test Equipment (BITE) is now common in commercial systems (not currently in EC). This allows off-site monitoring of the hardware and pro-active remedies which contribute to higher data quality and reliability and a reduced number of site visits (e.g., from 6 to 2 visits per year).

Off-site calibration may also be possible, further improving data quality and reliability.

A key consideration is the operational support and maintenance capability, capacity and cost of a mixed network but also for S-Band radars themselves, as EC has no experience with these systems. The following summarizes the issues:

- No orphans. The minimum number of radars of a specific configuration for cost- and technical-effectiveness has been found through experience to be four.
- Training and transition costs for multiple radar types.
- Occupational, Safety and Health (OSH) concerns, including tools, equipment, training, and required staffing levels.
- Cost of sparing multiple radar types. This is a depot and sparing management issue.

Our current network is maintained from 1 Headquarters (HQ) site in Toronto with 8 other office locations across the country. HQ is staffed with primarily engineers and senior technicians and the 8 field offices are staffed with technicians who are trained to support several of our networks – not just radar. Overall, the level of effort to operate the network is the equivalent of:

- 1 full-time field technicians per 3 radars (10 full-time technicians)
- 2 full-time engineers
- 3 senior HQ technicians (specialists)
- 3 HQ working-level technicians

A significant maintenance-related cost is travel. Almost all of the sites take 3 or more hours to drive to from the service offices and some take a full day. Some sites are an hour away from the nearest accommodation, which adds to travel time over the course of a week's work. Therefore; the fewer visits – either for preventive maintenance or return-to-service - the better.

Additionally, the cost of shipping parts to the technicians once they have made a diagnosis, and the time the technicians spend waiting for the required part is a large cost to the program.

For example, if we were to have the ability to diagnose and correct many problems remotely, utilize less-skilled but local staff or contracts for some issues, avoid sending two staff by minimizing Occupational Health and Safety risks; we could reduce our operating costs substantially.

6. SUMMARY OF KEY CONSIDERATIONS

Overall, the network design solution must, at a minimum, meet the following general requirements:

- Addresses the high-priority user needs
- Is affordable to maintain
- Improves radar data utility for current user requirements (summer and winter severe weather warnings for example
- Provides flexibility to address emerging user requirements and new technologies/techniques anticipated in the next 15 years.

6.1 Options under consideration

In Table 2, a summary of the various network options being considered is presented. Note: “Data quality” is a ubiquitous term and has many meanings, see Appendix 2 for further discussion.

Table 2 Pros and Cons for each option

Options	Pros	Cons
All C-Band	• Better detection of low level snow squalls and low level weather detection • Network uniformity • Efficiencies of scale and decreased operating costs • Better data quality due to uniformly filled beams at longer ranges • Spectrum frequency - primary	• Attenuation in severe weather results in lower data quality • Range and velocity issues • High dependence on development for range-velocity and QPE (moderate-high risk) • Spectrum sharing with RLAN
All S-Band	• Improved summer severe weather • Larger Doppler range and more flexibility in scan strategy • Less attenuation, better QPE with less science effort • Network uniformity • Efficiencies of scale	• Costs • Have less range, for due to 1° beam width, Low level snow squalls are not detected very far from radar since 0.65° not available in foreseeable future • Spectrum frequency – not primary but has special status • Spectrum sharing with WIMAX
Mixed	• Leveraging S-Band vs. C-Band trade-offs (eg. S-Band for Summer Severe Weather (SSW)-prone areas and major urban centers, C-Band for snowsquall	• Increased maintenance complexity

	areas) • "S keeps C honest"	

6.2 Discussion of options under consideration

These considerations are discussed further in Appendix 2 of this document

1. Historically, the use of radar is primarily justified by its qualitative use for severe weather. Both C and S-Band radars have been successfully used for operational severe weather.
2. The quantitative use of weather radar is still in development as both C and S have to be processed to remove the artifacts and Earth curvature effects at long range. This is not fully done at the moment and the qualitative use is still the highest priority. So this is a future application and will be a driving requirement in the next 25 years for hydrology and data assimilation, but not at the moment.
3. Both C and S-Band radars suffer from attenuation but it is less for S-Band. The critical question is whether dual-polarization techniques can overcome the attenuation and whether it is better to be more sensitive to attenuation or to be less sensitive to attenuation in order to determine when to apply the correction for most benefit. The correction for attenuation at C-Band has shown great promise. However, it may not be necessary for QPE as attenuation independent dual-polarization techniques using K_{DP} techniques may be superior. However, for radar algorithms where reflectivity is used as a threshold, attenuation correction is still required. Unless totally attenuated, it is assumed that C-Band dual-polarization attenuation and precipitation retrieval techniques will be adequate once the potential is realized. This means that there is a strong dependence or risk on scientific progress.
4. We are considering S-Band (1°) and C-Band (0.65°) radar systems. The analysis would be completely different if different beam-widths were being considered. The quality and advantages of small beam width radars are substantial – effective range due to beam filling, low level scanning, greater gain and greater sensitivity. Inherent, is that shallow weather is significant and important to detect and that long range quantitative use is highly desired. The critical question is where it is most important geographically/climatologically.
5. The numbers of radars do not substantially change. Experts (even S-Band proponents) agree that C-Band is fine for Canadian weather. However, the Earth curvature, the Doppler range limits and the network spacing of 300-350 km plus the requirement of full Doppler coverage promote the introduction of S-Band radars. Experts agree that introduction of additional C-Band radars would strongly impact the network design decision regarding the use of a mixed network or exclusively C or S-Band. However, with the exception of the Athabasca site, adding more radars is not being considered at this time.

6. Range/velocity extension to 180 km at C-Band is probably achievable with future improvements and advancements in phase coding techniques. Introduction of phase coherent transmitters (klystron, solid state, etc. vs. magnetron) may help to achieve this but require development and demonstration. This may still be far in the future for operational use.
7. Attenuation of C-Band radars in the Canadian weather can be significant but total attenuation occurs rarely and the promise of dual-polarization attenuation-adjustment techniques at C (and S-Band) will be realized. It has been spectacularly demonstrated in case studies but the full development and evaluation in all Canadian conditions has not been done.
8. For quantitative applications, attenuation is but one issue; there are many adjustments that need to be equally made for both S and C-Band radars for all the physical artifacts and Earth curvature effects (range extension). Both S and C will need attenuation correction; it remains whether it is better to have more or less attenuation for the implementation of dual-polarization adjustment techniques.
9. There are a myriad of other trade-offs, assumptions and details (see Appendix 2) but essentially these balance each other.

7. INPUT SOUGHT FROM INDUSTRY

In addition to registering for the Industry Engagement, we would appreciate it if you could provide the information requested below.

There will be more opportunities to engage prior to the release of the anticipated RFP as described in Annex B – Engagement Process; however, the sooner we have your input the more easily it can be integrated into our process.

1) A brief corporate profile of your organization (2 pages or less)
2) An indication of areas of product/service expertise and delivery capacity provided by your organization (3 pages or less)
3) A brief description of any similar projects you have been involved in.
4) What Project Management standard do you normally follow? What PM tools do you use?
5) How you would propose addressing some (or all) of our key considerations and trade-offs mentioned in this document? In particular, which option under section 6.1 would you propose and how would you recommend handling the following considerations under section 6.2:
    - #3 attenuation
    - #4 shallow weather and beam-filling
    - #5 geographic expansion of Doppler coverage

6) Are there any considerations you think we have missed which should be examined with respect to the requirements mentioned in this document?
7) What suggestions do you have for keeping operating and maintenance costs low, particularly given the fact that many of our sites are 4-8 hours travel from the nearest field office? (see Section 5)
8) We are looking for systems that can run in the field reliably (95+% up-time, 24/365) for years, with no more than 2 visits per year for on-site servicing/calibration - barring damage from outside sources, like lightning. Do you consider this reasonable?
9) What information do you think you will need regarding our current sites to be able to prepare costing for the site infrastructure?
10) We are considering including the harmonization of the 11 existing radars (see Figure 1) that will not be replaced to the new standard of these 19 replacement radars as indicated in Figure 1 and 1 new site in Northern Alberta as indicated in Figure 4; what approach would you propose to ensure an effective and cost-efficient harmonization? What information would you need about the 11 existing radars to inform this harmonization? (see activity 6 in the Executive Summary)
11) From previous experience, how long do you think it may take to prepare a bid response after the final RFP has been posted? (understanding that this is only an estimate for our rough planning purposes)
12) How would your organization build flexibilities into project plans to enable Environment Canada to adapt to changes in its operational environment during a long term period (approximately 8 years)?
13) Can you provide cost estimates and timelines for each of the options listed in Table 2 in section 6.1? Please include the following breakdown in these estimates:
    - Cost of the operational (not prototype or 'first article') radar systems (exclusive of tower and site-specific infrastructure, but including all radomes, required hardware, electronics, processing equipment, transmitter, receiver, and other items to ensure an operational system)
    - Cost of Project Management
    - Cost of system design
    - Time-line for delivery of the first article for testing (for a mixed network we would need both C and S-band for acceptance testing)
    - Capacity for delivery of the remaining operational systems (per year rate or delivery profile to March 31, 2023 (scheduled project completion).

APPENDIX 1

T0 ANNEX A,

CONTEXT AND CONSIDERATIONS DOCUMENT,

1. NEEDS ANALYSIS

To objectively and quantitatively identify and prioritize the radar coverage gaps, a risk-based analysis was conducted. The goal of this analysis was to use available data to conduct spatial analyses to quantify the user needs, to characterize potential radar sites, and to perform radar coverage and blockage analysis.

A Needs Index (NI) was created based on the ranking and weighing of significance of high impact weather risks, social economic values and infrastructures factors specified below:

High impact weather risks:

- Tornado density (50-km grid 1980-2009) and prob. tornadoes occurrence
- Lightning strike density (50-km grid 1999-2009)
- Days per year with hail (1971-2000)
- Days per year with freezing precipitation (1971-2010)
- Days per year with daily rainfall >=25mm (1971-2000)
- Days per year with wind>=63km/h (1971-2000)
- Days per year with snowfall>=10cm (1971-2000)
- Land falling Hurricanes (1851-2007)
- Shallow winter weather (snow squalls district, blowing snow, etc.)

Social factors:

- Population density
- Major urban centres
- Population change

Critical infrastructure and transportation factors:

- Transportation network (air ports, major highways, major ports, major railway)
- Major industrial complex (nuclear stations, major oil pipelines, major gas pipeline, oil tar sands leased area, oil platforms, hydro stations, refineries).

The climatological data used in this study was obtained from the Canadian Atmospheric Hazards DVD produced by Environment Canada, Climate Data Archive, Canadian Hurricane Centre (EC) / National Hurricane Center (NOAA) and Meteorologist Operational Internship Program (MOIP). In addition, critical hydrological basins were identified as well. Figure A1-1 provides a summary of spatial distributions of each high impact weather factor.

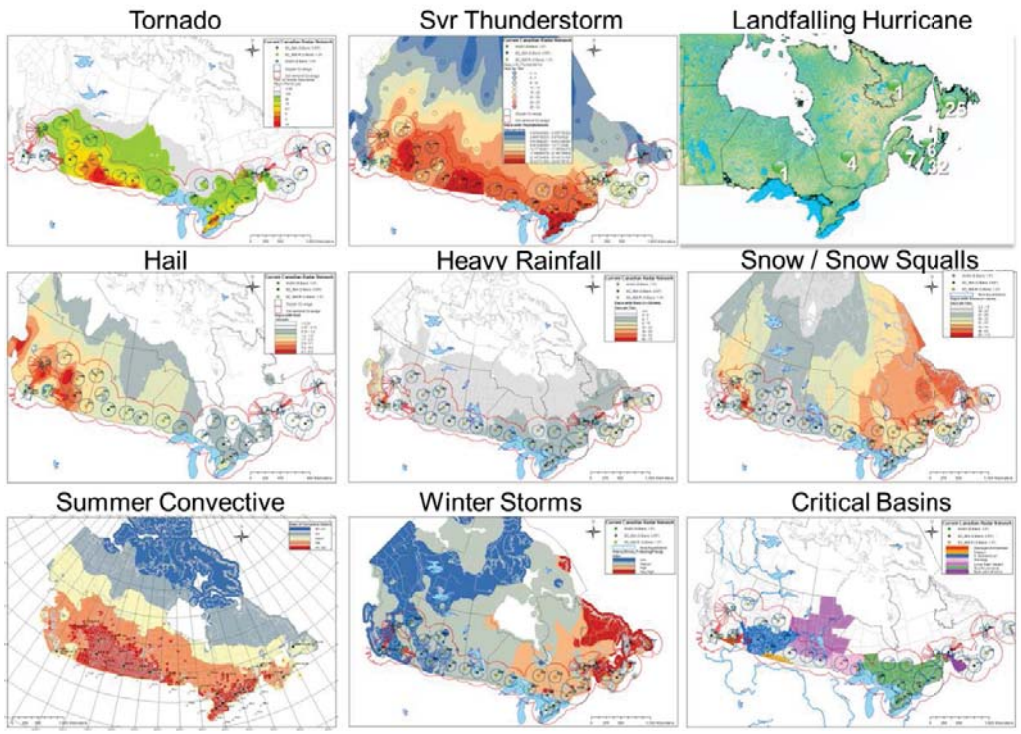

Figure A1- 1 Spatial Distribution of High Impact Factors

To quantify the relative importance amongst the factor layers, a questionnaire was designed to solicit decision makers for their opinions. The project / scientific team members were asked for their input. The questionnaire included the following:

- Reviewing the factor layers proposed for Needs Assessment
- Ranking each individual factor in terms of preference of importance, with respect to having coverage over a severe weather factor, an infrastructure or high population density
- Pair-wise comparison of the factors of each factors group against each other, in terms of preference of importance for the radar needs coverage using the Analytical Hierarchy Process (AHP).

The pair-wise comparison incorporated the comparison of 2 factors layers of the same factor group to determine the relative importance of one over another. For example "is tornado density more important than high winds when it comes to radar coverage?" Each judgment was assigned a number in a scale. This was done based on a 9 point scale where 9 represents one factor being significantly more important than the other and 1 represents equal importance.

- Pair-wise comparison of the factors groups against each other, in terms of preference of importance for the radar needs coverage. This determines the relative priority by factors groups. For example "is Severe Weather more important than Infrastructure?" This was done based on a 9 point scale where 9 represents one factor being significantly more important than the other and 1 represents equal importance.

The needs index (NI) was calculated using a weighted linear combination (WLC) method based on the assigned weight and ranking given by the AHP method. In this method, the need index value for each considered pixel was computed by summation of each factor's weight multiplied by factor group weight written as follows:

$$NI = \sum_{i=1}^{n} \left(R_f * W_f\right)_i * W_{g_i} \qquad \textbf{E. 1}$$

Where R_f is Factor rank, W_f is Factor weight in each factor group and W_g is the Factor group weight.

Applying different weighing values, a combination of six scenarios were created:

- Scenario 1: Applied the ranking and weighting values provided by survey participates
- Scenario 2: Applied the same ranking values as in Scenario 1, but equal weighting values to each of the factor groups.
- Scenario 3: Equally weighted severe weather factors, enhanced infrastructure (added Refineries, Pipelines, Oil tar sands, Natural gas and Generating stations) and population (added urban areas and population growth) data.
- Scenario 4: Same ranking and weighting as Scenario 2, but enhanced infrastructure and population data.
- Scenario 5: Sub-grouped severe weather factors into summer convective and winter storms sub-groups, applied un-equal weights between factor groups, enhanced infrastructure and population data.
- Scenario 6: Same as scenario 5, but applied equally weighted values to each of the factor groups.

Scenario 6 was selected as a good representation for the Needs Index because it considered high impact weather in the summer and winter situations, strengthened the economic value, and applied additional infrastructure and population data. Figure A1-2 shows the spatial distribution of NI derived from the Scenario 6. Snowsquall-prone areas and landfall hurricane data were overlaid on this map as well.

The Needs Index was used to characterize and prioritize the existing CWRN radar sites as well as to validate and prioritize user perceived radar coverage gaps.

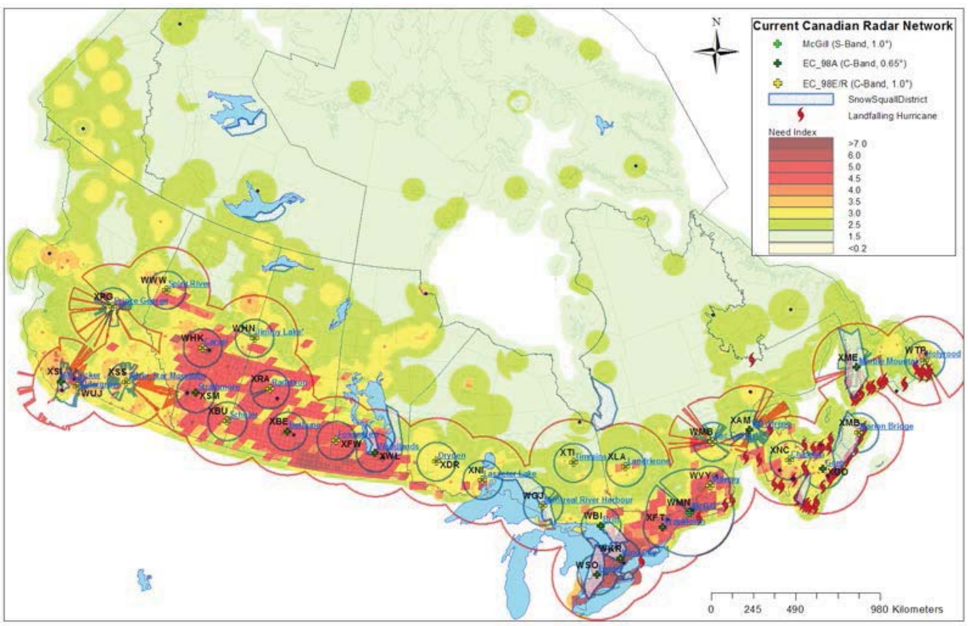

Figure A1- 2 Spatial Distribution of the Needs Index with equally-weighed impact of Severe Weather, Social, and Infrastructure groups

2. GAP ANALYSIS

Applying the Needs Index, a gap analysis was conducted to validate and prioritize user perceived radar coverage gaps. Gap areas were prioritized based on the NI values, the existing combined radar coverage from the CWRN, and the U.S. NexRAD along the border areas.

Figure A1-3 demonstrates the ranked gap areas for general radar coverage requirements (assumed radius = 250km) and areas with Doppler coverage needs (radius = 110km). Results suggested that, the top 5 gap areas for general radar coverage are: The Pas, Port Hardy, Fort McMurray, Yarmouth and Prince Rupert. For Doppler coverage, the top 5 gap areas are: Wainwright, Halliburton, Swift Current, Bruce Peninsula and Sundre.

Note that the study used the same threshold criteria across the country and not region dependent thresholds. Winds of the same strength are given the same importance in a calm area and in a windy area. It should be noted that threshold criteria for the issuance of severe weather warnings vary depending upon the location within Canada, as well as the time of year. For example, a wind warning is issued in Newfoundland and Labrador, and certain regions of Alberta, British Columbia, Yukon when sustained winds reach 80 km/h or more and/or wind gusts of 100 km/h or more, while for other regions such as Ontario and Quebec, the warning threshold is 70km/h and/or gusts of 90km/h. Regional specific severe weather criteria were taken into account qualitatively based on the regional specific requirements state in the national weather radar user requirements report as well as a regional report.

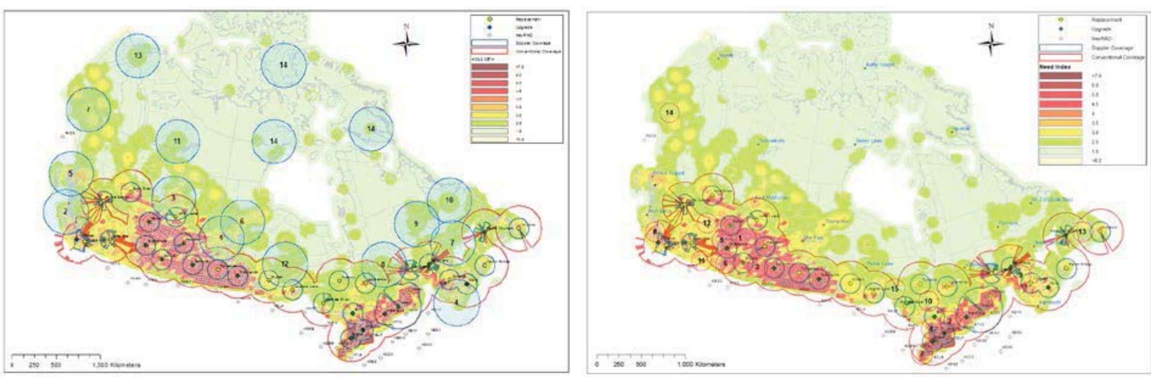

Figure A1- 3 Prioritized weather radar gap areas for general radar coverage (left) and Doppler coverage (right)

APPENDIX 2

T0 ANNEX A,

CONTEXT AND CONSIDERATIONS DOCUMENT

TABLE OF CONTENTS

1. QUALITATIVE USE OF RADAR DATA

This section addresses some issues have been raised about the qualitative use of radar. In this section, these issues are discussed and risks identified.

Echo shape: Figure A2-1 is an example of what is meant by the qualitative use of weather radar data from a C-Band radar (Exeter Radar, Goderich F3 Tornado of Aug 21 2011). In this example, the use of radar for understanding is illustrated. On the left, the reflectivity data shows a thunderstorm with a hook echo. If the signal is not totally attenuated, the severe weather analyst would likely issue a severe weather warning regardless of the values of the reflectivity (that is, attenuated or no). Although high values of reflectivity are also used to identify severe weather (red echo is > 55dBzdBz), in this example, the shape of the echo is indicative of updraft strength, longevity of the storm and the life cycle phase of the storm. On the right, even with noise (due to dual-PRF velocity technique), a rotation signal in the radial velocity (green, red couplet) can still be observed reinforcing the warning decision.

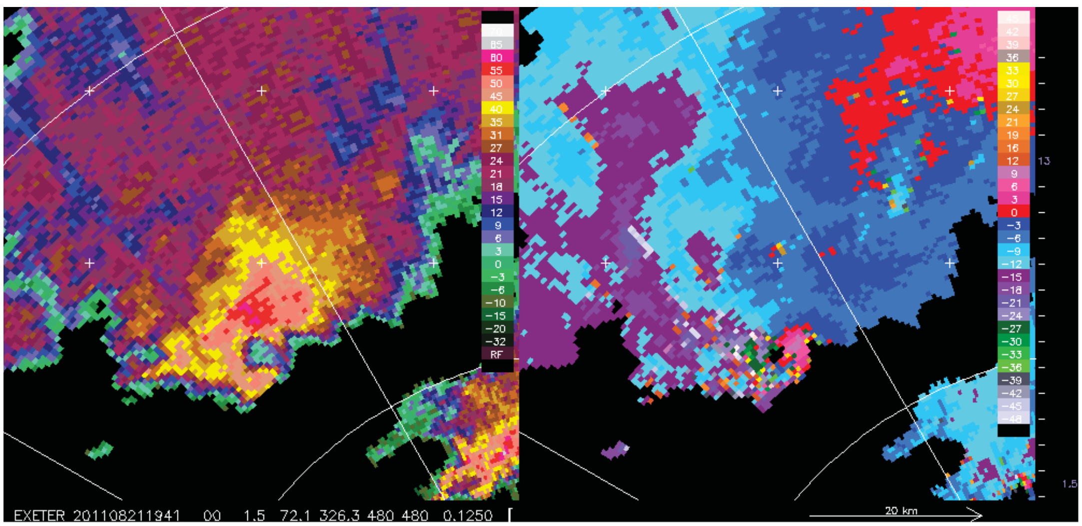

Figure A2- 1 Qualitative use of the weather radar data - pattern recognition

Effective Doppler Range for Mesocyclone (small meso-gamma scale) Detection: Analysis of the output of the automatic mesocyclone algorithm of the URP indicated a sharp drop off in the number of detections of rotational shear features beyond 60 km. This has prompted the notion that there is no point in having Doppler beyond 60km and that the forecaster's request for greater range coverage is not warranted. However, these statistics need to be taken in the context of the algorithm philosophy (high POD), the thresholds, the beam width, the quality of the velocity data, the increased smoothing of data with increasing range and validity of the detections versus actual mesocyclones observed in the data. The detection thresholds are tuned to detect every rotational shear feature (no matter how weak), and the high number of detections close to the radar is due to lack of beam smoothing resulting in greater apparent shear in the velocity field particularly in convective situations. Figure A2-2 is a clear example of a mesocyclone signature in a severe storm at ranges greater than 256 km distance from the radar (red arrows) with a 1^{o} beam radar.

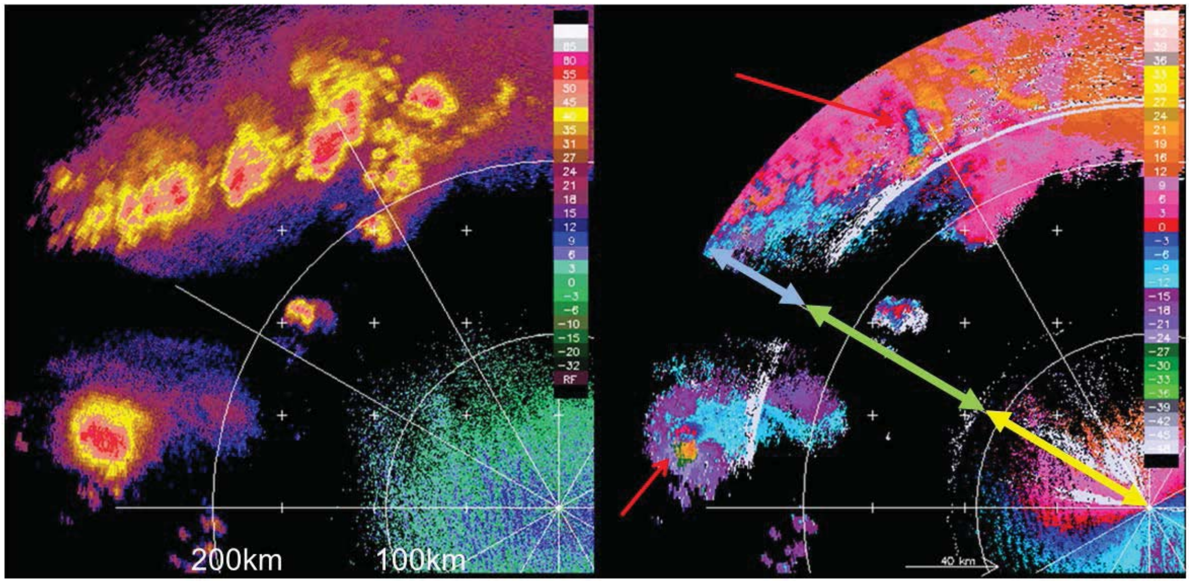

Figure A2- 2 An example of the qualitative use of Doppler radar for understanding and diagnosis of tornadic storms. This example shows the utility at long range (>126km). The red arrows point to two mesocyclone rotational signatures located at a range of more than 256km. The south-most signature shows velocity aliasing but it can still be accurately identified. This is also an example of Doppler velocity range extension using phase coding where the technique is applied to retrieve the 2nd and 3rd trip echoes. The example is from the KDMX S-Band WSR88D radar for 16 June 2014 at 2120Z.

Use of Doppler for Large Meso-Gamma Scale Convective Feature: Figure A2-3 is another example of "book end" vortices showing large meso-gamma to small meso-beta scale rotation (~20-50 km) in a squall line. This is associated with regions of large scale vorticity with enhanced lift and indicative of straight line severe winds at the leading edge of the squall line (at the bow of the echo). The data in this case is beyond 126km and within the second trip. The greyed out area is the first trip echo. This is an example of radial velocity recovered using the random phase range extension technique in the second trip.

This example also shows radial velocity that is aliased where the Nyquist velocity is 16 m/s. Velocities greater than +/- 16 m/s are aliased or folded back into the interval of +/- 16 m/s or the first trip.

Aside: Random phase has been considered a "prototype" in the operational suite of products. It has benefits of cleaning up the first trip (i.e., removes noise from the first trip echo due to the overlaying of the second trip echo). Random phase is used in all Doppler scans, but the second trip echoes are not always recorded due to the prototype nature and also due to bandwidth and data file considerations in the past. Random phase is used on magnetron radars where successive pulses are transmitted with phases that are randomly created. On klystron radars, the phases are the same and the equivalent technique requires adding a pseudo-random phase or applying a phase modulation to achieve this second trip recovery.

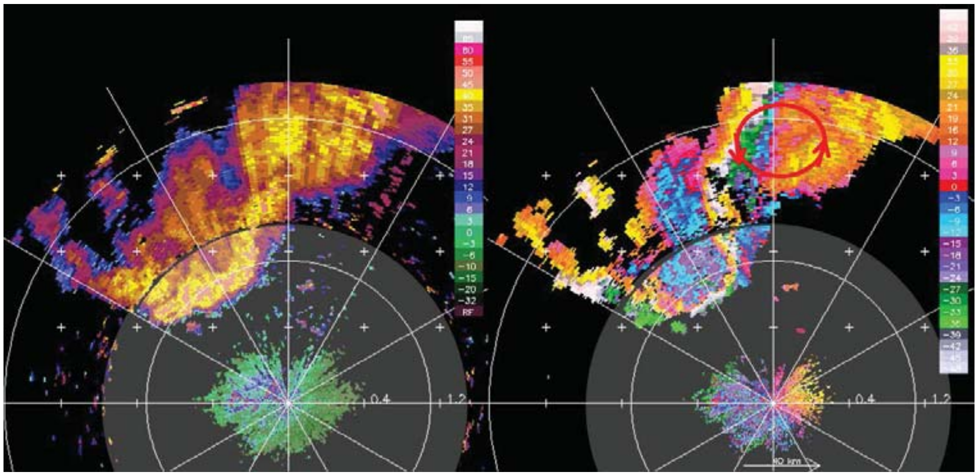

Figure A2- 3 Qualitative use of the weather radar data - coverage range matters. The shaded transparent part of the image is the 1st trip echo out to 126km and the clear area is 2nd trip echo retrieved with the random phase technique (a "good" example). This is to demonstrate the efficacy and need of Doppler data at ranges greater than the natural Nyquist range of a C-Band radar (>126km).

A Nyquist of 32 m/s is sufficient: There were questions regarding the minimum velocity that was required. Many of the Volume Coverage Patterns (VCPs) of NexRAD and of McGill (S-Band radars) use a Nyquist of 32m/s. Figure A2-4 is an image showing a EC radar with an extended Nyquist of 48 m/s (using the dual-PRF technique) and measured radial velocity values of near 48 m/s. While it is not common, it is also not uncommon to have velocities exceeding the extended Nyquist velocity where velocities greater than 55 m/s have been observed. Experience has shown that these high wind features are embedded in wide spread radar echoes and spatial continuity techniques may be used to extend the velocity range - i.e. extended Nyquist velocities of 32 m/s may be satisfactory for C-Band radars though this has not been demonstrated.

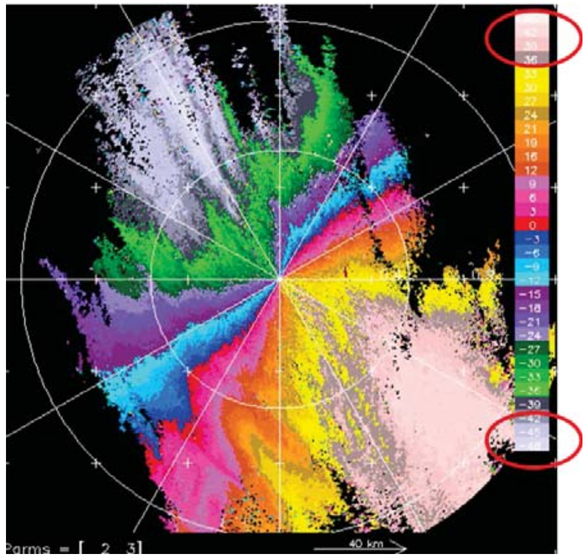

Figure A2- 4 Qualitative use of the weather radar data - Radial winds are greater than 45 m/s in Hurricane Igor

2. QUANTITATIVE FUTURE USE OF RADAR DATA

Quantitative use of radar data in NWP and hydrological applications relies on the accuracy and precision of radar observations. . Quantitative use of weather radar data reduces to relationships, such as that between radar versus gauge derived precipitation amounts. Outliers pose considerable problems in curve fitting of the results whereas these outliers can be easily filtered with the eye, it is not so easy to deal with on a quantitative basis (Figure A2-5). Good quality wind data upstream of critical areas and within 100 km of radar is essential for data assimilation; good quality reflectivity data (attenuation compensated) is essential for rainfall estimation.

Radar data is notorious for artifacts. Figure A2-6 illustrates the physical targets in the atmosphere and propagation issues that impact the quality of the weather radar data. These artifacts are external to the radar. Compensation requires considerable processing to ameliorate and the scientific community is still debating the best approaches. This and other issues have limited the use of radar for quantitative application. Despite this, expensive radar networks have still been funded.

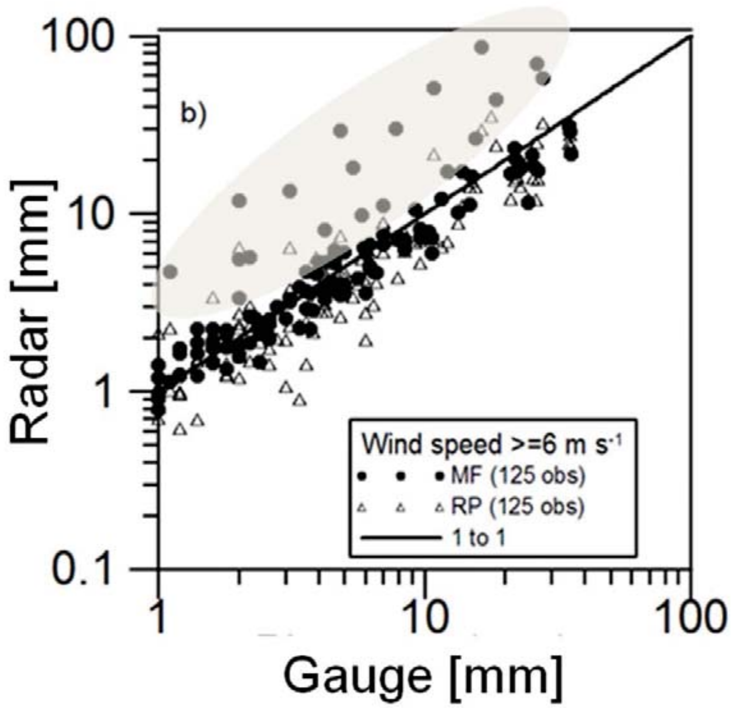

Figure A2- 5 Quantitative use of the weather radar data - radar/gauge relationship

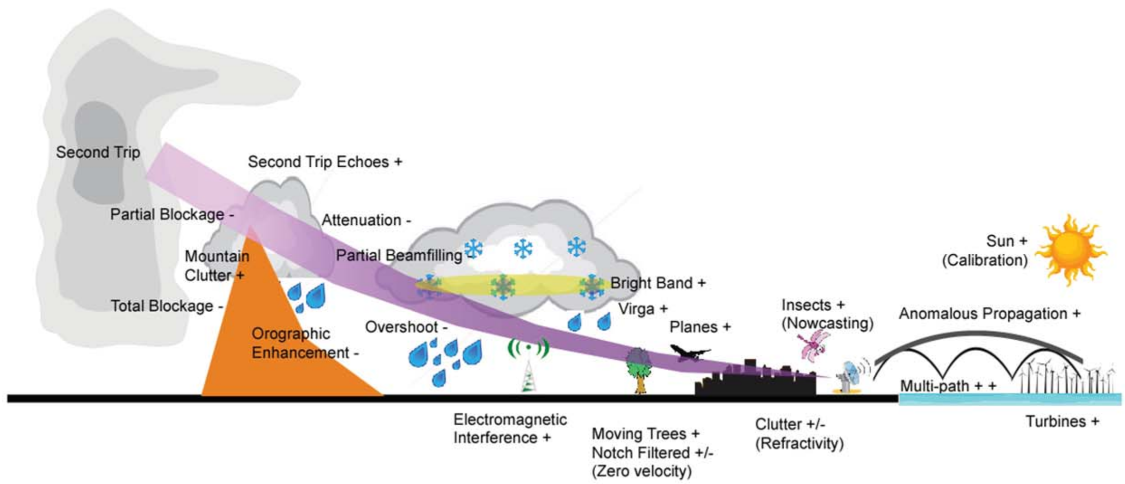

Figure A2- 6 Physical artifacts affecting radar data. These artifacts need to be corrected for use in quantitative precipitation applications.

3. OPERATIONAL SUSTAINABILITY REQUIREMENTS

The monitoring renewal project will address key issues with EC's foundational monitoring infrastructure, its long-term sustainability; one of requirements is to maintain the network in a cost-efficient way. This must be balanced with the user requirements and needs and a cost-benefit analysis is extremely difficult.

Technological ideas on how to reduce operating and maintenance cost revolve around more robust equipment, redundant components, better information, better depot and sparing management which the result of fewer maintenance issues and visits at the expense of greater initial capital costs.

Solid State Transmitters: While solid state technology is relatively new and unfamiliar to EC engineers, and there may still be growing or transition issues, it has been claimed/demonstrated elsewhere that it reduces maintenance issues. The only way to overcome the unfamiliarity (i.e., lack of experience or "ignorance" issue) is (i) invest sooner rather than later, or, (ii) to collaborate with the manufacturer or other National Hydrological and Meteorological Services (NHMS) to gain experience.

This technology will precipitate other technologies such as pulse compression (PC) to overcome the low powers. PC wave forms suffer from range side lobes but appear to have been mitigated in current radar systems. This was a concern in the past.

This has the promise of low maintenance (SST do not degrade over time) reducing visits (routine or emergency), redundancy (failure of the power modules are not critical) reducing over-time and emergency visits and high data quality.

Built-In Test Equipment: Built-in Test Equipment (BITE) is now common in commercial systems (not currently in EC). This allows off-site monitoring of the hardware, allow pro-active remedies and therefore higher quality and reliability of the data and reduce the number of visits significantly (e.g., from 6 to 2 visits per year).Off-site calibration may be implemented which will also improve the quality and reliability of the data.

4. LONGER TERM CONSIDERATIONS

Wind Farm Mitigation/Arctic Environments: Mitigation of wind farms, that cause broad areas of data quality issues, need for low level detection in critical areas and to meet potential detection requirements in Arctic environments, investments need to be made in low maintenance, low infrastructure and low cost X-Band or Ka Band radars.

Phase Array Radars: Figure A2-7 shows a traditional parabolic dish antenna (left) and a flat panel, phased array antenna (right) X-Band radar systems. The latter are just now commercially available but have lower performance (in terms of sensitivity) but may be most suitable for harsh Arctic environments - i.e. no moving parts - if the sensitivity issues can be resolved.

Figure A2- 7 Example of X-Band radars

It is conceivable that the flat panels may be feasible to be deployed in networks to retrieve 2D wind maps, something that was not conceived of a few years ago.

5. TECHNOLOGY CONSIDERATIONS

The solutions for the CWRN under consideration are:

- All C-Band network
- All S-Band network
- Mixed network of C-Band and S-Band
- Future inclusion of X-Band (targeted) – data assimilation (2D winds), implementation tool, gap filling, and terrain-driven

Table A2-1 presents a rough comparison of the general specifications of the three commonly used weather radar systems.

Table A2- 1 Comparison of the 3 most frequently used types of weather radar systems (modified from WMO report, 2009)

	S-Band	C-Band	X-Band
FREQUENCY	2-4 GHz	4-8 GHz	8-12 GHz
WAVE LENGTH	15-7.5 cm	7.5-3.8 cm	3.8-2.5 cm
TYPICAL RANGE	300-500 km	120-240 km	50-100 km
PEAK POWER	500 kW-1MW	250-500 kW	50-200 kW
BEAMWIDTH	1.0°	0.65°°	1.0°-2.6°
ANTENNA SIZE	8.5 m	6.1 m	1.8-2.5 m
MEASURING SENSITIVITY	Rain, snow, hail (The bigger particles as compared to C-Band)	Rain, snow, hail, drizzle (The bigger particles as compared to X-Band)	Rain, snow, hail, light drizzle (The smaller particles as compared to S-Band and C-Band)
ATMOSPHERIC ATTENUATION	Less attenuation as compared to C-Band and X-Band	Less attenuation as compared to X-Band while 4 times attenuation as compared to S-Band	Much attenuation as compared to C-Band and S-Band
ACQUISITION COST	~1.3x C-Band	1.0x C-Band	~0.7x C-Band

5.1 SENSITIVITY OF REPRESENTATIVE C AND S-BAND RADARS

It has often been stated that the smaller wavelength radars have a sensitivity advantage over the longer wavelength radars. This is a result of the wavelength factor being in the denominator of the radar equation shown below. Hence, they have been promoted as better detectors of drizzle, snow, insects, clear air and other low back scattering targets – if all the other parameters are the same. However, from a pragmatic perspective, they are not the same as there are transmit power differences (P_t), pulse length differences (τ) and averaging differences (radar equation is for one pulse). Often, C-Band radars transmit pulses with 250KW peak power and S-Band radars with 1 MW peak power and the wavelength advantage disappears. Pulse length, system losses, noise level and processing are therefore the biggest influence on sensitivity.

$$\overline{P}_r = \frac{c\pi^3}{1024\ln(2)}\left(\frac{P_t\tau G^2\Theta\Phi}{\lambda^2}\right)\left(\frac{|K|^2 Z}{r^2}\right)$$

The standard radar equation relates the power received to radar and target parameters. Waveguide and other losses are multiplicative factors and are not shown.

In the following table (A2-2), sensitivity is reported as the minimum recorded/detectable signal at 50 km range. The table shows the sensitivity of some typical S-Band and one high quality C-Band radar.

Table A2- 2 Sensitivity of C vs S-band Radars

Radar	MDS at 50 km
Z9110	-8.0 dBZ (few days in August) -10dBZ (2 months)
Z9220	-1.0 dBZ
King City CONVOL (2 us)	-11.0 dBZ
King City DOPVOL (0.5 us)	-5.0 dBZ
Twin Lakes, OK	-7.5 dBZ
Lake Charles, LA	-8.5 dBZ

C Band

5.2 THEORETICAL ATTENUATION AS A FUNCTION OF WAVELENGTH

Attenuation of the radar signal is a function of the target and of the radar wavelength (see Figure A2-8). All wavelengths are attenuated to different extents. At low reflectivities the attenuation is less than at high reflectivities. There are several questions (i) do the climatological (i.e. Canadian) distribution of reflectivities create significant attenuation and for what application, (ii) do the spatial distribution of reflectivities create significant attenuation, (iii) how often does total attenuation of the signal occur and have any warnings been missed as a result 9 (Figure A2-9).

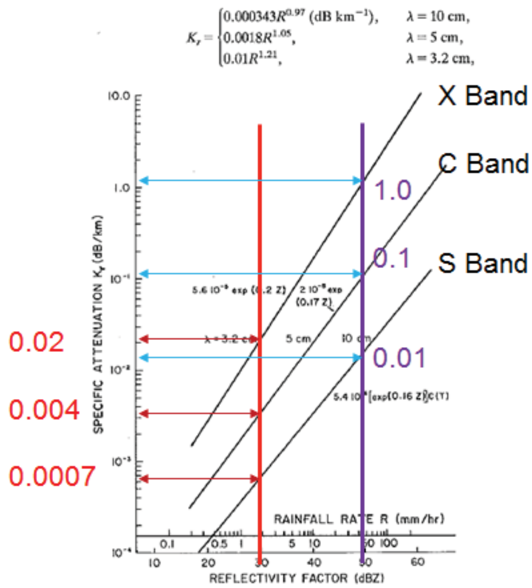

Figure A2- 8 Theoretical attenuation (dB/km) as a function of reflectivity and wavelength.

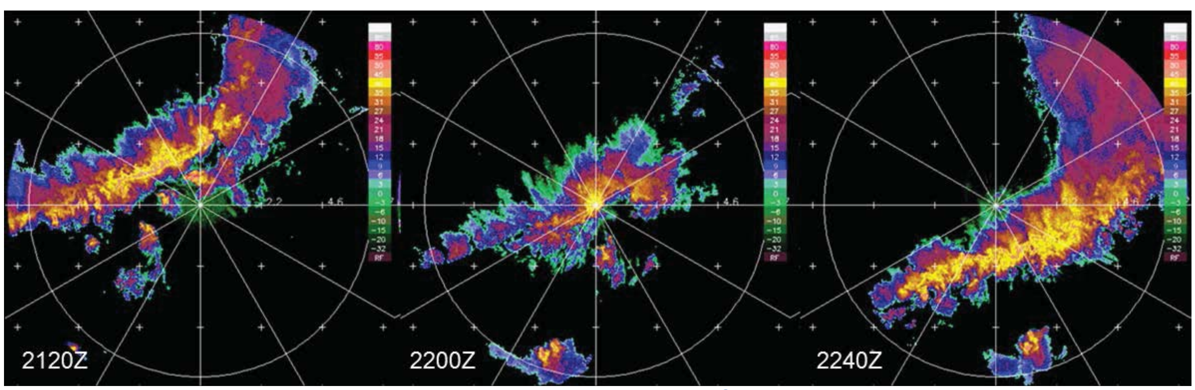

Figure A2- 9 This example from Jun 17 2014 shows three images (3.5° PPI) to illustrate attenuation at C-Band. Attenuation is evident along the squall line as the storm passes right over the radar. Total attenuation at ranges > 50 km occurs in the 300° to 60° azimuth line at 2200Z. (range ring is 100 km and the markers are at every 40km).

5.3 DOPPLER RANGE

There is a trade-off between the maximum first trip range and the Nyquist interval. Requirements for range-velocity within a radar network impact on the wavelength chosen. In order to increase the unambiguous range and accurately measure the Doppler velocity of meteorological targets, the pulse repetition frequency (PRF) must be high enough (smaller time interval between pulses) such that the maximum unambiguous range is reduced from that of a radar measuring reflectivity only. At higher speeds, additional processing steps are required to retrieve the correct velocity.

Figure A2-10 illustrates the "Doppler Dilemma" for the three common radar bands (X, C, and S). The dilemma arises because one parameter, the pulse repetition frequency which is the time between transmitted pulses, controls both the maximum unambiguous velocity and maximum unambiguous range in opposite ways. The markers and red lines indicate commonly used settings. The most robust of the velocity-range extension techniques is to use dual-PRF on an S-Band radar using 16 and 12 m/s unambiguous Nyquist intervals which will extend the maximum range to 230km.

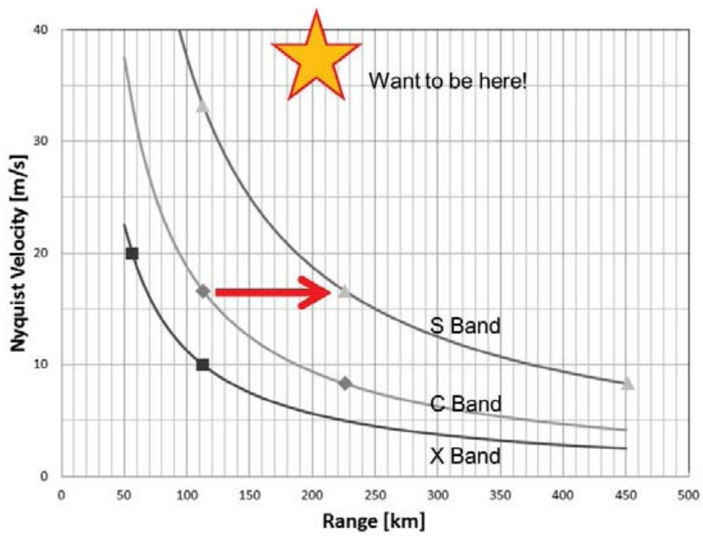

Figure A2- 10 Doppler Range - Velocity trade-off with common radar wavelengths

The maximum Doppler range is directly proportional to the wavelength. For example, given the same Nyquist velocity, an S-Band will have twice the Nyquist range compared to a C-Band radar. For the same range, a S-Band radar will have twice the Nyquist velocity as a C-Band radar. This is expressed in the following equation:

$$V_{max} R_{max} = c \lambda / 8$$

There have been different attempts to extend both the maximum velocity and the maximum range. To extend the velocity range, the dual-PRF technique is commonly used and can extend the Nyquist velocity by 2, 3 or 4 times before succumbing to the variance in the velocity data. That is, the Dual-PRF technique can result in additional noisy velocities in areas of high shear but if the technique is properly implemented, they can be mitigated as the errors are discrete at integer differences at the Nyquist interval.

However, the other issue in high shear areas is that the estimates of the mean velocity will be noisier (have greater variance) and this will ultimately limit how much the velocity can be effectively extended.

Continuity techniques, to extend the velocity, rely too much on the distribution of the precipitation echoes and the velocity patterns.

5.4 RANGE EXTENSION

Depending on the configuration of a Doppler radar, extending the range of the data is more difficult than extending the velocity because the data may be mutually contaminated. That is, the echo from a target within the first (second) trip may arrive at the same time as the echo from a target from the second (first) trip. The first trip is defined as the echo arriving from the most recently transmitted pulse and the second trip is defined as the echo arriving from the previous pulse. This could continue to third or fourth trips depending on the radar setup.

With conventional reflectivity-only radars, the pulses a transmitted far enough apart (PRF ~= 250 s^{-1}) so that the second trip is beyond where radar echoes exist (~20 km altitude) due the Earth's curvature.

The NexRAD techniques to extend the range involve using multiple PRF data. The reflectivity pattern from a low PRF scan (surveillance) is unambiguous and is used to locate the echo. High PRF data which is ambiguous is used to assign a velocity to the echo. The velocity is assigned to the echo with the highest returned power (not reflectivity which is range normalized, that is, there is an inverse square relationship with range). If there are overlaid echoes, the velocity is assigned to the location with the highest power above a threshold (typically 5 dB). If this condition is not met then both locations are quality controlled to indicate "range folded velocity" and a "no data" flag is assigned to both locations. Triple PRF techniques have been developed by the Japanese and the French to have another combination to resolve this ambiguity. Typically, the data is taken at the same elevation angle and taking data in such a fashion increases the time it takes to scan the atmosphere.

Continuity techniques in the vertical (increasing elevation angle) with the same or different PRF's have also been suggested and implemented in some radars (McGill). Wind shear in the vertical is generally greater than in the horizontal and EC has little experience with this scheme.

Phase coding concepts have been developed to recover first and second trip echoes using a single sweep or PRF of data. Phase coding essentially "tags" each pulse by the transmit phase by a random phase or pseudo-random. Statistically processing several echoes for velocity with respect to the current and previous transmit phases essentially results in creating a distribution of clustered velocities whose mean is the velocity of the first or of the second trip, respectively. This technique relies on there being enough power returned from the second trip echo. In the case of overlaid echoes, enough power means that the weaker second trip echo power (since it is farther away) is above the power noise level and the phase noise level. Typically, for magnetron and klystron radars, the powers must be within 40 or 60 dB of each other to retrieve both echoes. If there is moderate or strong echo right around the radar, the second trip will not be retrievable. Note that the first trip is always retrievable unlike the multiple PRF technique described previously. There is an advantage that the noise in the first trip echo due to that of the second will be removed and the quality of the first trip power and velocity will be better. The better the phase noise, the better the ability to retrieve the second trip echo. This is a rare situation in radar where there is no trade off except in terms of processing power and complexity.

The critical question is whether it is good enough even with klystron radars with very low phase noise. For improved data quality, this should be implemented. However, there are many occasions where the second trip is not recovered and this is dependent on the weather, the radar siting and the data quality. Despite this progress, it is still preferred not to use phase coding for second trip recovery but it should also be a requirement as well (Figure A2-11).

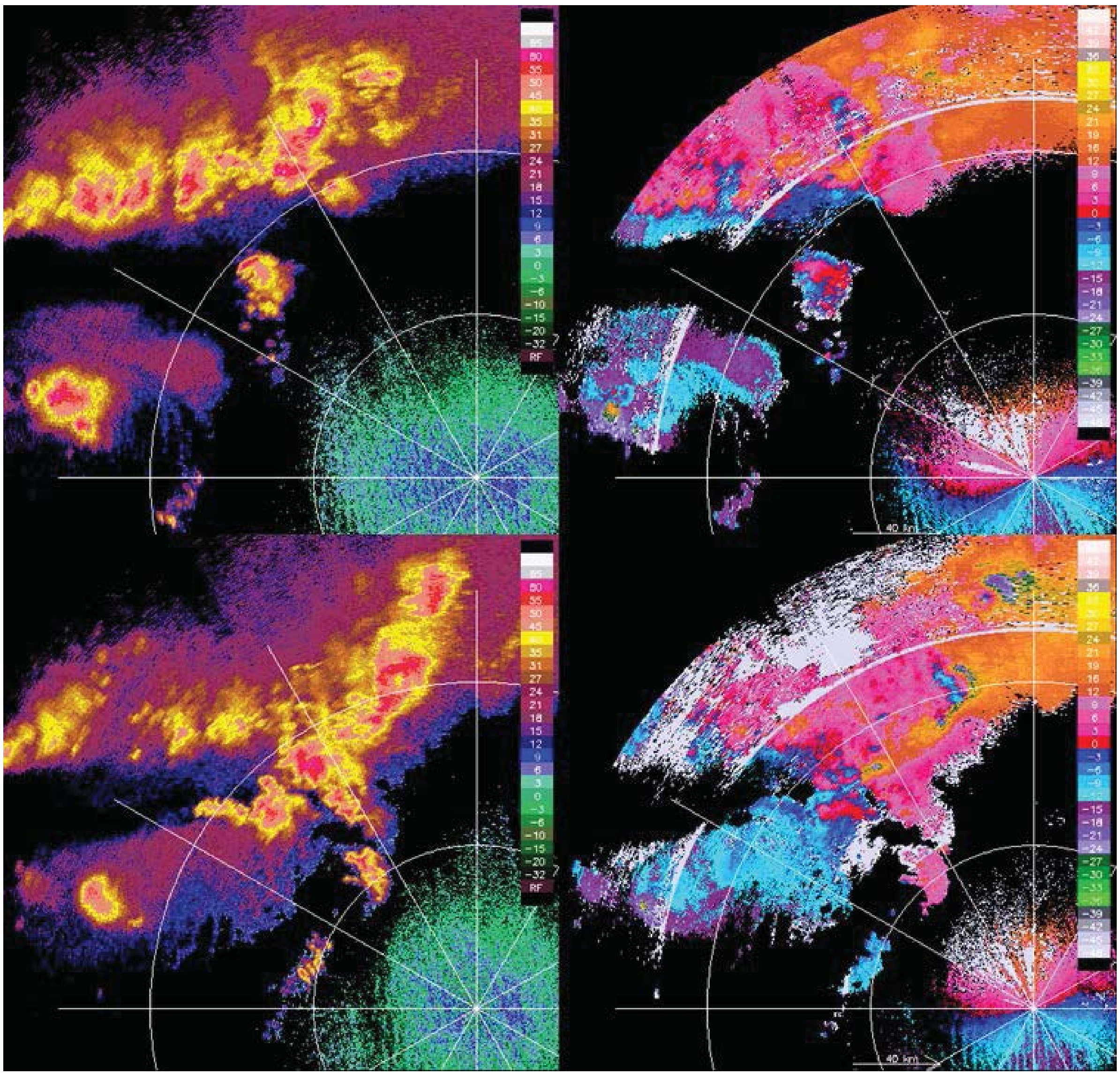

Figure A2- 11 an example of retrieval capability of phase coding. The top figure shows that the echoes in the first three trips are mostly recovered. The white in the radial velocity figures on the right indicate where the technique fails. In many case, the technique is successful but depends on the relative location and strength of the overlaid echoes.

5.5 SOLVING THE DOPPLER DILEMMA

Given the discussion, the following is suggested for solving the range-velocity trade-off. Figure A2-12 shows the trade space. The target is the upper right hand corner of the diagram where we have large velocity (50 m/s) and large range (250 km).

The starting points for the discussion are the points marked with the subscript "o" in the Figure A2-12. They represent the "natural" first trip limits for velocity and range for C and S-Band radars as shown in Figure A2-11.

The solid lines represent velocity extension using the dual-PRF (or the dual-PRT) technique (without specifying the details). As described above, they are considered robust and hence the solid lines. The thin arced lines (solid and dashed) indicate range extension using phase coding techniques and work well in certain conditions but not in all, as described above. The thin vertical lines apply the continuity technique to retrieve even higher velocities. This uses a pragmatic observation and assumes that the high velocities are observed with significant wind fields only observed in wide spread precipitation as shown in Figure A2-8

The purpose of Figure A2-12 is to graphically indicate the current state of the art techniques to achieve velocity and range extension. The thickness of the lines indicates comfort or confidence, or alternatively risk, level in a qualitative way. The dashed line indicates that while theoretically possible, the technique has not actually been demonstrated and some development needs to be done to achieve.

"If" Doppler range of 180km or more is the driving requirement, then ignoring all other requirements and factors, the figure indicates that S-Band radars can achieve this with less technological risk. This is a result of the spacing within the CWRN network. If the radars were spaced at 220-250 km instead of 300-350 km range then the range requirements are significantly relaxed! However, this requires a higher density of C-Band radars.

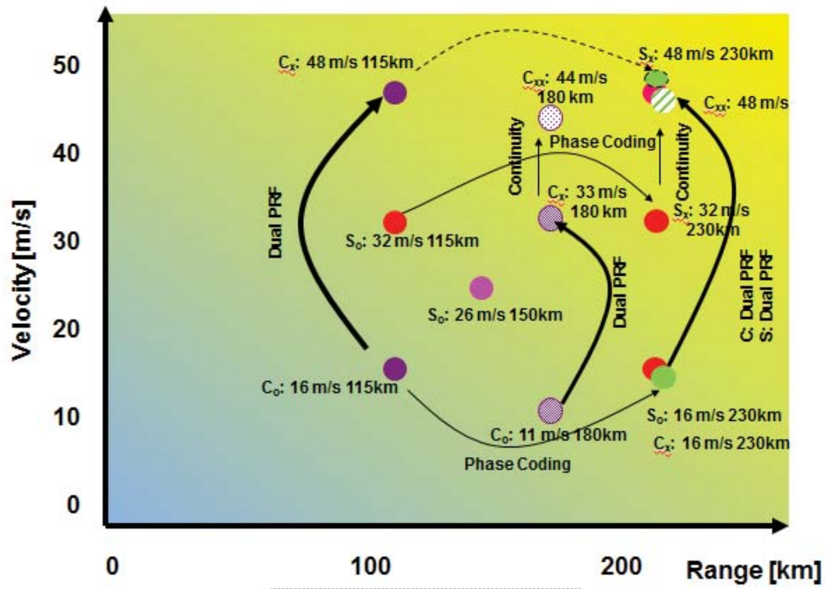

Figure A2- 12 Solving the Doppler dilemma. See text for details.

5.6 SPIN RATES AND SAMPLING REQUIREMENTS

The user requirements usually state the need to scan the three-dimensional space with as much resolution as possible and with a repeat cycle as fast as possible. All the radar trade-offs discussed result in a scan strategy that is a compromise of many factors. Many have already been discussed. The rotation rate is largely governed by the user requirements, the required range and azimuthal resolution, the tolerable data quality (variance in parameter estimates) and Doppler clutter rejection applied.

Conventional radars require about 30 uncorrelated or independent samples for estimate of reflectivity. Fast scanning (6 rpm) with good quality reflectivity data (~< 1 dB in variance) is achieved by transmitting a pulse (~1 microsecond pulse width or ~250m range resolution), sampling at low PRF (250 s^{-1}), range (4 samples in range or ~1 km range resolution) and azimuthal (7 samples in azimuth or ~1^{o} degree resolution) averaging of the data samples (28 samples in this case).

It should be noted that the range and azimuthal resolution are determined by the user requirements. There are radar systems recording less than 1^{o} resolution data for example (400, 600 or 720 azimuths in 360^{o}).

However, Doppler processing requires correlated samples from pulse to pulse. Correlated samples are achieved through higher PRF (equivalently smaller sampling between pulses) but also with no range averaging (since range bins are uncorrelated). This condition is achieved if the variance in the velocity (σ_v) is small compared to the Nyquist velocity as shown in the following equation. The typical variance is of the order of 2-4 m/s and less in snow. So this is not generally an issue except in high shear regions. In tornadic situations, the variance is very high and affects the quality of both C and S-Band radars.

$$\lambda/2T_s >> \sigma_v$$

Another critical factor determining sampling and rotation rate is the use of Doppler filtering to remove the ground clutter. This is one of the most significant benefits of the Doppler processing. The number of samples determines the resolution of the velocity estimate. For example, with a Nyquist velocity of 16 m/s equivalent to a Nyquist interval of 32 m/s and 64 samples, the resolution is 0.5 m/s. The resolution increases with more samples. The sampling resolution needs to match that of the ground clutter signal and the clutter filter. This is also determined by the antenna rotation rate and the nature of the clutter.

5.7 MIE SCATTERING/RESONANCE AT C-BAND

The boundary between Rayleigh and Mie scattering is around 3 mm for C-Band radars. Theoretical scattering computations indicate a resonance in polarimetric variables and are illustrated by Figure A2-13. This effect occurs with other polarimetric variables as well. This effect has been used to indicate the problem of polarimetric C-Band radar. However, in the Canadian climate 6 mm drops are quite uncommon. Also, if 6 mm drops occur, they are likely associated with the "bright band" radar artifact as well and so pragmatically, are not likely to be a significant issue. Another situation in which 6 mm particles may exist is with small hail and optimistically, one could use the "enhanced signature" to interpret the presence of 6 mm particles or hail in convective storms.

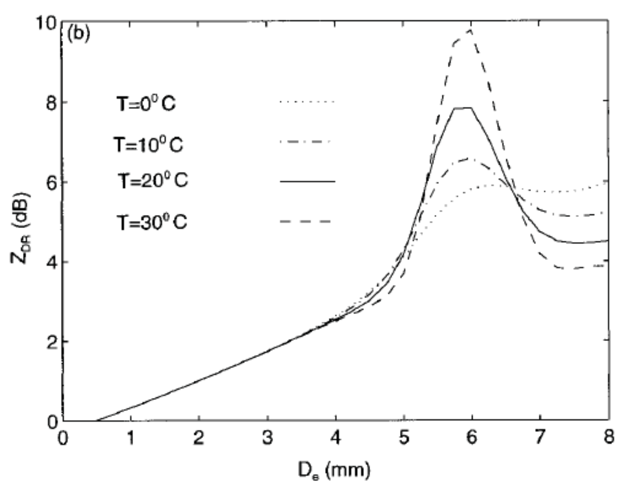

Figure A2- 13 Theoretical differential reflectivity (ZDR) as a function of drop size for a C-Band radar.

5.8 BEAM WIDTH

Narrow beam width is important to collect finer spatial resolution and more precise data. It is also possible to scan lower, isolate point clutter and be beam filled to longer ranges. It also results in greater sensitivity without increasing the transmitter peak power, pulse width or longer sampling. Regions with frequent low level or shallow precipitation should consider radar with a narrower beam width. Figure A2-14 shows the beam pattern of a 1° and 0.6° beam width radar located a 0 and 300 km range, respectively. This is approximately equal to the radar spacing in the Canadian Radar Network. The blue shaded band represents shallow weather such as snow squalls that occur often in the lee of lakes. If we assume that the radars have sufficient and equal sensitivity to detect the weather if the beam is filled, the figure indicates that a 0.6° beam width radar will be able to have the beam fully filled about 20 km farther than a 1° beam width radar. In the region, where the beam is not completely filled, the radar will still be able to detect the weather but the reflectivity values will be diminished. Eventually the beam will not see the shallow weather due to Earth curvature. Weather radars with greater sensitivity will be able to detect the weather with partially filled beams and hence detect the shallow weather to greater ranges.

So the impact of the narrow beam is many-fold: higher data quality, ability to scan lower, beam filled farther for greater range for QPE, and detect farther due to greater sensitivity. This is arguably the greatest benefit of the 0.65° beam width radar. These benefits addresses some of the key issues in the CWRN as radars are spaced far apart (compared to 200 km in many European countries), have shallow weather and have low reflectivity weather. This has been used uniquely in Canada (98A radars) and available at C-Band. This beam width is not viable for S-Band radars as the antenna would be 12 m in diameter with an even larger radome.

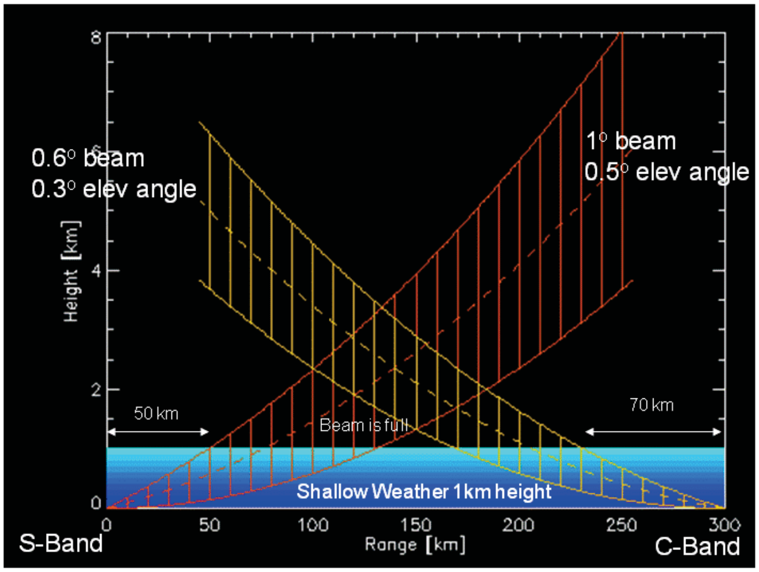

Figure A2 - 14 Beam width is important for lower to the ground detection for shallow weather.

5.9 DUAL-POLARIZATION

Current generation of radar transmit horizontally polarized waves. Dual-polarization radars provide the addition of vertically polarized waves. While explored for many years, it is only

relatively recently that the benefits have been demonstrated and the technology available to deploy in an operational environment. The break-through technology was the development of simultaneous transmit and receive (STAR) of the electro-magnetic wave. This design eliminated the need for a fast high-power switch (operating every millisecond) that was prone to failure. It also significantly reduced the capital costs.
The research at the King City radar has demonstrated the value of dual-polarization capability. The scientific merit in a Canadian and EC context was accepted and approved by the Technology Transfer Advisory Committee (TTAC). The benefits included improved data quality, particle classification ability and improved quantitative precipitation estimation. Current state of the art radars have this capability.

Figure A2-15 shows a diagram of the nature of the polarization parameters. The dual-polarization parameters are sensitive to the size and shape of the large particles and the smaller the wavelength, the more sensitive the radar.

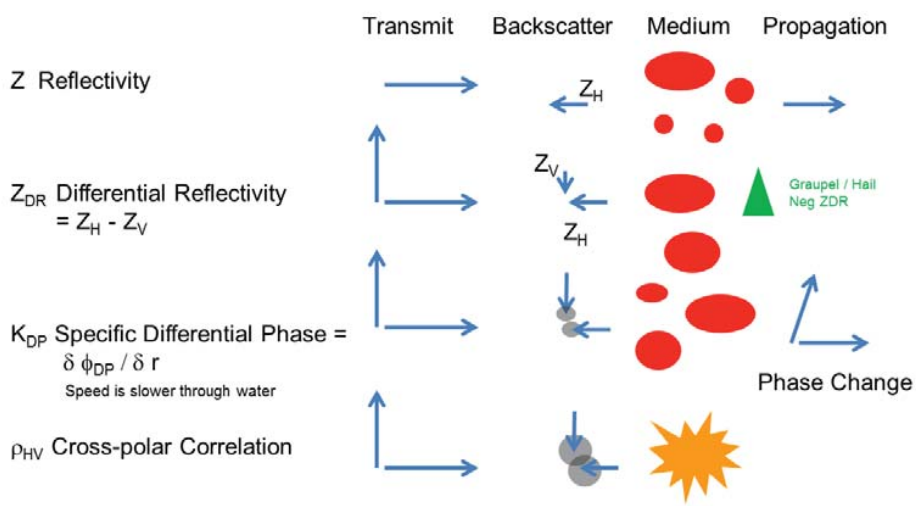

Figure A2- 15 Dual-Polarization Parameters. Some parameters are related to backscatter from the target (Z, Z_{DR}), some are dependent on the propagation path (ϕ_{DP}) and some are independent (K_{DP}) of the system calibration and attenuation and some are affected by the non-uniformity of the particle distribution (ρ_{HV}).

5.10 ATTENUATION, QPE AND DUAL-POLARISATION

Attenuation is dependent on various factors: the size and mass of the target and the type of target. Snow, ice particles or hailstones can grow much larger than raindrops. They become wet as they begin to melt and result in a large increase in reflectivity, and therefore, in attenuation properties. This can distort precipitation estimates.

C-Band attenuation is 4 times that of S-Band. For heavy rainfall and hail, attenuation and Mie scattering (see previous resonance discussion) become a critical issue for C-Band radars. However, Dual-polarization radars can overcome attenuation, partial beam filling and partially blocked beams.

In the example shown on Figure A2-16, a precipitation system that caused localized flooding was observed by a C-Band and an S-Band radar. The C-Band (King City with a 0.65° beam) was about 40km away from the flooding, and the S-Band (Buffalo with a 1° beam) was about 100 km away. Figure A2-16 (a) and (b) show one instance of the low level radar reflectivity from both radars. The red grid lines indicate the location of a rain gauge (next figure). The C-Band radar data is attenuated compared to the S-Band data (that is, the image b is more intense than image a). During the event, the C-Band radar also experienced a wet radome which strongly attenuates the signal. Figure A2-16 (c) and (d) are accumulations based on their respective dual-polarization derived precipitation products from over the 8 hour period of the event (see Figure A2-17). The resolution difference is evident but the accumulation patterns are very similar.

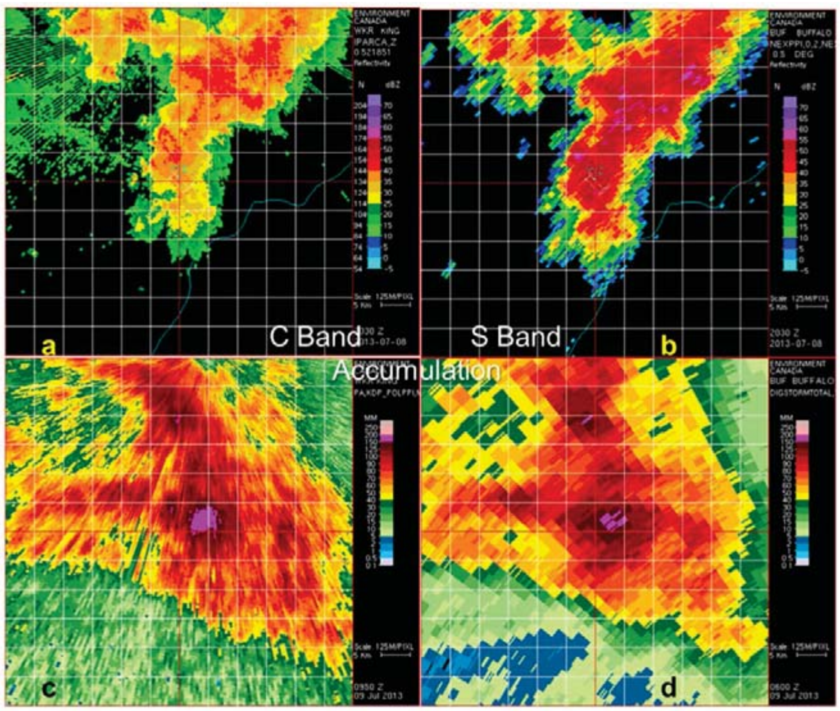

Figure A2- 13 An example of S vs. C for July 8 2013 Toronto flooding case. Figure courtesy of Sudesh Boodoo of Environment Canada.

Figure A2-17 shows a meteogram of accumulated rain from a gauge (yellow line with symbols) as well as three C-Band (C1, C2, C3) and two S-Band (S1, S2) estimates of the precipitation accumulation from the previous figures (at the intersection of the red grid lines). The bottom (C1) and top (S1) lines are accumulations based on traditional and simple reflectivity converted to rain rate (Z=300 R^1.4) from the King City C-Band (40 km from gauge site) and the Buffalo S-Band (100 km from gauge site) radars. Both radars are well calibrated and only Doppler ground clutter rejection has been applied to the data. The Z_{AC}-R line (C2) is a ZDR-only attenuation corrected reflectivity converted to rain rate and accumulated. The dashed (S2) and dark blue (C3) lines are the precipitation estimates using a mix of dual-pol techniques from the S-Band radar (S2) and from the K_{DP}-R technique from the C-Band radar (C3), respectively. The improved Buffalo S- Band results are attributed to removing the hail bias using the dual-pol particle classification technique. Hail was reported in this storm at the Toronto airport.

The K_{DP} technique, which is insensitive to attenuation, partial beam blockage and partial beam filling, improves the King City C-Band estimates. This illustrates the potential impact of dual-polarization on the quantitative use of both S and C-Band radars in this one example. It remains to be demonstrated that these results can be generalized to an operational situation all across Canada. It also illustrates the larger impact of dual-polarization on C-Band radars than S-Band radars.

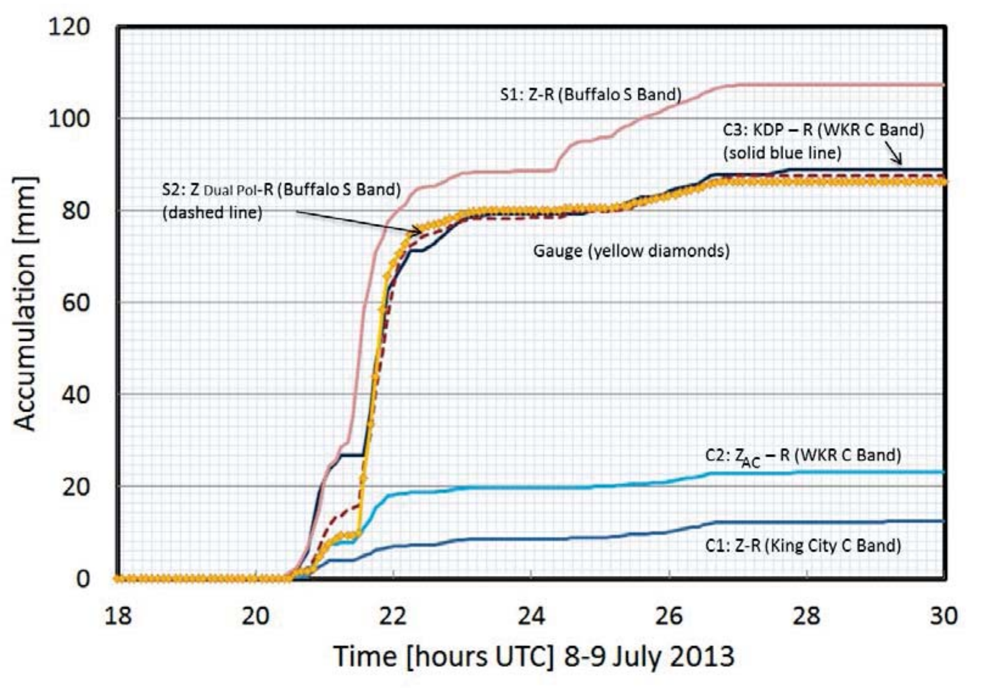

Figure A2- 17 A meteogram of accumulated rain from a gauge (yellow line with symbols) and three C-Band (C1, C2, C3) and two S-Band (S1, S2) estimates of the precipitation accumulation from Figure A2-16 (at the intersection of the red grid lines).

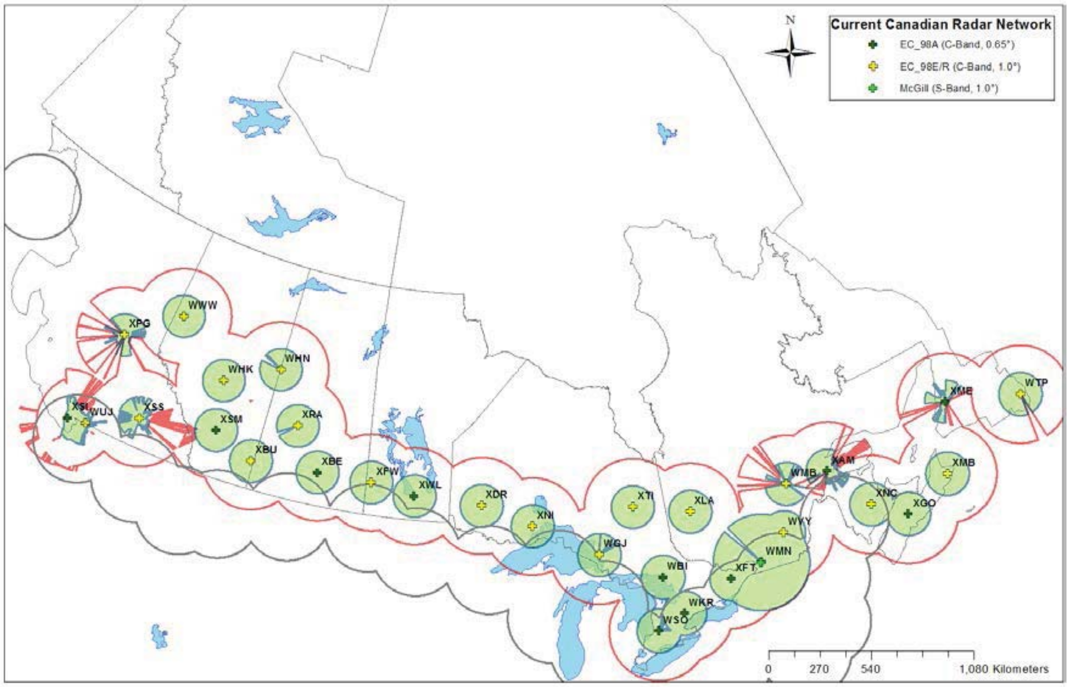

Figure A2- 14 Current Canadian Weather Radar Network (CWRN). The EC radars currently have a Doppler Range of 126km.

Annex B – Industry Engagement Process

1. Industry Engagement

The Industry Engagement Process (“Process”) begins with the initial Letter of Intent (LoI) and concludes when an official Request for Proposal (RFP) or other competitive process is published on the Government Electronic Tendering Service (GETS), or when the Government of Canada (GC) advises Participants that the Process has concluded. The Process may involve the following activities:

1. Letter of Intent (LOI)
2. Industry Day (Web Conference Meeting)
3. One-On-One meetings with individual suppliers
4. Draft Request for Proposal (draft RFP) including a Statement of Work (SOW)

Participation in the Process will be strictly reserved to registered individuals who sign and submit, to the PWGSC Contracting Authority named herein, the ***Engagement Rules (Mandatory Form), provided in this Annex D.***

Phase 1 - Initial Contact with Industry - Letter of Intent (LoI)

This LOI is posted on GETS to seek interest from companies in participating in the Process. It will be the chance for Industry to share with PWGSC, information on the current marketplace, available technology and supplier capabilities.

Phase 2 - Industry Day Session

The purpose of the Industry Day (*Web Conference Meeting*) is to present Industry representatives with information about the Canadian Weather Radar Network, an overview of the current status, and its future objectives for the consultative process. The Industry Day session will only be set up as *Web Conference Meeting* due to the geographic distribution of different suppliers. It is intended to be an open forum allowing GC to communicate its requirements at a high level, and for Industry to ask questions and seek information in order to gain a sound understanding of the business needs of the GC.

Industry is invited to tell us what they would like to hear from us when they register to the Industry Day session. GC will do its best to reflect your requests in the agenda. Multiple Industry Day Sessions might be arranged based on the information acquired from Industry.

The proposed agenda for the Industry Day session will be:

1. Opening Remarks
2. Procurement Process – Engagement Approach
3. Strategic Overview of the National Radar Program
4. Next Steps
5. Questions/Answers Period

Material provided to attendees on Industry Day:

- Agenda

Material provided to attendees after Industry Day:

- Copies of presentation material (after presentation)

Phase 3 - One-on-One Industry Meetings

One-on-one meetings will take place subsequent to the Industry Day. It is anticipated that Industry participants will be requested to provide to the Contracting Authority identified short written answers (short paragraphs or bullet points) to an anticipated questionnaire that would be provided prior to the One-on-one meetings. Although the intent is to arrange an in-person meeting, GC will also arrange Web Conference or Teleconference meetings to accommodate the suppliers if required.

Phase 4 – Draft Request for Proposal (Draft RFP)

A draft RFP will be issued to Industry to further refine the requirement by addressing Industry concerns and considering Industry recommendations.

Phase 5 - Final Request for Proposal (Final RFP)

A final RFP will be issued to Industry. A standard Q & A process will be followed. As the Industry is actively consulted in the Process, fewer questions or concerns are expected.

2. Registration Process for Industry Day & One-on-One meetings

Interested suppliers are encouraged to register for the *Industry Day* and *One-on-One meetings* prior to **8 am EDT (Eastern Daylight Time) September 15, 2014,** by submitting, to the PWGSC Contracting Authority identified herein, a signed copy of *Annex D – Engagement Rules* for each individual that chooses to participate.

At the time of registration, Participating Suppliers may submit a first and second preferred dates and times for the one-on-one meeting, which the GC will do its best to accommodate. Industry representatives traveling from far distances will be given priority to have their One-on-One meeting held the earliest day possible during the period from September 23, 2014 to October 10, 2014. See *Annex C – Industry Day and One-on-One Meetings Schedule* for details. Participating Suppliers will be contacted by the GC representative, prior to the Industry Day, with:

1. Details for the Industry Day in the Ontario Region (Toronto, Ontario) or instructions regarding the Web Conference Meeting; and
2. The date, time and detail of their one-on-one meeting.

3. Information Prior to Industry Day

Suppliers may provide comments, questions or proposed topics for discussion for the Industry Day or one-on-one meetings by submitting their information to the Contracting Authority no later than **8 am EDT (Eastern Daylight Time) September 15, 2014.**

4. Notes to Interested Suppliers

This is not a bid solicitation and a contract will not result from this request.

Potential respondents are advised that any information submitted to GC in response to this *Process* may be used by GC in the development of a subsequent competitive RFP. However, GC is not bound to accept any Expression of Interest or to consider it further in any associated documents such as a RFP.

The issuance of this *Process* does not create an obligation for GC to issue a subsequent RFP, and does not bind GC legally or otherwise, to enter into any agreement or to accept any suggestions from organizations. GC reserves the right to accept or reject any or all comments received.

There will be no short listing of suppliers for purpose of undertaking any future work as a result of this *Process.* Similarly, participation in this *Process* is not a condition or prerequisite for participation in any

RFP(s). Industry representatives that do not participate in the Process or leave in the middle of the Process will remain eligible to submit a bid in response to any future RFP or other competitive process relating to this requirement.

Suppliers participating in this *Process* should identify any submitted information that is to be considered as either company confidential or proprietary.

Media cannot participate in the one-on-one meetings or any engagement sessions.

A third-party Fairness Monitor will participate in the entire Process.

All enquiries and other communications related to this *Process* shall be directed exclusively to the PWGSC Contracting Authority by email. Suppliers intending to be part of this Industry Engagement are asked to advise the Contracting Authority of their intention to participate, in order that they may receive notification of any changes to the notice which may occur during the posting period on GETS.

5. Communication with Industry

Canada will document all Industry concerns/issues, questions, suggestions, together with their responses. During the *Process*, the PWGSC Contracting Authority may choose to communicate with registered Industry participants through direct email rather than posting additional notices on Government Electronic Tendering Service. To ensure the fairness, transparency and integrity of the Process, PWGSC will share information resulting from the Process (excluding proprietary and/or confidential information) with the Industry.

6. PWGSC Contracting Authority

Long Pan
Supply Team Leader
Public Works and Government Services Canada
Acquisition – Ontario Region
Tel: (001) 905-615-2076
E-mail: long.pan@tpsgc-pwgsc.gc.ca

Annex C – Industry Day and One-on-One Meetings Schedule

Letter of Intent release: **August 7, 2014**
Registration Deadline: **8 am EDT (Eastern Daylight Time) September 15, 2014**
Industry Day: **September 18, 2014**
One-on-One meetings: **September 23, 2014 to October 10, 2014** (*business days only*).

GC appreciates your time to meet with us and to engage in this extensive process and we would like to provide you with enough time during your one-on-one meetings by offering you variable time slots between 8AM and 8PM Eastern Time on any business day between September 23, 2014 to October 10, 2014. GC will make its best effort to accommodate your needs based on dates and time availability with priority based on distance. A GC representative will contact you, prior to Industry Day, to confirm your schedule, the location of the meetings, to discuss any special requirements, confirm technical support available on site and help you with your planning.

Registration to the Industry Day and/or One-on-One meetings must be made through the Contract Authority Long Pan at long.pan@tpsgc-pwgsc.gc.ca and **MUST** include the following information:

- A signed copy of Annex D – Engagement Rules (Mandatory Form) must be provided by **8 am EDT (Eastern Daylight Time) September 15, 2014;**

- Your first and second option for dates and times for the One-on-One meeting(s);

- Number of people to attend the Industry Day and/or One-One meetings;

- Name and title of each participant;

- One main contact person's email and phone number;

<u>Note:</u>

The *Industry Day Web Conference Meeting – Agenda & Instructions* will be provided to the registered suppliers.

Annex D – Engagement Rules (Mandatory Form)

An overriding principle of the Industry Engagement Process (Process) is that it be conducted with the utmost fairness and equity between all parties. No one person or organization shall receive or be perceived to have received any unusual or unfair advantage over the others.

All Government of Canada (GC) documentation provided throughout the industry engagement process will be provided to all participants who have agreed to and signed the Terms and Conditions of Engagement Process ("Participant"). The Process begins with the Letter of Intent (LoI) and concludes when an official RFP is published on the Government Electronic Tendering Service (GETS) or when the GC advises Participants that the Process has concluded.

The GC will not disclose proprietary or commercially sensitive information concerning a Participating Supplier to other Participating Suppliers or third parties except and only to the extent required by law.

TERMS AND CONDITIONS

The following terms and conditions apply to the Process. In order to encourage open dialogue, Participants agree:

- To discuss their views concerning the Canadian Weather Radar Network Modernization Project and to provide positive resolutions to the issues in question. Everyone shall have an equal opportunity to share their ideas and suggestions;
- To allow the GC to record and/or make notes during the one-on-one meeting sessions and/or Industry Day sessions should clarification of information be required;
- NOT to reveal or discuss any information to the MEDIA/PRESS regarding the requirement during this Engagement Process. Media information on EC's radar replacement requirements can be obtained from Environment Canada Media Relations at 819-934-8008.
- To direct enquiries and comments only to authorized representatives of the GC, as directed in notices given by the Contracting Authority from time to time;
- That the GC is not obligated to issue any Request for Proposal (RFP), or to award any Contract for the Canadian Weather Radar Network Modernization Project ;
- That the GC retains absolute discretion over the terms and conditions of the RFP, if it is released;
- That the GC will not reimburse any person or entity for any cost incurred in participating in this Process;
- To direct all enquiries with regard to the procurement of the solution to the Contracting Authority;
- That participation is not a mandatory requirement. Not participating in this Process will not preclude a supplier from submitting a bid;
- That a Draft RFP may be posted on GETS for Industry comment;
- That failure to agree to and to sign the Terms and Conditions will result in the exclusion from the Engagement Process;
- That any information submitted to the GC as part of this Process may be used by the GC in the development of a subsequent competitive RFP. However, the GC is not bound to accept any expression of interest or to consider it further in any associated documents such as an RFP;

- That the GC may disclose the names of Participating Suppliers that choose to participate in the Process;

- That other Participants may join the Process at any time in the process; and,

- That a dispute resolution process to manage impasses throughout this Process shall be adhered to as follows:

DISPUTE RESOLUTION PROCESS

1. By informal discussion and good faith negotiation, each of the parties shall make all reasonable efforts to resolve any dispute, controversy or claim arising out of or in any way connected to this Process.

2. Any dispute between parties of any nature arising out of or in connection with this industry engagement shall be resolved by the following process:

   a. Any such dispute shall first be referred to the Participating Supplier's Representative and the PWGSC Manager managing the Process. The parties will have three (3) business days in which to attempt to resolve the dispute;

   b. In the event the representatives of the parties specified in Article 2.a. above are unable to resolve the dispute, it shall be referred to the Participating Supplier's Project Director and the PWGSC Director General of the Directorate responsible for managing the Process. The parties will have three (3) business days to attempt to resolve the dispute;

   c. In the event the representatives of the parties specified in Article 2.b. above are unable to resolve the dispute, it shall be referred to the Participating Supplier's Chief Executive Officer and the PWGSC Assistant Deputy Minister of the Sector responsible for managing the Process, who will have five (5) business days to attempt to resolve the dispute; and,

   d. In the event the representatives of the parties specified in Article 2.c. above are unable to resolve the dispute, the Contracting Authority shall within five (5) business days render a written decision which shall include a detailed description of the dispute and the reasons supporting the Contracting Authority's decision. The Contracting Authority shall deliver a signed copy thereof to the Participating Supplier.

By signing this document, the individual represents that he/she has full authority to bind the Participating Supplier listed below and that the individual and the company agrees to be bound by all the terms and conditions contained herein.

Name of Participating Supplier: ______________________________

Name of Individual & Signature: ______________________________

Telephone: ______________________________

E-mail: ______________________________