# Review of the Statement of Operational Requirement for the Fixed Wing Search and Rescue Aircraft – FINAL Report

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# Executive Summary

**Background**

The existing Fixed Wing Search and Rescue (FWSAR) capability is currently provided by two fleets of ageing aircraft. The Department of National Defence (DND) has produced a Statement of Operational Requirement (SOR) to acquire modern, effective replacement FWSAR aircraft to provide the capability for thirty years. The Department of Public Works and Government Services Canada (PWGSC) contracted the National Research Council Canada (NRC) under a Memorandum of Understanding (MoU) to conduct an independent review of the SOR.

**Assumptions, Constraints and High Level Mandatory Capability Requirements**

This report documents a review of the assumptions and constraints used to derive the fifteen High Level Mandatory Capability (HLMC) requirements followed by a review of each HLMC as they are presented in the FWSAR SOR. NRC has provided qualitative assessments and, in some cases, specific recommendations for each assumption, constraint and HLMC requirement.

**Principal conclusions**

The SOR as written is over-constrained. Stated mission scenarios, preservation of the status quo regarding standby posture, CF crewing, and the four existing main operating bases may limit the potential number of solutions industry could propose.

The stated objective of the SOR is that new FWSAR aircraft provide a level of service to Canadians equal to that currently provided; a level that is not currently defined in Government of Canada policy. An aircraft compliant with the SOR as written may not achieve the above objective.

**Recommendations**

A principal recommendation is that the SOR be amended to better reflect a capability-based requirements rationale rather than a platform-centric approach. The capabilities required should not refer explicitly to those provided by existing DND FWSAR fleets. The SOR should describe the FWSAR capability sought by the Government of Canada in terms of SAR service to Canadians. It should also include a list of mandatory requirements reflecting the nature of service to be delivered and the timely delivery of this service. The SOR should also include a minimum list of constraints on any proposals. This document provides recommendations regarding the list of mandatory requirements and constraints.

NRC recommends that the FWSAR SOR be amended in light of the review documented herein.

**Existing HLMC Requirements**

Several of the derived HLMC requirements could be substantially amended if constraints were relaxed. The principal FWSAR HLMC performance requirements of range and response time in the SOR are not supported by the analysis used to derive them. If the SOR were to articulate the required SAR level of service and associated technical capabilities with respect to SAR load and the tasks of the crew members, then industry could analyse and submit mission scenarios that meet the requirements and are supported by the performance (range and speed) capabilities of their products. These particular HLMC requirements for range and response time could then be deleted from the SOR.

The majority of the remaining HLMC requirements can be improved as documented in this report. Compliance with some requirements such as cockpit visibility and manoeuvrability would be difficult to assess as prescribed in the current SOR. For other requirements such as cargo compartment height, the requirement is not supported by the referenced documentation. More rigorous analytic techniques should be applied to determine required cabin dimensions. NRC has concluded the FWSAR aircraft must be equipped with a ramp. The specified minimum number of aircraft (fifteen) is not adequately supported.

**Potential Additional HLMC Requirements**

It is recommended that several of the requirements presently listed as "Tier 1 rated" be upgraded to "High Level Mandatory Capabilities". A small number of additional mandatory requirements are also recommended as additional mandatory requirements that any proposed capability must include. These are:

- Integration of SAR sensors such as electro-optical and infrared (EO/IR), search radar and night vision imaging systems (NVIS)
- Ability to: operate from short gravel runways and austere airfields; fly in icing conditions; operate in ground icing conditions where facilities exist
- Estimated life expectancy (ELE) of 30 years based on an average YFR that meets the capability and level of service requirements
- Ergonomic design of crew workstations
- Compliance with relevant civil operating rules (e.g. PBN and RVSM capability; equipped with TCAS and TAWS) as necessary to achieve required capabilities and level of service
- Inclusion of the SAR interagency frequency in the communications suite

Notwithstanding the conclusion that the SOR as written is over-constrained, these are capabilities that must form a part of any solution.

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# 1. Background

**History and Process**

The existing Fixed Wing Search and Rescue (FWSAR) capability is currently provided by two fleets of ageing aircraft. The Department of National Defence (DND) has produced a Statement of Operational Requirement (SOR) (DND, 2006) to acquire modern, effective replacement FWSAR aircraft to provide the capability for thirty years. The Department of Public Works and Government Services Canada (PWGSC) contracted the National Research Council Canada (NRC) under a Memorandum of Understanding (MoU) (Government of Canada, 2009) to conduct an independent review of the SOR.

**Mandate and Terms of Reference**

The terms of reference of the review are provided in Appendix A of the MoU and restated here:

- NRC will conduct an independent review of the FWSAR SOR to assess the validity of the various assumptions and constraints used to derive the "high level mandatory capabilities" as specified.
- The review will include, but is not limited to, a review of supporting documentation in the context of the Canadian SAR environment.
- The review will be conducted in conjunction with one or more reputable academic institutions.

NRC has assigned a project manager and team of five experts in various aerospace fields to conduct the assessment. Appendix A lists NRC team members and details their qualifications and expertise.

In addition, the NRC has contracted Professor Eric Van Blaeren of Ottawa University to conduct an independent review of both the SOR and this report. Because of the tight timelines involved, NRC considered this tandem approach the most effective way to complete the necessary assessments to deliver an interim report by February 5, 2010, and a final report by March 12, 2010.

# 3. Limitations and Scope of NRC Review

In accordance with the terms of the MoU, PWGSC provided the SOR and all supporting documentation to NRC. Any material referenced in this report was either provided by or approved by PWGSC, or was readily available in the public domain.

In addition, the terms of the MoU required that all communication outside NRC be approved by PWGSC. Accordingly, the NRC asked for and received permission from PWGSC to conduct the visits and interviews listed in Appendix B.

Figure 1 of the SOR shows eight mandatory capability requirements listed in summary form, which are expanded in Annex E of the SOR in a Table of items numbered one through fifteen. Although the terms of the MoU limited the scope of this review to an assessment and review of the assumptions and constraints used to derive the High Level Mandatory Capability (HLMC) requirements listed in the SOR, the NRC team considered it part of its mandate to assess each of the fifteen HLMC requirements and to identify any omissions to the them. The NRC team recognized that many assumptions and constraints have been imposed for budgetary reasons. However, the NRC review is of a technical nature that, while sensitive to, is not constrained by budgetary and strategic requirements of DND.

# 3. Assumptions and Constraints

A capability-based rather than platform-centric SOR would allow for more flexibility in developing proposed solutions. It is concluded that the SOR is over-constrained to the extent that very few compliant solutions are possible. The requirements of the FWSAR platform are unnecessarily sensitive to speed and range requirements as three other critical parameters that drive FWSAR response to incidents were constrained at the outset to remain as the status quo: main operating base locations; CF crewing; and standby posture.

The SOR as written is predicated on a collection of assumptions and constraints discussed below. Each assumption and constraint is quoted verbatim from the SOR and gives the relevant paragraph references, followed by analysis and discussion of its validity in the opinion of the NRC.

## a. Assumptions

I. **Capabilities assumption:** "It is an assumption of this SOR that the new FWSAR overall level of service provided to the Canadian public must be at least equivalent to the current capability." (A1.2.8.2)

**Analysis and Discussion**
The key phrase in this assumption is "equivalent to the current capability." The "current capability" could be interpreted to include the speed at which an existing FWSAR aircraft can reach a given location in the Canadian Search and Rescue Region (SRR) and the time it can remain there conducting a search using existing sensors. If this interpretation is correct, then this assumption is not currently met by the SOR for the reasons described below.

First, an aircraft compliant with the SOR may not provide the same transit time and/or time-on-station in far north and mid-Atlantic scenarios as the current legacy CC-130 Hercules.

Second, the assumption is not applied consistently in developing the HLMC requirements. For example, the SOR does not require that the FWSAR be capable of operating in icing conditions, from gravel runways or from austere airfields, all of which the current fleets are able to do.

Third, this assumption does not require any enhancement of SAR method, such as significant technological advances in search radar and electro-optical and infrared (EO/IR) sensors. As currently specified, an aircraft could comply with the SOR HLMC with sensors no more sophisticated than the eyes of its crewmembers.

**Conclusion**
The required FWSAR capability is not clearly articulated by the assumption as written. Reference to existing capabilities of the two aircraft to be replaced should be removed; instead, required capabilities that stand alone should be derived.

ii. **Level of service (LOS) assumption:** "This SOR defines a minimum requirement that can maintain a similar level of SAR service to that currently provided by those FWSAR aircraft that are being phased out." (A1.2.8.3)

    "…..the Canadian Forces SAR level of service commitment stipulates that a primary CF SAR aircraft be capable of arriving at the start of a search pattern (Commence Search Point) for any aeronautical or maritime SAR incident occurring in a Canadian Search and Rescue Region within 4.0 hours of being tasked for 90% of SAR incidents and within 11 hours of being tasked for 100% of SAR incidents." (A2.4.1.4)

**Analysis and Discussion**
The quoted LOS is not currently supported by Government of Canada policy. It is, instead, what the Chief of the Air Staff (CAS) committed the CF to achieving in a letter to the National Search and Rescue Secretariat (NSS) (DND, 2002). The Department of National Defence (DND) Chief Review Services has also identified this policy gap (DND, 2008). Although it has been acknowledged that the existing LOS commitment is the best available substitute for a statement of policy, the absence of policy regarding LOS undermines the validity of the assumptions used to develop the SOR.

In conjunction with the capabilities assumption discussed in the previous section and the mission planning scenarios described in SOR Annex A, Section 2.1 (which allow for a one-hour refuelling stop en-route and specify a minimum on-scene search time of one hour), an aircraft compliant with the mandatory requirements of the SOR would not be capable of delivering the CF SAR LOS commitment in all circumstances. Furthermore, based on discussions with the 424 Squadron personnel, arriving on scene within eleven hours with only one hour to conduct the search falls well short of the current capabilities of the CC-130.

Despite frequent references to the level of service throughout the SOR, the speed required of a potential solution to meet the demands of both the 90% and 100% coverage areas is disregarded in determining the platform's cruise speed requirement in the SOR. Furthermore, the stipulated minimum cruise speed of 273 knots would not satisfy the level of service assumption, nor maintain the current level of service that includes the CC-130 Hercules aircraft which cruise at 300 knots.

**Conclusion**
The level of service assumption should not be written in terms of that provided by the existing FWSAR fleets. Though it may be derived from what can be achieved under the status quo, it should be expressed in a manner that stands alone, ideally backed by government policy.

iii. **Crew Complement Assumption:** "It is assumed that the crew complement for the new FWSAR aircraft will be similar to that of the CC-115 Buffalo, and will be further defined following a comprehensive crew task analysis to be conducted during the Definitions Phase."

**Analysis and Discussion**
The NRC agrees with the intent of this assumption based on the task analysis documented in CMC report number 1000-1392 entitled "FWSAR Human Factors Engineering System and Operator Task Analysis" (CMC Electronics, 2007). However, as discussed for other assumptions, the reference to existing FWSAR aircraft is not appropriate.

**Conclusion**
The assumption should state that the crew complement of new FWSAR aircraft is assumed to be six positions identified in the references cited in the discussion section. References to existing FWSAR aircraft should be removed. As written in the current SOR, it is appropriate that this be subject to further definition following a comprehensive crew task analysis during later procurements phases of the project.

iv. **Off-the-shelf assumption:** "The FWSAR aircraft requirement is to be addressed by an off-the-shelf solution that maximizes SAR capability and interoperability with CF resources and minimizes development costs and risks. Modifications may be necessary to enable the aircraft to meet the FWSAR requirements detailed in this SOR. Any re-design and modification will require certification to internationally recognized military or civil standards of airworthiness and will ultimately require approval of the DND Technical Airworthiness Authority" (3.1.1)

**Analysis and Discussion**
The definition of "off-the-shelf" is not specified and has been shown to be problematic in previous acquisitions. Associated with this assumption is an expectation that the level of effort required by both the vendor and DND to certify the aircraft will be minimal. This expectation was shown to be invalid as described in the Review of the Canadian Search and Rescue Helicopter Acquisition by DND Chief Review Services in July 2007 (DND, 2007a), and a similar expectation in this case may have significant implications on both budget and delivery schedule. Recent acquisitions such as the CC-177

Globemaster III have not included significant modifications and might therefore be appropriately described as “off-the-shelf”.

If the intent is to preclude solutions that have not achieved series production of the basic aircraft including certification by an airworthiness authority recognized by the TAA, then it would be clearer to state that intent explicitly. The scope of the project would then be defined by the level of effort required by all parties to achieve Canadian military certification of the basic aircraft plus that needed to certify and qualify the design changes required for the operational role.

**Conclusion**
Use of the term “off-the-shelf” should be avoided unless it is anticipated that aircraft may be procured in the form they are currently produced with no design changes.

v. **Single Aircraft Type assumption:** Throughout the SOR is an implicit assumption that a single aircraft type with twin engines will be selected to meet all requirements. It is stated as a preferred option as quoted below.

“…preliminary costing data indicates that replacement with a new twin-engine aircraft would cost less than the status quo over a 30-year life cycle. The preferred option is to replace the CC-115 Buffalo and up to ten older CC-130 Hercules with a new multi-engine aircraft, which would be common to all current and/or proposed FWSAR bases.” (A 1.3.3)

**Analysis and Discussion**
The preferred option is also presumed in the Statement of Operating Intent (DND, 2005) to be a single aircraft type with two engines. This assumption effectively precludes serious consideration of a multiple-fleet solution.

If the small number of very long distance scenarios is distinguished from the majority of SAR incidents, it may be practicable to provide FWSAR coverage for those scenarios using a small number of long-range, relatively high-speed aircraft. The balance of scenarios could then be served by an aircraft with range and speed capabilities more modest than those required by the present SOR. Stating the single aircraft type assumption in the SOR is a significant disincentive to multi-fleet proposals from industry and may therefore be seen as an unnecessary constraint on the project.

**Conclusion**
Despite the preliminary costing data, the assumption of a single aircraft solution should be removed to allow industry to submit single or multi-fleet proposals. Such proposals can then be assessed on the basis of their merits including costs.

**vi. CF Personnel crewing assumption:** The SOR assumes that the FWSAR aircraft "is to be operated and maintained by currently trained and qualified CF personnel." (7.1.1)

**Analysis and Discussion**

Discussion with staff at the Trenton Joint Rescue Coordination Centre (JRCC) revealed that the CF has access to and makes frequent use of civilian rotary wing aircraft operators to help rescue people in distress through a National Master Standing Offer for Air Charter Services with PWGSC. This matrix approach of using civilian crewed and maintained aircraft, on occasion with a CF SAR technician aboard, represents a novel approach to the challenges of providing quick and reliable SAR response.

**Conclusion**

Assuming that the FWSAR capability can only be provided by an all-military team while also constraining main operating base locations has a significant impact on the possible solutions to the FWSAR requirement and is inconsistent with existing practices for rotary-wing assets. An in-depth analysis of the cost and potential benefits of providing part of the FWSAR solution through contracted support for elements such as aircraft, aircrew, and maintenance functions may lead to a lower cost solution and a more effective response. A capability-based SOR should not preclude options such as having part of the FWSAR capability contracted outside of the military especially when it is already an existing practice in the rotary wing SAR community.

## b. Constraints

i. **Mission requirements:** "The proposed FWSAR solution shall address mission requirements in terms of required standard SAR load, required operating range and response time, as detailed in section 2.1 Missions and Scenarios of this annex" (A1.4.1a)

**Analysis and Discussion**

The above constraint as written, when combined with those of FWSAR Main Operating Bases (MOBs) and standby posture, drives speed and range requirements for the entire FWSAR fleet to meet a small number of extreme scenarios constituting a tiny fraction of the historical SAR incidents. It effectively precludes a mixed-fleet solution in which the needs of the majority of incidents could be met adequately with aircraft of modest range and speed capability while a small number of longer-range, higher-speed aircraft could meet the needs of these extreme scenarios.

**Conclusion**

Rather than provide the mission scenarios as constraints, the required capability should be articulated in terms of providing a defined level of SAR service to Canadians. The requirement can be expressed as a definition of the geographic areas to be served and the allowable response times to reach those areas and provide aid to SAR victims. Industry can conduct the scenario planning to meet these needs in support of selection of their products.

ii. **Defence Plan scenarios:** "The FWSAR capability shall be able to support the relevant Defence Plan 2003 Force Planning Scenarios" (A1.4.1b)

**Analysis and Discussion**

NRC did not have access to Defence Plan 2003. In any case, it has been superseded by the Canada First Defence Strategy, which does not describe Force Planning Scenarios. Reference to Defence Plan 2003 should be removed.

The scenarios used for operational planning, particularly with respect to base locations, are largely based on historical distribution of SAR incidents. In discussions with National Search and Rescue Secretariat (NSS) and Trenton Joint Rescue Coordination Centre (JRCC) staff, NRC has determined the data available for this purpose are not particularly robust or readily searchable. Furthermore, there are virtually no forecasts based on changing trends such as increased trans-polar airline traffic, arctic shipping, northern mining activity, or generally increased human presence in the north to provide additional inputs to operational scenario planning. Consequently, the analysis was conducted using data that were insufficient to predict future SAR requirements, because comprehensive retrospective and predictive data were unavailable. The NSS is actively developing a Knowledge Management System (KMS) to address many of the deficiencies listed above. Discussion with NSS staff and a KMS backgrounder (NSS, 2010) indicate the system will be available within two years.

**Conclusion**

Mission and scenario planning should be based on robust data whenever possible. Consideration should be given to accessing the NSS Knowledge Management System, should its availability be timely, to improve this aspect of deriving the FWSAR capability requirements.

iii. **SOI and SSI:** "The FWSAR project is constrained to operating and maintaining the FWSAR aircraft in accordance with the Statement of Operating Intent and the Statement of Support Intent." (A1.4.1c)

**Analysis and Discussion**

The Statement of Operating Intent (SOI) and Statement of Support Intent (SSI) are frequently cited in the text of the SOR but are not included in the list of references. Even if they had been, this constraint is confusing as it constitutes a circular reference.

According to Part 2, Chapter 1, of the DND Technical Airworthiness Manual (DND, 2007b), the SOI can only be written after a specific aircraft type has been selected as suitable to meet the SOR; it is intended to be a "living" document adapted to reflect operational changes during the life cycle of the aircraft. This implies bidders are required to comply with a document that is not static, but that will be used to define the Basis of Certification (BoC) for the aircraft. A preliminary SOI that is not type-specific should be provided as a reference in the SOR to facilitate establishing an appropriate BoC and as the foundation for the SOI of the selected aircraft.

In several instances, the SOR makes reference to the SOIs of the existing CC-115 and CC-130 fleets. This is inappropriate due to the type-specific nature of an SOI. Instead, those aspects of the existing SOIs relevant to FWSAR should be used to derive mandatory requirements that, in turn, form the basis for a preliminary SOI for FWSAR.

**Conclusion**
References to SOI of existing FWSAR aircraft should be removed from the SOR. A generic "preliminary SOI" should be written and provided as a reference to the SOR to aid potential vendors in establishing the Basis of Certification for their proposed solutions and to provide a starting point for the SOI of the aircraft eventually selected.

iv. **SAR equipment airlift capability:** "The new FWSAR aircraft is to be capable of airlifting all relevant SAR equipment required for deployed search operations;" (A1.4.1d)

**Analysis and Discussion**
The definition of relevant SAR equipment and how it is packaged is key to establishing compliance with this constraint. The notion of a "standard SAR load" is discussed elsewhere in the report. Presently, EO/IR and other sensors are listed as rated requirements and may not be integral to the aircraft; it is possible that they will be included as part of a palletized SAR load. Integrating the sensors with the aircraft is highly desirable. This constraint does not imply any airlift capability beyond that required to accomplish the primary SAR task.

**Conclusion**
The SAR equipment airlift capability constraint is valid provided "relevant SAR equipment" is properly defined.

v. **Cargo airlift interoperability:** "Allow for cargo interoperability with Strategic Air Transport (SAT), Tactical Airlift Transport (TAT) aircraft and Medium-Heavy Lift Helicopter (MHLH) aircraft;" (A1.4.1e)

**Analysis and Discussion**
The SOR is written to address the primary SAR mission and a secondary utility airlift mission. The inclusion of this constraint is reasonable, but it appears to affect only rated requirements. The exception is the mandatory capability requirement to carry a NATO standard pallet discussed elsewhere in this report.

**Conclusion**
The cargo airlift interoperability constraint is valid as written.

vi. **Level of FWSAR service:** "The new FWSAR aircraft will provide a level of FWSAR service equivalent to or better than the current FWSAR aircraft" (A1.4.1f)

**Analysis and Discussion**
This constraint is a re-statement of an assumption discussed above in which the "LOS" is defined in terms of response time. However, some uses of LOS in the SOR (such as the mandatory requirement on manoeuvrability) are really meant to discuss capability or aircraft performance. Usage of the terms "LOS" and "capability" should be clarified throughout the SOR. Reference to the existing level of service should be replaced with a stand-alone definition.

**Conclusion**
It is recommended that the required level of FWSAR service be defined without reference to the existing aircraft and to clarify what is meant by "level of service" as distinct from "capability".

vii. **FWSAR Asset Replacement:** "The FWSAR project will replace all primary FWSAR assets in Canada." (A1.4.1g)

**Conclusion**
This constraint is valid as written.

**viii.** **FWSAR MOBs:** "The current four FWSAR MOBs will continue operation." (A1.4.1g)

**Analysis and Discussion**
The operational analysis document in "Analysis of Fleet Requirements for Fixed-Wing Search and Rescue Replacement Aircraft " (Bourdon & Rempel, 2005) details optimum basing options to best

respond to the distribution of fixed-wing SAR response incidents from 1998 to 2001, which were deemed representative of typical activity.

From this analysis, it is clear that the existing bases of Greenwood, Trenton, Winnipeg and Comox do not represent the best option for SAR response. In particular, basing aircraft in Gander rather than Greenwood would have had a significant positive impact on the response time to a vast majority of the incidents examined as the range required to respond to 90% of the historical incidents reduced from 653 nautical miles (nm) to 533nm. The analysis shows that "the greatest reduction in cruise speed that can be achieved by moving a single base arises when the Main Operating Base (MOB) in Greenwood is relocated to Gander."

The mandatory requirement for aircraft range was derived based on an incident in the mid-Atlantic at N51 00 W30 00, with response from Greenwood and a refuelling stop in St. John's. However, a Gander base in lieu of Greenwood, had it been considered in the SOR, would have impacted the range requirements of a single aircraft solution slightly by requiring an increase in the range requirement for a new aircraft by 43 nm to 1742 nm from 1699 nm, while the response would be greatly improved as a transit leg from Greenwood to St. John's plus a 1-hour refuelling stop would be unnecessary.

**Conclusion**

Given the existing SAR role of the Cormorant in Gander, and the improvement in response time of a platform based there, it is unfortunate that such a basing option is excluded due to this constraint. While the option of using Gander in lieu of Greenwood is the only one outlined here, many other viable options exist within the operational analysis document (Bourdon & Rempel, 2005) that should be revisited. Utilizing some contracted fixed-wing SAR response that is strategically postured may provide a cost-effective alternative to alleviate some of the costs associated with establishing or relocating a MOB or requiring an aircraft with high cruise speed for all scenarios.

ix. **FWSAR Standby posture:** "A change of the SAR standby posture is not within the mandate of this project." (A1.4.1i)

**Analysis and Discussion**

The Analysis of Fleet Requirements for FWSAR (Bourdon & Rempel, 2005) details how sensitive the response to SAR incidents is depending on the standby posture given that 90% of the SAR incidents occur with 653nm of the current SAR MOBs. The posture currently used and considered in the SOR is that SAR units hold 30- minute standby for 40 hours per week, and 2-hour standby for the remaining 128 hrs weekly. Further, normal standby posture is held from 0800-1600h daily on Monday through Friday, although this period can be shifted. Changing the amount of time on 30-minute standby has a significant effect on the response time after notification is received, which reduces the speed requirements of the platform significantly or allows FWSAR resources to arrive on scene earlier assuming equal speed.

The increased project costs and potential increased life-saving opportunities associated with holding continuous 30-minute standby as analysed in "CF SAR 30-minute Continuous Readiness Posture FG Analysis" (DND, Director Air Force Readiness, 2008a) concludes that of 2700 lives at risk in 1054 CFSAR cases over a four-year study period from 2000-2004, "six [people] might have had an increased chance of survival if a 30-minute posture had been in effect." Further, the study claims that "the likelihood of survival statistically decreases by approximately 3% for every hour that passes after an incident occurs" based on the percentage of victims found alive upon arrival of SAR resources. However, the data used to determine both the hourly decrease in survivability and also the number of people that might have survived was highly filtered and conclusions were drawn based on "witness testimony and anecdotal evidence" with no raw data presented as "there was insufficient data within the text of the mission reports to properly assess each case for reaction consequence." Further, only 119 of the 1054 cases were used to draw conclusions on survivability and chances of survival. This study should not be used as a cornerstone to assess either survivability or the impact of holding 24-hour per day 30-minute standby on survivability. However, it is a valuable tool to assess the costs associated with the increased readiness posture in terms of crews required, aircraft, maintenance and flying rate.

It is understood from the Analysis of Fleet Requirements for FWSAR (Bourdon & Rempel, 2005) and 30-minute Continuous Readiness Posture Analysis (DND, Director Air Force Readiness, 2008a) that maintaining a 100% 30-minute standby response is very expensive; however, there was no evidence as to an assessment of an intermediate solution between 8 and 24 hours per day of 30-minute standby and the cost thereof as compared to the cost of acquiring faster aircraft.

**Conclusion**

Given how sensitive the solution is to standby posture for a vast majority of incidents, consideration should be given to analyzing in detail the cost of an increased 30-minute standby period versus the cost of acquiring much higher performance aircraft in terms of cruise speed. Further, such an investigation should be core to the mandate of the project as any changes in standby posture have significant impact on project costs, personnel levels, aircraft required, yearly flying rate (YFR), infrastructure, and the SAR level of service.

# 4. High Level Mandatory Capability Requirements:

The foregoing assessment of the assumptions and constraints leads to the conclusion that the SOR is over-constrained. Should the constraints be relaxed, several of the derived mandatory requirements could be substantially amended. Nonetheless, the mandate of the review necessitated an assessment of each High Level Mandatory Capability (HLMC) Requirement as written. The HLMC requirements could be improved within the context of the present approach as described in this section.

Each of the fifteen HLMC requirements is reviewed individually below in the same order as presented in Annex E of the FWSAR SOR. In each case, the HLMC is quoted in full, followed by a summary of its assessed validity and any recommendations for amendments to it.

1 **Range:** "An un-refuelled range of 1,699 nm/3,147 km at normal cruise power (Annex A, 2.4.1.19), while carrying the crew (6) and standard SAR load (6,902 lbs/3,130 kg) as established by the maritime SAR scenario presented in Annex A (2.4.1.13). Range performance must include sufficient fuel reserves to meet the CF mandated instrument flight rules (IFR) minimum fuel requirements plus one hour of residual fuel to allow for the conduct of SAR (one flight hour at 1,000 feet altitude above ground-level (AGL) or above water-level (AWL) and a search speed between 110 and 140 knots indicated airspeed (KIAS) as per Annex A (2.4.1.20))"

**Analysis and Discussion**

The SOR determines the maximum range requirements of the new FWSAR platform based on the challenges of responding to worst-case scenarios in each Search and Rescue Region (SRR) region using the current four MOB locations. The scenarios include an en-route fuel stop for the longer-range cases, and the requirement to search for at least one hour in the search area before transit to destination for landing. The Victoria – Overland scenario involved a deployment to an incident in extreme north-west Canada (on the Alaskan border) with recovery in Inuvik for a total range requirement of 1468 nm. The Victoria – Maritime Scenario detailed responding to an incident at the western extreme of the SRR with recovery to Sandspit, B.C. for a total range requirement of 1378 nm. The Trenton – Arctic Scenario involved responding to an incident at the North Pole with an en-route refuelling stop in Resolute Bay prior to the search and recovery in Alert. The initial transit leg drove the range requirement of 1493 nm for this scenario, although the total distance travelled for this scenario would be 2865 nm (Winnipeg-Resolute Bay-North Pole-Alert). This Trenton – Arctic scenario was used to derive the aircraft's minimum airspeed requirement of 273 knots based on a 15-hour crew day and will be discussed later within this document.

The final scenario considered in the SOR for the minimum range requirement was the Halifax SRR response to an incident at the extreme east of the area of responsibility at N51 00, W30 00 with an en-route refuelling stop in St. John's and recovery in Shannon, Ireland. The longest un-refuelled leg in this scenario drove the minimum range requirement in the SOR, as the St. John's to N51 00, W30 00 to Shannon distance was the greatest of all scenarios at 1699 nm, while the total distance travelled for the overall scenario was 2229 nm.

All of the range requirements took into account a one-hour on-station search time. Within the SOR it is stated that the aircraft would ideally have two hours minimum on-station, and further, that one hour was an absolute minimum amount of time. As quoted in (Bourdon & Rempel, 2005), "while the use of emergency beacons and other technologies can reduce the actual search times, these times regularly exceed the 1 hour minimum by a significant amount." Through interviews it was clear that an incident site would have to be located very early in the search in order to allow time to dress the SAR technicians, fly the appropriate pre-drop wind assessment patterns, and drop both SAR technicians and equipment.

For the flight scenarios to the north where an en-route fuel stop is required, the refuelling process can easily exceed one hour, as was confirmed through interviews with crews at 424 Squadron. Furthermore, in this scenario the primary and alternate landing fields are located in very sparse areas where few or no other options exist, which can often negate the capability of the aircraft to complete the mission.

One of the core concepts of the FWSAR SOR was that "the new FWSAR aircraft shall maintain or improve the FWSAR level of service for Canadians." While this statement pertains directly to responding to a certain percentage of incidents in a certain amount of time within Canada's areas of responsibility, it also pertains to not degrading the service Canadians enjoy today. Currently, the long-range response off the east coast of Canada and to the far north is provided by CC-130 Hercules aircraft with a cruise speed of 300 knots and range in excess of 3500 nm in the SAR configuration. Both the un-refuelled range and speed capabilities of the CC-130 are far in excess of that proposed under the new FWSAR SOR.

Through analysis of historical data (Bourdon & Rempel, 2005), it has been shown that 90% of the current FWSAR incidents occurred within 653 nm of the current MOBs. Further, 95% occurred well within 800 nm. Therefore, of the total of 1775 incidents that occurred in 3 years fewer than 90 incidents occurred beyond 800 nm from an existing MOB.

**Conclusion**
The mandatory range requirement of 1,699nm degrades the capability currently provided by CC-130s in the Trenton and Halifax SRRs, although it would improve the range capability vis-à-vis that provided by CC-115 Buffalos in the Victoria SRR. The very limited 1 hour search capability and the need to refuel to accomplish moderately long range missions is a further degradation of capability vis-à-vis the CC-130. The mandatory range requirement is inconsistent with the stated core objective of the SOR of maintaining or improving the SAR level of service for Canadians and the range requirement must either be increased to match that currently provided to the majority of Canada by the CC-130 or the core objective must be modified to a lower standard than that currently provided.
Alternatively, if the few long distance scenarios are distinguished from the majority of SAR incidents, it may be cost-effective to provide FWSAR coverage for those scenarios using a small number of long-range, relatively high-speed aircraft. The balance of scenarios could then be served by an aircraft with range and speed capabilities more modest than those required by the present SOR.

2 **Response time:** " A minimum level flight average cruise airspeed of 273 knots true airspeed (KTAS)/ 505 km/h while carrying the crew (6), the standard SAR load (6,902 lbs/3,130 kg) and fuel necessary to complete any of the SAR scenarios outlined in Annex A (2.4.1.10 to 2.4.1.13) within a 15 hour crew

day (Annex G) from an existing FWSAR Main Operating Base (MOB) so as to ensure, that at least, the same level of FWSAR service is maintained (Annex A, 2.4.1.19)."

**Analysis and Discussion**

The SOR determines the minimum speed requirements based on various scenarios, differing standby postures, and various levels of service and crew-day requirements. The SAR level of service of reaching 90% of the SAR incidents within four hours of being tasked, and 100% of the incidents within eleven hours was used as a baseline in a portion of the SOR and was further analysed in historical data (Bourdon & Rempel, 2005) to determine the minimum cruise speed of the new FWSAR aircraft. Although the FWSAR level of service was put forward by the Chief of the Air Staff (DND, 2002) after communication with the National Search and Rescue Secretariat, it was not formalized in National Policy or Doctrine. As such, the cruise speed requirements that result from analysis of scenarios against this level of service can only be regarded as guidelines rather than hard requirements.

The historical analysis explores cruise requirements against the SAR level of service notion with a 90% incident probability range of 653 nm as previously presented, and 100% coverage in eleven hours. Based on the notional SAR level of service and the current four MOBs, the historical analysis concludes that for aircraft on 30-minute standby posture, reaching 90% of the incidents in four hours would require a cruise speed of 187 knots, and satisfying 100% in 11 hours would require 262 knots cruise speed. For aircraft on two-hour standby at the time of the incident, the cruise speed requirements increased to 347 knots and 316 knots respectively. It is readily apparent that the most significant impact to cruise speed requirements for 90% of the incidents is the standby posture – demonstrated by the drastic increase in required cruise speed from 187 to 347 knots for 90% of the incident cases.

In the current SAR posture, crews spend 40 hours per week holding 30-minute standby, which represents 23.8% of the week. As detailed in the historical analysis (Bourdon & Rempel, 2005) and confirmed during interviews, the 30-minute standby posture is normally held between 0800-1600h on weekdays, although variability exists as to when the posture is held. Based on this analysis, for 1677 of 1775 incidents that occurred in the three year study period for which time information was available, 17% occurred during the period of 0800-1600h on weekdays.

The third scenario that was analysed and finally used to derive the FWSAR cruise speed requirements was based on crew day limits of 15 hours on duty. The scenario used was the Trenton SRR – Arctic incident detailed in the previous mandatory requirement for range. This scenario involves an incident at the North Pole, with response from Winnipeg via Resolute Bay for refuelling, and eventual landing in Alert after one-hour on-station search time. In order to satisfy the limit of 15 hours on duty, the aircraft would have to cruise at 273 knots throughout the transit portion of the flight if the incident occurred during a two-hour standby posture and 238 knots if it occurred during a 30-minute standby period.

The SOR selected 273 knots for minimum cruise speed based on the crew duty day limit of 15 hours, and the Trenton SRR – Arctic response scenario when the crew was on two hours standby. Crews that are on 30-minute standby would be better able to meet this requirement during their first 90 minutes at work; however, as crews on 30-minute standby are required to be at work to meet this quick response posture, their crew duty day would be expiring throughout the day and after the first 90 minutes the cruise speed they would have to fly to meet the intent of the crew duty day limitation would in fact increase beyond 273 knots for the majority of their day. Beyond the first 90 minutes, having a fully rested crew on 2-hour standby is more beneficial to the overall capability to respond as a full 15-hour crew day remains available in executing the task.

In addition, all minimum speed requirements derived from the FWSAR level of service guidance are discarded in the final determination for minimum cruise speed. The selected cruise speed does not allow the aircraft to meet the stated SAR level of service targets for 90% or 100% of the incidents when the aircraft is on 2-hour standby. It is not clear why the 273 knots cruise speed was chosen to be the target over the other calculated cruise speeds and the effect on crews that are on duty (30-minute standby) is not addressed in the SOR or the operational research paper used to derive the cruise speed requirement. As the selected cruise speed of 273 knots does not allow the aircraft to meet with many of the stated requirements of the program, it is difficult to defend this speed as a mandatory minimum requirement. Cruise speed is a key discriminator in this program.

As detailed in "CF SAR 30-minute Continuous Readiness Posture FG Analysis" (DND, Director Air Force Readiness, 2008a) the current level of service using a CC-130 aircraft from Winnipeg would provide a superior level of service to that recommended in the SOR as the CC-130 could cruise faster, does not require an en-route refuelling stop, and could search longer on station. For the North Pole scenario, even on 2-hour standby a crew from 435 Sqn (Winnipeg) "allowing for a full two-hour launch, a crew can accomplish this type of mission within 15 hours (and still have three hours flexibility)."

**Conclusion**
Selecting a minimum cruise speed that does not meet the intent of all of the elements of the program, while potentially excluding many aircraft from competing for the project as a result of the speed chosen is a weakness of the SOR.

3 **Cockpit Visibility:** "Provide both pilots with sufficient unimpaired vision from the cockpit windows, comparable to the current CF FWSAR aircraft, to enable the safe and effective conduct of all current search and rescue sequences in all physical environments within the SAR area of responsibility. In order to visually clear medium to steep bank turns (Annex H) to achieve a course reversal in a confined mountainous valley, both pilots must have sufficient visibility from the cockpit of the terrain that is level with the aircraft, to visually clear the projected flight path of the aircraft throughout the turn (Ref A)[ (CMC Electronics, 2006)] "

**Analysis and Discussion**

The SOR makes oblique reference to the report "Fixed Wing Search and Rescue Aircraft Cockpit Field of View Analysis and Requirements Definition" (CMC Electronics, 2006), but does not explicitly require compliance with its recommendations. Furthermore, the SOR is in contradiction to the report, in that the SOR requires a field of view sufficient to "visually clear the projected flight path of the aircraft throughout the turn", whereas the report only requires a field of view sufficient to clear the flight path "to a point 90 degrees into the turn" when flying toward the side upon which the pilot is seated and to a point 45 degrees into the turn when flying cross-cockpit. It is not realistic to insist, as stated in the SOR, that the field of view facilitate clearing the flight path "throughout the turn"; a statement that would in effect require the pilot to see behind him during sustained turns. In any event, given that turn radius is a function of bank angle and velocity, there is enough data implied in the SOR to allow the explicit calculation of the required cockpit field of view; a step that would make this HLMC clearer.

The report on cockpit field of view explicitly recommends upper quadrant transparencies, and suggests that candidate aircraft demonstrate compliance in accordance with the methodology prescribed in FAA Advisory Circular AC 25.773-1 (U.S. Department of Transportation, 1993). Neither recommendation is articulated in the SOR; a situation that would make it difficult for a potential vendor to demonstrate compliance.

The title of this HLMC, "cockpit visibility" should be renamed "cockpit field of view" to better reflect standard usage of terminology. Cockpit visibility typically refers to the distance one can see in the presence of obscuration.

**Conclusion**

The requirement as defined fails to delineate the required fields of view in such a way that a clear and objective means of evaluating compliance is made explicit. It is recommended that either a specific angular field of view be specified or a methodology be prescribed whereby a vendor could demonstrate compliance.

4 **Cargo Compartment: "**Cargo compartment must be of sufficient, unobstructed width and height dimensions to provide the target population (as defined in 4.2.2.c.ii) with the clearance necessary to safely perform all ground and airborne tasks. The manual handling of SAR equipment while in-flight can lead to crewmember injury if the FWSAR aircraft cargo compartment is not ergonomically designed. For this reason, the cargo compartment width and height, and the load configuration of the SAR equipment, must combine to ensure the risk of physiological injury is minimal while ensuring that crewmembers can operate through the full range of their required duties without risk of long-term physiological effects (as per Ref D)[ (U.S. DoD, 1999)]. Mandatory requirements relating to the cargo compartment dimensions are outlined in para 5.9.1."

Paragraph 4.2.2.c.ii of the SOR defines the target population as a Rated Requirement for Operability:

a. "The FWSAR aircraft is to be suitable for operation (including crew seating/stations and interface design) by the target population as defined by:

ii.Navigator/Sensor Operators (Nav/SensO), Search and Rescue Technicians (SAR Tech), and Flight Engineers (FE) - donning associated ALSE, as represented by 95% accommodation of the population defined in the Anthropometric CF Survey of the Land Forces Ref B [ (Chamberland, Carrier, Forest, & & Hachez, 1998)]."

**Analysis and Discussion**

The assertion that the "cargo compartment width and height, and the load configuration of the SAR equipment, must combine to ensure the risk of physiological injury is minimal while ensuring that crewmembers can operate through the full range of their required duties without risk of long-term physiological effects (as per Ref D (U.S. DoD, 1999)" is an important one, and it is certainly appropriate to ensure that the mandatory requirements specify an ergonomically sound cabin that is appropriate to a SAR role. The reference used to support this statement is, unfortunately, a reference to a Military Standard (MIL-STD-1472) that does not discuss the risk of injury or long-term physiological effects related to work space height and width. MIL-STD-1472 (U.S. DoD, 1999) indicates only that "Clearance dimensions (e.g., minimum dimensions for passageways and accesses), which must accommodate or allow passage of the body or parts of the body, must be related to performance of tasks before being substituted for performance criteria" p. 106. Indeed, there is no national or international standard that specifies minimum cabin height and width requirements. The SOR does not reference an analysis of the body envelope over time during the conduct of SAR Technician tasks. Similarly, the SOR does not provide any references describing the relationship between cabin size and "long-term physiological effects", nor does it describe evidence that such effects exist in the SAR Technician population. Anecdotally, there are reports that the SAR Technicians suffer from both acute and chronic back injury. If a systematic analysis of injury in this population were to exist, it might, in combination with a biomechanical analysis of SAR Technician tasks, provide an informed justification for specific constraints on multiple aspects of the aircraft design beyond cargo compartment height, width, and load configuration. Indeed, the specific aspects of the role found to underlie such documented medical issues could then be specifically addressed through appropriate mitigations. A biomechanical study that includes an analysis of spine loadings for SAR tasks could shed light on the mechanism of putative injuries. Similarly, the potential benefits of the ability to maintain an upright posture prior to lifting could be specifically modelled in terms of the subsequent compressive effects on the spine. In any case, the diverse body positions used throughout the range of SAR Technician tasks have not been documented to-date.

By referencing the rated requirement in 4.2.2.c.ii, this mandatory requirement effectively transforms the rated requirement into a mandatory requirement as well. It is appropriate that the SOR specify an aircraft design that should safely accommodate population extremes in size. The current SAR Technician population is likely not sufficiently numerous to be used to reliably predict the anthropometric characteristics of a future population. It should be noted that anthropometric characteristics extend beyond height to include multiple relevant body dimensions. DND has modelled aircrew but not SAR Technicians using the Body Sizing System (BoSS), a capability available in house at Defence Research and Development Canada's Toronto Laboratory. BoSS combines a full-body scanner with software to quickly and accurately obtain a person's measurements in three dimensions ( (Bain & Meunier, 2008; Courchesne, Bain, Gray, Meunier, Morissette, & Marrao, 2008; Meunier, 2008). The output of this system could in turn be used to aid in the definition of body envelope analyses for tasks performed in an aircraft cabin. It should be noted that the use of anthropometric data drawn from the Land Forces is not ideal, given that the land forces population may differ in unknown ways (through self-selection or other mechanisms) from the population of those aircrew who are not subject to the CF Aircrew Height Restrictions. However, given the absence of a more appropriate anthropometric survey, the 1985 Land Forces anthropometric survey (Chamberland, Carrier, Forest, & & Hachez, 1998) is likely the best available data upon which to estimate the target population.

Informal observation of the SAR Technicians loading, unloading, jumping from and working within a CC-115 Buffalo reveal the diverse and occasionally extreme demands of the role, and suggest that a biomechanical analysis of all aspects of the position might be warranted with a view toward optimizing the work environment within the FWSAR aircraft. Modern software techniques such as HumanSantos™ and the Jack (Siemens) modeling tool can combine appropriate three-dimensional anthropometric models such as those derived using the BoSS system with motion capture techniques. This approach permits data captured in a body envelope analysis of task performance to be used to create avatars representing the 95% percentile on all relevant dimensions. This minimizes the need to capture motion data on a range of individuals working in a range of different environments and completing a full set of tasks. The avatars may be modelled working in complex environments such as aircraft with doors in different positions and irregular aisle widths. The overall shape of the aircraft interior may be modelled rather than assuming a rectilinear cross section that does not occur in aircraft. A further advantage of using software-modeling techniques is that once an aircraft is selected the same models and avatars can be used to ensure that the design of storage systems, spotter windows and chairs etc. is ergonomically sound. These models remain available to analyse the human factors implications of modifications to the work environment over the lifetime of the aircraft. Alternatively, classic mock-up techniques that permit the analysis of the body envelope over time may also be used to define the required cabin dimensions for the FWSAR aircraft (ASIC, 1987).

**Conclusion**

The inclusion of minimum cabin height and width requirements in the SOR is appropriate. A systematic analysis of the entire work envelope for the tasks to be performed must be carried out in order to derive the minimum requirements for cabin height and width. These techniques are identified as those typically used to ensure adequate cabin space in the background section of DAES TN 54-05-04 (DND, 2006b).

The SOR as worded does not offer supporting evidence to indicate that the tasks required of SAR Technicians may cause "long-term physiologic injury" nor does it suggest a mechanism for such injuries. Furthermore, no evidence is provided to indicate that cabin accommodation would reduce the incidence of the putative back injuries associated with manoeuvring heavy objects in a cramped cabin. Given that it may be possible to establish such evidence through further analysis, it is recommended that a retrospective study of injuries in the SAR Technician population be undertaken if the risk of particular classes of injury is to be used to support cabin spacing requirements.

5 **Cargo Compartment:** “Equipped with a primary para/cargo door capable of accommodating rapid loading/off-loading of the palletized (NATO Standard 88”x108”) SAR load without specialized loading equipment, as well as serving as the primary exit for airdrop of SAR personnel and equipment. The aircraft must also be equipped with an alternate para door in the case of a primary para/cargo door malfunction. The primary para/cargo door and the alternate para door must be certified for in-flight operation and their location within the cargo compartment and dimensions must provide for: i) safe parachute delivery of personnel (using the CSAR-7 parachute) and equipment from either door without undue risk from airflow to personnel, equipment and aircraft; and ii) Minimum primary para/cargo door size of 72 inches (183 cm) in height (Ref G) [ (U.K. MoD)]to accommodate safe parachute delivery of personnel and sufficient width to allow the rapid loading/off-loading of the palletized (88” X 108”) SAR load”

**Analysis and Discussion**

Section 5.1.1a of the SOR describes a requirement for a primary “para/cargo” door that would be best plainly described as a ramp. From a human factors perspective, an aircraft in a primary SAR role requires a ramp as it provides the most effective means of ensuring the safe ingress and egress of people, as well as the loading, unloading and deployment SAR equipment to and from the aircraft. The use of a ramp allows SAR Technicians, who are routinely required to jump with heavy loads (119lbs, 54 kg of gear plus clothing), to attain a stable body position more readily. When a rear ramp exit is used the body is symmetrically exposed to the wind (on both horizontal and vertical axes). In contrast, a side door exit necessitates a manoeuvre to expose the hips to the relative wind (which is typically equivalent to the airspeed of the aircraft). This manoeuvre can be difficult to execute correctly, particularly when weighed down with equipment. If one part of the body hits the relative wind first then the jumper will turn or flip. This is problematic because it is critical that SAR Techs maintain situational awareness of the location of the landing zone and ultimately of the intended target. It is more difficult to fixate the drop zone under conditions in which the SAR Technician is required to manoeuvre sideways or is rotating involuntarily. Furthermore, although airflow dynamics vary with aircraft type, more favourable airflow dynamics will generally be present for ramp exits than for side-door exits. Deflectors may be installed to create a dead space at the side door to give the SAR Technician a greater opportunity to attain the correct position, but where such systems are in use the challenge of rapidly moving to the correct position upon exit remains an issue. There is a documented risk for injury to the neck when a stable posture cannot be obtained by the time that the parachute deploys (Huston & Kamman, 1981). When parachuting using a static line from the side door it is critical that the chin be tucked to the chest to minimize the risk of neck injury. If the body is symmetrical upon exit as occurs with the use of a ramp this manoeuvre may be less critical, and since less active positioning is required it may also be easier to execute. A large percentage of injuries in static line jumps have been demonstrated to occur during the opening shock of the parachute (Craig, 2000). If more positional adjustment is required to get the body into the correct position to reduce the risk of injury, it follows that there is more opportunity for injuries in a side-door exit. In addition, the training requirement to achieve and maintain a measure of automaticity in this skill may also be greater.

Aircraft strikes are another mechanism of injury and airflow patterns around side door exits are a predisposing factor to this type of injury (Craig, 2000). The sides of CC-115 Buffalo aircraft attest to the tendency for deployed objects to impact the fuselage of the aircraft, as multiple dents are visible in the skin of this fleet just aft of the side doors. The same forces that predispose objects to bounce along the side of the aircraft act upon SAR Technicians upon exit. Both speed at exit and design of the aircraft influence the risk of hitting the fuselage, but in general side door exits require the adoption of a specific position to reduce the risk of striking the aircraft. A similar concern does not exist for ramp exits.

The use of a side door as a primary para door would complicate the management of jumps. A ramp also provides better visibility for those inside the cabin to manage incidents such as static line hang ups (which can happen when a piece of equipment, such as the liferaft, shifts into the direct deployment path of that parachute). Visibility of the fouled jumper is important in terms of ability to assess the situation, view hand signals, and manage the winch operation if required. In addition, during ramp jumps the static line does not normally contact the aircraft, allowing a clean deployment bag separation during the opening sequence. During a door jump the static line inevitably contacts the door of the aircraft prior to full separation of the deployment bag from the parachute container. This increases the risk of static line damage and possibly failure. Once such incident has recently been documented involving a side-door jump from a CC-130 Hercules; in that case the static line was severed on a sharp edge of the door.

In addition, practical concerns regarding the loading and unloading of the aircraft necessitate the availability of a ramp. Indeed, it may be extremely difficult to load patients onto the aircraft via a side door and manoeuvre them into the correct location within the cabin. The risk of injury of personnel is heightened when they are required to lift heavy objects to the height of a side door. Sight lines of crew loading and unloading the aircraft may result in improved efficiency and a decreased risk of injury when personnel are able to view activities within the cabin during the loading and unloading process.

**Conclusion**

It is recommended that a mandatory requirement for a ramp be explicitly identified in the SOR. Appropriate dimensions for the ramp could be determined via body envelope modelling techniques and identified in the SOR. In order to facilitate safe loading and unloading, it is recommended that the ramp be outfitted with a hydraulic lift capability such that it may be raised and lowered with heavy SAR equipment attached to it.

6 **Cargo Compartment:** "Equipped with a minimum of two bubble style spotter windows, capable of sustaining aircraft pressurization and, located on each side of the cargo compartment to facilitate effective visual searching."

**Analysis and Discussion**

It is essential that the FWSAR aircraft have well-designed and well-positioned spotter windows. Given the emphasis that is placed on accommodation of SAR Technicians elsewhere in the SOR it is inconsistent that the discussion of the window design does not take into account the human factors associated with the entire SAR spotter observer station system. The SAR spotter position requires that the SAR Technician lean into the bubble window in order to view the area below the aircraft. This forward-leaning position requires that adequate support be provided to the upper body, and that the seat be designed to accommodate this position. The physiological strain of assuming this forward-leaning position is exacerbated when a helmet is worn or NVGs are used. Furthermore, the ability of SAR Technicians with a range of anthropomorphic characteristics to position their (sometimes helmeted) head in the window such that they are able to comfortably view the area beneath the aircraft is an important consideration. Indeed, according to the "Spotter field-of-view analysis for FWSAR aircraft" conducted by DRDC CORA, if the spotter observer station is not designed correctly SAR Technicians may be unable to position their head at a part of the bubble window at which the depth of the window is sufficient to image the area beneath the aircraft resulting in reduced detection performance (Scales, 2007). Similarly, an analysis of the "Effects of search window size on search and rescue call around performance" (Grant, 2007)conducted by DRDC Toronto states categorically that "In order to obtain the full benefit of the field of view afforded by the window, the observer must be provided with an ergonomically sound work station", p. i.

The DRDC Toronto report on call-around performance also provides guidelines for specifying the field-of-view of the spotter window and the requirement for an overlap between spotter and pilot fields of view; however the SOR makes no mention of the field of view in either the mandatory or rated requirements. Spotter bubble windows need to be positioned in such a way that during steeply banked turns (exceeding 45 degrees) it should be the case at all times that one of the SAR Team Lead and Pilot Flying team is able to maintain an unobstructed line of sight to the target on the ground (Grant, 2007). An additional consideration with regards to the SAR bubble window location is that hand signals are routinely used by the SAR Team Lead to communicate with the SAR Technician air dropping items in accordance with Standard Operating Procedures (SOPs) for airdrop and parachute operations (DND, 2009). Depending on aircraft type, two of the spotter bubble windows will need to be positioned aft of the wings in order to ensure visibility of such hand signals.

The SOR requires that the SAR spotter windows be “capable of sustaining aircraft pressurization” as a mandatory requirement. This exceeds the current capability of CF aircraft. The need to visualize the ground means that search from a SAR bubble window is not typically conducted at high altitude The fact that the Hercules has not been retrofitted with spotter windows capable of withstanding pressurization despite many years of service in a SAR role suggests that this might best be considered as a rated requirement. The advantage to pressurized windows extends beyond searching as during searches the aircraft is often required to transit to a new location. If the windows cannot withstand pressurization, this can only be accomplished above 10,000 feet by requiring the crew to don supplemental oxygen masks (DND, 2001). Although searches conducted above 10,000 feet are extremely unusual, they can occur. In 2009 a search of Mount Logan was required. Elevation of the mountain ranges from the base of 10,000 feet to the summit of 19,550 and it was necessary to search the entire contour of the mountain. An un-pressurized Buffalo aircraft was able to complete the search; however, increased crew fatigue was reported anecdotally and attributed to the use of supplemental oxygen and high cabin altitudes. A Hercules was available to assist in this search but for several reasons the Search Master chose not to utilize this asset; the fact that supplementary oxygen could not be made available to SAR spotters at the SAR spotter windows may have been one of these underlying considerations. Ensuring that oxygen systems are designed to accommodate un-pressurized searches is less desirable than conducting all searches from a pressurized cabin, but the rarity of these events suggests that further analysis of the impact of conducting un-pressurized searches at high altitude would be appropriate before requiring this new capability in the FWSAR aircraft.

Many of the rated requirements identified in 5.9.2.a of the SOR are issues that affect many or all searches. The requirement of an ergonomically designed spotter station has been discussed above. The rated requirement for demisting and defrosting is a frequent occurrence and the lack of such systems certainly hampers visual detection. The remainder of the rated requirements retaining to the SAR spotter window pertain to the field of view of the spotter window; the mandatory requirement should include a minimum field of view based on the DRDC Toronto analysis (Grant, 2007).

**Conclusion**

The inclusion of the SAR spotter bubble windows in the mandatory requirements is appropriate. The requirement that the SAR spotter station be ergonomically sound for the target population should also be mandatory. The requirement should specify the required field of view of the spotter windows and this definition should consider the relationship between the fields of view of the flying pilot and the SAR Team Lead. Consideration should be given to changing the rated requirements to mandatory requirements and to downgrading the window pressurization requirement to a rated requirement.

7 **Cargo Compartment: "**Sufficient, unobstructed, length, width and height dimensions to allow for the safe and effective loading, securing, transport, in-flight access, airborne dispatching and subsequent unloading of the standard SAR load (Annex A, Figure 5). The cargo compartment must be of sufficient size to provide an unobstructed aisle that is at least 30.5 inches (77.5 cm) in width and 83 inches in height (210.8 cm) […] measured from the intended standing surface along the full length of the utilized cargo compartment with the aircraft configured with the standard SAR load (6,902 lbs/3,130 kg)."

**Analysis and Discussion**

It is appropriate for the SOR to include cabin height and aisle width requirements as mandatory requirements. The stated requirement of 83 inches (210.8 cm) was derived from two supporting documents produced by Human Factors experts at the Directorate of Technical Airworthiness and Engineering Support (TN 54-05-04 [ (DND, 2006a)] and DAES TN 54-06-03 [ (DND, 2006b)] and). In the background section of TN 54-05-04 (DND, 2006a) the authors did a thorough job of documenting the constraints of the approach they took to the issue of defining cabin dimensions:

> Typically, to ensure adequate cabin space is available, task-based performance requirements are specified as part of the acquisition process, with compliance shown either through analyses conducted in full-scale mock-ups or through CAD-based evaluations of the proposed cabin layouts with computer generated mannequins demonstrating that critical tasks can be completed in the space provided. Because of the significant level of expertise and amount of time required to complete these types of evaluations, it was determined that insufficient time is available to include an all encompassing performance-based requirement as part of SOIQ, as proof of compliance data could not realistically be expected in the time frames planned. Consequently, a decision was made to relegate this type of all encompassing requirement as part of the RFP process […]. As minimum cabin height and aisle width can easily be verified through engineering diagrams, and yet address to some degree cabin clearance requirements, a decision was made to include these factors as prescriptive requirements as part of SOIQ. As a result, DAES 5-4 was tasked to analyze minimum cabin height and aisle width requirements for the FWSAR cabin, and provide specific recommendations to the PMO Air Mobility. This tech note summarizes results of this analysis, [p.2.]

While useful, the specification of minimum height and width requirements cannot ensure that a workspace that meets or exceeds those requirements can be configured as an ergonomic workplace. For example, if an aircraft without a ramp were to meet these requirements the crew would be required to turn long objects such as the toboggan, stretchers etc. potentially causing additional back strain as they manoeuvre the heavy objects. A straight run from the ramp would avoid this additional manoeuvre and provide more appropriate sight lines for the personnel engaged in the task as well as easier movement within the cabin for additional personnel.

A more generally accepted approach to an evaluation of cabin space issues is outlined in the Air Standardization Coordinating Committee Standard entitled "Aircraft Mock-Up Inspection Techniques", (ASIC, 1987) that had been ratified by Canada (Chief of Defence Staff) in 1987 but is no longer in use. Current software tools employing animated mannequins (avatars) in three- dimensional representations of the space may also be used to perform this type of analysis. DAES TN 54-06-03 (DND, 2006b) represents an effort to conduct a more thorough analysis approaching the more conventional evaluation techniques. The authors outlined a number of constraints and limitations to their approach: they considered only a small subset of tasks, and regularized rectilinear workspaces (the way SAR aircraft are loaded this may never occur in practice because aircraft cabins have curvilinear boundaries, particularly if pressurized). In addition, because they were using a mock up, the stretcher loading and unloading manoeuvres were executed to a platform only a few centimetres above the ground. Observation of an attempt to load an empty stretcher through the side door of a CC-115 Buffalo made it quite clear what the shortcomings of a platform-based analysis are as this manoeuvre could not be executed without risk to the person who is supporting the stretcher from the outside of the aircraft due to the requirement to lift the stretcher's weight with arms extended above the shoulders. Furthermore, because they lacked any method of recording the body envelope over time, the authors were forced to analyze the task in terms of the extremes of the work envelope rather than the overall patterns of space usage or an understanding of when and under what conditions the extremes of the work envelope are reached.

The justification for 83 inches (210.82 cm) of cabin height is derived from an analysis of the total height of a 95th percentile Land Forces male adjusted for secular growth at a rate of 0.55 cm of growth per decade in DAES TN 54-05-04 (DND, 2006a). Although secular growth should be considered in the acquisition of future aircraft, the report that was used to justify the selection of a growth rate of 0.55 cm per decade (DCIEM, 1985) also proposes an alternate methodology that leads to the prediction that aircrew stature will level off. The paper further suggests that the analysis used to derive the 0.55 cm per decade projection might have overestimated secular growth because a portion of the aircrew trainees in the 1958 survey (who were compared to 1985 aircrew trainees) may have not achieved their full adult stature (DCIEM, 1985). The paper also contains projections to 2005 that could now be compared to data collected with the BoSS system (Bain & Meunier, 2008) to evaluate the predictive value of each model of secular growth. The rationale for 83 inches (210.82 )of cabin height would be to allow this possible future 95th percentile male (73 inches or 186.23 cm in height) to walk the length of the cabin wearing boots, helmet, and Night Vision Goggles (NVGs) stowed on his helmet with an additional 4 inches (10.16 cm) of clearance above his head.

However, observation of SAR Technicians working within the CC-115 indicated that they do not work with NVGs stowed on their helmets, and indeed some wear helmets that are not fitted with NVG mounts. Helmets are required only in a defined area of the aircraft that is in proximity to an open door during flight. Because the helmets are heavy and impose strain on a bent neck (Adam, 2004), the observed SAR Technicians preferred to wear headsets when manoeuvring equipment to the appropriate positions for deployment, switching to helmets only when a door was open. Interviews of and demonstrations by SAR Technicians revealed that if they require the use of NVGs, they either wear them on the helmet in the “down” position or hold them in their hands. They do not typically require either NVGs or helmets until a door is open. SAR Technicians conning the aircraft into position by leaning into the bubble window do not typically wear NVGs, preferring to configure them with a battery pack on the bottom so that they form a hand-held device. Presumably, the neck strain imposed by leaning a helmeted head into the bubble window approaches physical tolerances without the additional weight of the NVGs.

Therefore, the requirement for an extra two inches (5.08 cm) to allow for NVGs is not valid for the task as performed by CC-115 Buffalo SAR Technicians. Furthermore, the authors of TN 54-05-04 (DND, 2006a) justified the extra four inches (10.16cm) of clearance above the NVGs on top of the helmet entirely to provide room for the NVGs in the stowed position on the helmet while ensuring that the NVGs not be bumped during turbulence. Four inches of head clearance is substantial and is not supported by human factors literature. Thus TN 54-05-04 (DND, 2006a) justifies a total of 6 inches (15.24 cm) of headroom in terms of NVGs, though in current practice they are not worn in the position described.

DAES TN 54-06-03 (DND, 2006b)acknowledges that for some tasks NVGs are not worn and states ”that the additional 4 inches for ‘head clearance’ remains valid for stretcher tasks as factors such as managing patient lifelines (intravenous (IV) medication, ECG leads, etc) will occupy this space.” However, since the NATO STANAG 3204 AMD (NATO, 1990) requires only 18 inches (45.72 cm) vertical separation between litters in order to accommodate such tasks and equipment, this requirement cannot be considered valid. If a patient were placed in a position that required an extra clearance for equipment they would be in a position that would be too high to be properly monitored. The requirement for four inches of head clearance above the top of the helmet is therefore unsupported.

An analysis of sufficient aisle height should take into consideration a (future) 95th percentile SAR Technician’s ability to walk through the majority of the aisle upright wearing a headset and jump boots (1.5 inches). It should be noted that the same SAR Technicians work in the CC-115 Buffalo and CH-149 Cormorant . The CH-149 Cormorant has considerably less headroom (71.25 inches, 180.98 cm, at the highest point). Clearly, the tasks the SAR Technicians perform are different in the Cormorant, as they hoist rather than airdrop equipment, and do not parachute. However, much of the heavy SAR equipment that must be manoeuvred is the same on both platforms. If accommodation issues exist on the CH-149 Cormorant they could be used to inform an analysis of FWSAR cabin height requirements. All SAR Technicians with CC-115 Buffalo experience interviewed indicated that they are vertically accommodated by the CC-115 Buffalo; no one who was interviewed (including one SAR Technician who exceeded the 95th percentile for height) expressed any reservations about the currently available height in the aisle of the CC-115 Buffalo (ranging from 78 to 82 inches, 198.12 to 208.28 cm to the lowest members with padding in place). The assertion made in DAES TN 54-05-04 (DND, 2006a) that the cabin environment should be made as close to optimal as possible given the fact that SAR Technicians are routinely required to lift and manoeuvre loads that exceed human factors standards (e.g. MIL-STD-1472, (U.S. DoD, 1999) has merit and the optimization of this environment therefore belongs amongst the mandatory requirements.

The mandatory requirement specifies an aisle width of 30.5 inches (77.5 cm), which was defined as the minimum aisle width for forward facing SAR Techs fully dressed to move unobstructed in DAES 54-05-04. The width of the aisle in the CC-115 Buffalo loaded in a night SAR configuration (with flares loaded) was noted to be non-uniform, ranging from 22 ¾ inches to 34 inches (57.79 to 86.36 cm). In general objects that reach less than 12 inches (30.48 cm) in height above the walking platform (such as the ALSE life raft as stowed on the CC-115 Buffalo) are generally thought to acceptably intrude farther into the aisle than are higher objects, as long as they do not constitute tripping hazards. Body envelope analysis of a SAR Technician donning full gear (including bush suit) would permit determination of the optimal aisle width; variations in this value along the length of the aisle could be considered. It should be noted that this minimum aisle width to transport a bariatric patient using an ambulance stretcher modified for this purpose was defined by DAES 54-05-04 (DND, 2006a) as 34" (86.36 cm), so the minimum aisle width specified would not be sufficient to transport this type of patient. Bariatric patients are regularly transported in the CC-115 Buffalo because they cannot be accommodated on board many civil aircraft serving this Aeromedical Evacuation (AME) role. Consideration should be given to the ability of the new FWSAR aircraft to carry out this AME role in SAR configuration despite the provincial jurisdiction of this role.

**Conclusion**

The stated requirement for a minimum cabin height of 83 inches in height (210.8 cm) is not supported. Given the importance of minimum cabin dimensions in discriminating between candidate aircraft, it is important that the definition of minimum requirements be based on a sound and comprehensive analysis of accommodation requirements. It is recommended that DND conduct an analysis of the work envelope of SAR Technicians across a complete range of tasks and roles. This analysis should be based on motion capture techniques and complete anthropometric data and should be conducted using either realistic mock-ups or modern software modelling techniques.

8 **Cargo Compartment: "**Carry the standard SAR load of 6,902 lbs/3,130 kg (Annex D) consisting of 400 cubic feet of containerized SAR equipment and crew Aerospace Life Support Equipment (ALSE) dispersed upon NATO (88" X 108") standard pallets and a two-crew position Nav/SensO station (5.10.1). The SAR equipment must be stowed and placed in a manner that allows for visual spotting and conning of the aircraft from the spotter windows. Placement of the SAR load within the cargo compartment must also ensure free and unencumbered access to all SAR equipment while providing sufficient flat and unobstructed workspace immediately adjacent to the primary para/cargo door and alternate para door to permit the preparation and aerial dispatch of personnel and SAR equipment (Annex A, 2.4.1.5). The dimension of this workspace shall provide, as a minimum, a lateral width of 73 inches (185.4 cm), a longitudinal length of 81 inches (205.7 cm) and a vertical height of 81 inches (205.7 cm) (Ref I) [DND, 2006b]."

**Analysis and Discussion**

The "standard SAR load" is not common to either of the current fixed-wing SAR aircraft in the fleet, but was derived to optimize the load for a single aircraft solution. If the CF were to reconsider this approach, the "standard SAR load" would need to be reconfigured. The CC-115 Buffalo can carry a load of only 2000 lb when configured for mountain manoeuvres and therefore does not meet this minimum requirement. In general, the required SAR load changes according to task. Containerized, deployable, roll-on SAR loads might be designed in such a way that this load could be modularized and rapidly optimized for different types of missions with the understanding that missions may change during flight. Such a system could be designed to minimize the spine loading on the individuals responsible for loading, rigging, deploying and unloading the very heavy gear that is required for search and rescue.

The dimensions of the workspace adjacent to the primary para door were defined in DAES TN 54-06-03 (DND, 2006b). However, the report indicated that it was not possible given the means available at that time to conduct a comprehensive analysis to derive such dimensions, "each aircraft has a unique fuselage curvature and therefore this factor was not considered in determining the minimum workspace". An analysis of the space envelope surrounding the body of a SAR Technician conducting SAR tasks should be analyzed as the vertical limits of this space may indeed be most important adjacent to the fuselage of the aircraft. For side-door operations and stowing of equipment, many of the SAR Technicians' activities occur close to the lateral sides of the aircraft fuselage, where the vertical dimensions of this space may be critical.

A workspace analysis that considers the entire body envelope over time is the best way to determine the required width for dispatching SAR personnel and SAR equipment from both the side doors and the ramp. The vertical height of 81 inches derived from the analysis in DAES TN 54-05-04 (DND, 2006a) is predicated on the assumption that vertical 2 inches (5.08 cm) are required above the helmet to accommodate stowed NVGs and an additional 4 inches (10.16 cm) of clearance are required to ensure that the NVGs may be replaced in that position and not jarred during movement. As the SAR Technicians observed at 442 Squadron did not have any requirement to stand upright with stowed NVGs on their helmets this, clearance requirement should not be considered valid.

**Conclusion**

The "standard SAR load" described in the SOR is not currently carried by either the CC-130 Hercules or the CC-115 Buffalo, and indeed cannot be carried by the CC-115 Buffalo but represents an attempt to define a SAR load that is sufficient for most SAR missions. The words "primary para door" should be replaced with the word "ramp." A side cargo door would represent an inefficient and unworkable configuration from a human factors perspective. The deployment of objects such as the toboggan from the side door is an inefficient manoeuvre and should be carried out only when the ramp is unserviceable or when training for this scenario. The height requirement identified in the SOR is not supported. A more comprehensive analysis of the space requirements for tasks carried out by SAR Technicians adjacent to the door should take into consideration the curvature of the fuselage and the complete scope of tasks; such an analysis would yield a more readily supportable estimate of space requirements.

9 **Cargo Compartment: "**A cargo compartment capable of carrying, loading and unloading three patients on the NATO pattern litter and palletized SAR equipment on a standardized NATO 463L (88"x108") pallet without specialized airfield loading or unloading equipment."

**Analysis and Discussion**

A roll-on roll-off system cargo system should be considered mandatory for FWSAR aircraft as the role is one of delivery of equipment and personnel. As air transport is not a primary role for SAR aircraft it is unclear what justification exists to require this system be a NATO standard pallet. Clearly, interoperability requirements make the use of a NATO standard pallet highly advantageous. If a non-NATO standard roll-on, roll-off system were to be adopted it could be made compatible with a NATO standard pallet system; a blank could be engineered so that the system could readily be placed in a NATO pallet. A half-pallet system or similar arrangement configured with a SAR load could then be readily loaded on a transport aircraft. Further analysis might be warranted to consider alternatives to the NATO pallet. There is no doubt that the NATO standard pallet would be optimal in terms of interoperability, however.

More generally, the SOR as written implies that the design and configuration of the equipment contained in the "standard" SAR load does not require analysis and optimization. Informal observation of the activities required to airdrop SAR equipment and parachute personnel suggests that the status quo might not be the most efficient means of accomplishing this. SAR Technicians are currently required to secure, un-secure, manoeuvre and deploy heavy and irregularly shaped equipment. If the equipment were secured on a NATO pallet it is possible that this situation might be somewhat improved, but it remains the case that the individual pieces of kit must be manoeuvred to the exits and rigged for deployment. A well-configured load design is by no means assured through the use of a NATO pallet as this is an airlift rather than SAR standard. There is no real requirement for ease of access to loaded equipment in an airlift role. This situation might be complicated if the EO/IR system is to be part of the palletized system, further constraining the configuration of the cabin in ways that might not be optimal. The design and acquisition of new aircraft might provide an opportunity to revisit how the load is designed and work within the cabin is accomplished. This analysis could be carried out with a view toward creating a modular deployable SAR system that minimizes the requirement for SAR Technicians to secure, un-secure, drag and lift heavy loads about the cabin. If a new roll-on roll-off system were to be designed perhaps this could be done with a view to making components of this system air-droppable. A modular, air-droppable, roll-on roll-off SAR system could be designed to optimize task flow within the cabin and minimize the risk for long-term physiologic injury to SAR Technicians.

The requirement that the FWSAR cargo compartment be capable of carrying, loading, and unloading three patients on a NATO pattern litter without specialized loading and unloading equipment is appropriate for the AME role. The use of ambulance stretchers or ability to accommodate bariatric patients is not discussed, but does form a part of the humanitarian role that is regularly performed by current SAR aircraft.

**Conclusion**

Consideration should be given to the design of a modular roll-on, roll-off SAR system. The requirements to carry, load, and unload three patients on a NATO pattern litter would be supported for any Aeromedical Evacuation (AME) role, and any implementation should be in accordance with ASIC Advisory Publication 61/115/15. The need for a NATO standard pallet is not supported as a mandatory requirement in the SOR; a smaller pallet may be sufficient for SAR equipment. However, compatibility with a NATO standard pallet should be mandatory.

10 **Cargo Compartment:** **"**Cabin floor roller and securing system or cargo handling system optimized for the loading, securing, transport, and off-loading of NATO standard 88" x 108" pallets."

**Analysis and Discussion**

The requirements for loading, securing and unloading cargo is abundantly clear as discussed elsewhere in this report. It follows that a suitable cargo handling system is also required. In the previous section of this report, it is concluded that a pallet system for FWSAR is required and that it should be compatible with a NATO standard pallet but that carriage of a NATO standard pallet should be a rated requirement.

**Conclusion**

For consistency with other assessments in this report, the reference to a NATO standard pallet should be removed from this requirement. Cargo handling and securing provisions are required for the pallet system selected for the SAR equipment.

11 **Manoeuvrability:** **"** Capable of safely and effectively conducting all current search and rescue manoeuvres conducted by the CC-115 Buffalo and the CC-130 Hercules, as specified in the FWSAR SOI, so as to ensure the same or better SAR level of service. In the event of a critical engine failure while searching in confined mountainous terrain (airspeed between 110 and 140 KIAS as per Annex A para 2.4.1.20) and at an altitude of 5,000 feet Mean Sea Level (MSL), must be capable of safely reversing course by executing a level, 45-degree bank, and constant energy turn through 180 degrees of heading change."

**Analysis and Discussion**

The SOR makes clear that DND values the capability to conduct search operations in confined mountainous terrain; however, requirements based solely upon the capabilities of the CC-115 Buffalo and the CC-130 Hercules are not likely to be demonstrable by the potential vendor. This HLMC seems to confound the requirements for satisfactory flying qualities and single-engine manoeuvrability, in the process making a clear requirement for neither.

The necessity for satisfactory flying qualities is implied by the statement that the aircraft be ”capable of safely and effectively conducting all current search and rescue manoeuvres”, however no explicit flying qualities specification is invoked nor is it foreseeable what potential submission on the part of the vendor would establish compliance.

Quantifying the “manoeuvrability” requirement solely in terms of single-engine agility is insufficient. While anecdotal evidence indicates that the CC-115 Buffalo may be capable of ”executing a level, 45-degree bank, and constant energy turn through 180 degrees of heading change” following a failure of the critical engine, this capability is not documented in either of the Buffalo’s technical manuals referenced namely the Aircraft Operating Instructions (AOI) and the Standard Manoeuvre Manual (SMM) (DND, 2009). This assertion implies the unlikely capability that the Buffalo can sustain altitude under a 1.4 g normal acceleration (45° bank turn) on a single engine without loss of airspeed (i.e. “constant energy”). Furthermore, even if the Buffalo possessed the specific excess power required to complete the manoeuvre, it is not documented whether such a manoeuvre can be conducted safely and repeatably. The SOR transfers this ambiguity to the new FWSAR aircraft.

While of fundamental importance to the requirement for manoeuvrability, the fact that a manoeuvre is possible does not warrant that it is safe and repeatable. The SOR attempts to address this by stating in Figure 1 that the FWSAR aircraft possess “sufficient aircraft power and flying qualities (comparable to existing CF FWSAR Aircraft) to ensure the aircraft can safely and effectively manoeuvre during search and rescue operations” (DND, 2006). The requirement, stated thus, is insufficient to select a suitable aircraft. The flying qualities of an aircraft are quantifiable in accordance with an accepted methodology described in (Cooper & Harper, 1969), and this requirement should be explicit in the SOR. This would require that the DND define the acceptable performance parameters for a selection of mission-critical operational SAR tasks, and to assess the flying qualities of the aircraft against those criteria. The rationale for such an assessment is underscored by the fact that the SOR will likely be addressed by transport aircraft that were neither designed specifically for the SAR role nor for operations in confined mountainous terrain. An acceptable requirement should specify that the FWSAR aircraft be required to demonstrate Level 1 flying qualities for all mission-critical SAR tasks in accordance with (Cooper & Harper, 1969). A suitable requirement regarding flying qualities may also invoke an appropriate flying qualities specification, such as MIL-F-8785C (US Department of Defense, 1980) or those invoked in civil Canadian Aviation Regulations, Airworthiness Manual Part 525. In any event, the requirement, as stated by the SOR, that the aircraft possess flying qualities, is insufficient to specify an aircraft suitable for the SAR mission.

**Conclusion**

Single-engine manoeuvre agility is not a conventional design criterion for transport category aircraft, nor is such performance typically tested or documented. Data for the specified manoeuvre is unlikely to be available. The critical parameter defining safe operations in confined mountainous terrain is the minimum sustained level flight turn radius. It is recommended that this requirement be quantified for a specific operating weight and density altitude.

The HLMC for manoeuvrability as written is insufficient to ensure procurement of an aircraft with suitable flying qualities for the SAR mission, and should be rewritten. Alternatively, such manoeuvres can be included in a preliminary SOI referenced by the SOR.

12 **Aircraft Certification:** "Quality/ Aircraft Certification: i) the proposed aircraft design, from which the FWSAR aircraft will be derived, must be either civil certified or military qualified to airworthiness certification standards accepted by the Technical Airworthiness Authority (TAA) as specified in the DND Technical Airworthiness Manual (TAM, Ref E, Part 2, Chapter 5); and ii) The FWSAR aircraft must be capable of meeting the eligibility requirements to obtain an Airworthiness Clearance from the DND TAA as specified in the DND TAM (Ref E, Part 2, Chapter 3)."

**Analysis and Discussion**

This requirement does not relieve the DND's obligation to certify a new aircraft type. It appears the intent is to reduce the level of effort required for DND to meet its obligations by leveraging an existing certification using a process known as Type Design Examination (TDE). Although a candidate aircraft design may have been civil certified to a typical design standard (such as US CFR Title 14 FAR Part 25 for Transport Category Airplanes), this may not provide an acceptable level of safety for FWSAR given the intended use of the aircraft. Civil Certification provides a good starting point for establishing a suitable Canadian military Basis of Certification (BoC), which is how the requirement should be stated.

Part 5, Chapter 1, of the DND Technical Airworthiness Manual (TAM) at Change 5 (DND, 2007b) provides definitions of the "acceptable level of safety" for various classes of Canadian military aircraft. Figure 5-1-2-3 of the TAM provides the hazard probability thresholds at the system level; FWSAR should be classed as "military aircraft," which means the probability of occurrence for a system level hazard assessed as "catastrophic" should not exceed $1x10^{-8}$ per flight hour (or $1x10^{-6}$ at the aircraft level.) The acceptable level of safety should be specified as a requirement the vendor must achieve during DND certification to meet the SOI.

The requirement uses the phrase "…airworthiness certification standards accepted by the TAA..." This appears to imply that the TAA need only assess the BoC. In fact "acceptability to the TAA" of a previous certification consists of two parts: the first is agreement on the BoC as discussed above; the second is TAA confidence in the certifying authority. It is the level of confidence in the certifying authority that determines the scope and depth of the review conducted by the TAA as part of the TDE. Therefore, even if the TAA fully accepts the BoC of the existing certification as directly applicable to FWSAR it is possible that the certifying authority does not have the confidence of the TAA and therefore a full review of the demonstration of compliance against the BoC might be necessary.

The SOR anticipates the basic aircraft will require modifications to meet the needs of FWSAR. Each of these modifications will require certification. The extent of the modifications will determine how well the final design meets the definition of "off-the-shelf" and, consequently, how large the certification effort will be. The CRS review of the CH-149 Cormorant acquisition (DND, 2007a) documents the gulf that can exist between acquiring an airframe and certifying it for the intended purpose.

The TAA does not issue an Airworthiness Clearance (AC). For any new aircraft type or design change, the TAA issues a Technical Airworthiness Clearance (TAC) and the Operational Airworthiness Authority (OAA) issues an Operational Airworthiness Clearance (OAC). The DND/CF Airworthiness Authority (AA) then issues the full AC. The AA is the Chief of the Air Staff (CAS).

The need for a Statement of Operational Requirement to contain the above level of detail regarding what is primarily a technical issue is a point worthy of consideration. The forgoing discussion applies to any aircraft acquired by DND for the CF and is therefore not peculiar to FWSAR. The operational requirement drives the technical requirement and must therefore be described in sufficient detail to facilitate establishing the BoC; however, details of how the technical requirements are to be met are outside the scope of an SOR.

**Conclusion**

It is recommended the wording of this requirement be amended to better reflect the intent of the existing HLMC while accommodating the needs of the TAA.

The wording of the requirement regarding obtaining an airworthiness clearance from the TAA should be amended to reflect the current version of the TAM.

13 **Fleet Size: Quantity.** "A minimum complement of 15 new FWSAR aircraft are required to provide the requisite SAR capability, maintenance, test and evaluation, and training. A more detailed explanation of the FWSAR Aircraft fleet size requirements can be located at Annex B."

**Analysis and Discussion**

The SOR states a minimum of 15 aircraft are required to achieve FWSAR mission readiness requirements of 99% probability that one aircraft and 80% probability that a second aircraft will be continually available for SAR dispatch at each MOB. These and additional mission readiness requirements for training aircraft at the Operational Training Unit (OTU) are listed in section 4.5 of the SOR. The principal factors driving mission readiness are the operational availability of each individual aircraft and the number of bases at which readiness is to be maintained for the primary SAR mission and for training.

SOR Annex B and the Analysis of Fleet Requirements for FWSAR (Bourdon & Rempel, 2005) provide analysis based on individual aircraft operational availability of 80%. Paragraphs 1.10 and 1.11 in Annex B of the SOR discuss the contribution of serviceability to individual aircraft operational availability.

Paragraph 1.11 states "current generation aircraft are designed to be more reliable, maintainable and supportable than the legacy systems they replace" and that "the end result is increased operational availability which is the key determinant for levels of aircraft mission readiness."

There is no analysis of the sensitivity of operational availability to serviceability. Sections 4.4, 4.5 and 4.6 of the SOR list supportability, aircraft mission readiness and reliability as rated requirements. The table of HLMC at SOR Annex E does not require FWSAR to achieve 80% operational availability although minimum fleet size is predicated on this figure. Some aspects of operational availability are not within the control of the aircraft vendor but serviceability is. A minimum level of serviceability could be defined and made a mandatory requirement. Furthermore, the validity of the statistical technique used to perform the analysis is questionable in that it assumes that operational availability of each aircraft is independent of all the other aircraft. However, serviceability of a given fleet is dependant upon the maintenance program common to all aircraft in the fleet.

A DRDC Technical Memorandum (Pall, 2008) describes how operational availability of the CH-149 Cormorant has been below expectations since its introduction primarily due to serviceability issues. This situation represents a risk that required SAR mission readiness may not be achievable with the specified minimum fleet size.

The Canada First Defence Strategy (Government of Canada, 2008) states that the Government in intends to acquire 17 FWSAR aircraft, rather than a minimum of 15 stated in the SOR. It is not known what justification exists for the two different numbers.

The readiness posture analysis in (DND, Director Air Force Readiness, 2008a) concludes that a minimum of 19 aircraft are required to maintain crew proficiency without exceeding the planned yearly flying rate (YFR) per aircraft while maintaining the status quo standby posture.

**Conclusion**

There are conflicting data on minimum number of aircraft required to meet the operational needs of FWSAR that must be resolved. The SOR states the requirement is 15 aircraft; two other references quote 17 and 19 aircraft, respectively.

It is recommended that fleet size sensitivity to operational availability and serviceability be investigated using a statistically valid method. In addition, the minimum level of aircraft operational availability and serviceability should be explicitly stated as a mandatory requirement in the SOR.

14 **Fleet size: Location / Basing.** "FWSAR services will continue to be provided from the four existing FWSAR MOBs (Annex A, para 2.4.2.1). Basing issues are discussed further in Annex B."

**Analysis and Discussion**

The selection of the current four MOBs as the future operating location of FWSAR assets was listed as a project constraint and assumption within the SOR as discussed previously in section 3. A comprehensive assessment of the basing options using historical data is provided in (Bourdon & Rempel, 2005). This analysis shows that the current basing options of Comox, Winnipeg, Trenton and Greenwood ranked fourth in terms of response to 90% of the incidents and 10th for 100% coverage of the Search and Rescue Regions (SRRs) and also 10th for cruise speed required to respond within a 15-hour crew day. Response to SAR incidents in a timely fashion is critical to the survival of those awaiting rescue. Achieving a high level of service in terms of SAR response to an incident is primarily dependent upon: main operating base location, standby posture, aircraft speed, aircraft range, and incident location. As the SOR project team was also constrained to exclude any change in standby posture, the only variables that could be considered to achieve the aim of keeping the same or better SAR level of service to the Canadian people were aircraft range and speed.

As detailed in the analysis of FWSAR fleet requirements (Bourdon & Rempel, 2005), "a fleet that is properly situated is better suited to respond to the Canadian SAR demand", and "the location of the SAR MOBs is perhaps the most straightforward place to start when looking at ways to reduce the cruise speed requirements" or to decrease response time.

The existing bases of Greenwood, Trenton, Winnipeg and Comox do not represent the best option for SAR response as shown in the analysis of FWSAR fleet requirements (Bourdon & Rempel, 2005). Opting to consider using Gander rather than Greenwood as a FWSAR base reduced the distance to cover 90% of the historical SAR incidents examined in the study from 653 nm to 533 nm. This one FWSAR base change to an existing rotary wing SAR base would also benefit response time over the mid-Atlantic Ocean as it would remove a transit and refuelling stop that is necessary for aircraft originating in Greenwood. Such a basing option should not have been excluded under a blanket assumption.

**Conclusion**

The SOR should allow for some flexibility to investigate basing options as relatively small adjustments to basing can have a significant effect on the required minimum cruise speed and maximum range of the aircraft.

15 **Delivery:** “Delivery date of first aircraft as soon as possible but no later than 36 months after contract award and final aircraft delivery no later than 60 months after contract award.”

**Analysis and Discussion**
The analysis in section 3 of this report regarding the off-the-shelf assumption and the need for certification of all design changes, significantly affect this requirement. The time required to deliver a compliant aircraft depends to a large extent on the level of effort required of all parties to achieve Canadian military certification of the basic aircraft and all modifications necessary to meet the needs of FWSAR. The experience of the Cormorant acquisition as documented in the CRS Review (DND, 2007a) in this regard is particularly instructive. Several years have elapsed since the Cormorant was acquired so the lessons learned from that experience may already have been applied to FWSAR and will be reflected in procurement documents yet to be produced such as the RFP.

**Conclusion**
NRC is not in the position to comment extensively on this HLMC as the delivery date requirements should be driven by the state of FWSAR capability at the time of the project launch and the forecasted state to the completion of deliveries. Available funding and the project funding profile will also impact the delivery dates, but both are outside the scope of NRC review. Nonetheless, on the basis that an off-the-shelf purchase is not well defined, it is difficult to make a reasonable estimate of the time required for industry to deliver a compliant aircraft. Consequently, the delivery schedule as currently written may not be achievable and should be reviewed in the context of other SOR amendments.

# 5. Potential Additional HLMC Requirements

Several requirements currently listed as “Tier 1 rated” should be upgraded to be “mandatory” as discussed below:

- Integrated EO/IR sensors and NVG capability; the international state of the art in SAR is rapidly embracing these technologies. Difficulties in introducing them to the existing FWSAR fleet as retrofits demonstrate the value of integrating new sensors in the aircraft from the outset.
- Short gravel runway operation capability;
- Operations using austere airfields;
- Flight into known icing conditions; ground de-icing/anti-icing clearance;
- The 30- year estimated life expectancy (ELE) for the FWSAR aircraft based on an average yearly flying rate (YFR) that meets the capability and level of service requirements.

- Ergonomic design of the seating and workspace at the spotters' windows.
- Compliance with relevant civil operating rules such as access to airspace requiring Performance Based Navigation (PBN) and Reduced Vertical Separation Minima (RVSM) capability; installation of Traffic Collision and Avoidance (TCAS) and Terrain Awareness and Warning Systems (TAWS);

To address long-standing interagency communications deficiencies, Industry Canada has made available a SAR Interagency Frequency (SAR-IF) at 149.080 MHz in the land mobile band for use by on-scene SAR responders (NSS, 2009). The National Search and Rescue Secretariat (NSS) is promoting the adoption of this frequency by all primary and secondary SAR agencies in Canada. Inclusion of this capability should be mandatory for a new FWSAR asset.

# 6. Conclusions

NRC recommends that the FWSAR SOR version 4.1 (DND, 2006) be updated incorporating the recommendations provided in the conclusions to each item analysed in this report. Conclusions from the forgoing sections are repeated below.

**Assumptions**

**Capabilities:** The required FWSAR capability is not clearly articulated by the assumption as written. Reference to existing capabilities of the two aircraft to be replaced should be removed; instead, required capabilities that stand alone should be derived.

**Level of Service (LOS):** The level of service assumption should not be written in terms of that provided by the existing FWSAR fleets. Though it may be derived from what can be achieved under the status quo, it should be expressed in a manner that stands alone, ideally backed by government policy.

**Crew Complement:** The assumption should state that the crew complement of new FWSAR aircraft is assumed to be six positions identified in the references cited in the discussion section. References to existing FWSAR aircraft should be removed. As written in the current SOR, it is appropriate that this be subject to further definition following a comprehensive crew task analysis during later procurements phases of the project.

**Off-the-shelf assumption:** Use of the term "off-the-shelf" should be avoided unless it is anticipated that aircraft may be procured in the form they are currently produced with no design changes.

**Single Aircraft Type assumption:** Despite the preliminary costing data, the assumption of a single aircraft solution should be removed to allow industry to submit single or multi-fleet proposals. Such proposals can then be assessed on the basis of their merits including costs.

**CF Personnel crewing assumption:** Assuming that the FWSAR capability can only be provided by an all-military team while also constraining main operating base locations has a significant impact on the possible solutions to the FWSAR requirement and is inconsistent with existing practices for rotary-wing assets. An in-depth analysis of the cost and potential benefits of providing part of the FWSAR solution through contracted support for elements such as aircraft, aircrew, and maintenance functions may lead to a lower cost solution and a more effective response. A capability-based SOR should not preclude options such as having part of the FWSAR capability contracted outside of the military especially when it is already an existing practice in the rotary wing SAR community.

**Constraints**

**Mission requirements:** Rather than provide the mission scenarios as constraints, the required capability should be articulated in terms of providing a defined level of SAR service to Canadians. The requirement can be expressed as a definition of the geographic areas to be served and the allowable response times to reach those areas and provide aid to SAR victims. Industry can conduct the scenario planning to meet these needs in support of selection of their products.

**Defence Plan scenarios:** Mission and scenario planning should be based on robust data whenever possible. Consideration should be given to accessing the NSS Knowledge Management System, should its availability be timely, to improve this aspect of deriving the FWSAR capability requirements.

**SOI and SSI:** References to SOI of existing FWSAR aircraft should be removed from the SOR. A generic "preliminary SOI" should be written and provided as a reference to the SOR to aid potential vendors in establishing the Basis of Certification for their proposed solutions and to provide a starting point for the SOI of the aircraft eventually selected.

**SAR equipment airlift capability:** The SAR equipment airlift capability constraint is valid provided "relevant SAR equipment" is properly defined.

**Cargo airlift interoperability:** The cargo airlift interoperability constraint is valid as written.

**Level of FWSAR service:** It is recommended that the required level of FWSAR service be defined without reference to the existing aircraft and to clarify what is meant by "level of service" as distinct from "capability".

**FWSAR Asset Replacement:** This constraint is valid as written.

**FWSAR MOBs:** Given the existing SAR role of the Cormorant in Gander, and the improvement in response time of a platform based there, it is unfortunate that such a basing option is excluded due to this constraint. While the option of using Gander in lieu of Greenwood is the only one outlined here, many other viable options exist within the operational analysis document (Bourdon & Rempel, 2005) that should be revisited. Utilizing some contracted fixed-wing SAR response that is strategically postured may provide a cost-effective alternative to alleviate some of the costs associated with establishing or relocating a MOB or requiring an aircraft with high cruise speed for all scenarios.

**FWSAR Standby posture:** Given how sensitive the solution is to standby posture for a vast majority of incidents, consideration should be given to analyzing in detail the cost of an increased 30-minute standby period versus the cost of acquiring much higher performance aircraft in terms of cruise speed. Further, such an investigation should be core to the mandate of the project as any changes in standby posture have significant impact on project costs, personnel levels, aircraft required, yearly flying rate (YFR), infrastructure, and the SAR level of service.

## High Level Mandatory Capability (HLMC) Requirements

**1 Range:** The mandatory range requirement of 1,699nm degrades the capability currently provided by CC-130s in the Trenton and Halifax SRRs, although it would improve the range capability vis-à-vis that provided by CC-115 Buffalos in the Victoria SRR. The very limited 1 hour search capability and the need to refuel to accomplish moderately long range missions is a further degradation of capability vis-à-vis the CC-130. The mandatory range requirement is inconsistent with the stated core objective of the SOR of maintaining or improving the SAR level of service for Canadians and the range requirement must either be increased to match that currently provided to the majority of Canada by the CC-130 or the core objective must be modified to a lower standard than that currently provided.

Alternatively, if the few long distance scenarios are distinguished from the majority of SAR incidents, it may be cost-effective to provide FWSAR coverage for those scenarios using a small number of long-range, relatively high-speed aircraft. The balance of scenarios could then be served by an aircraft with range and speed capabilities more modest than those required by the present SOR.

**2 Response time:** Selecting a minimum cruise speed that does not meet the intent of all of the elements of the program, while potentially excluding many aircraft from competing for the project as a result of the speed chosen is a weakness of the SOR.

**3 Cockpit Visibility:** The requirement as defined fails to delineate the required fields of view in such a way that a clear and objective means of evaluating compliance is made explicit. It is recommended that either a specific angular field of view be specified or a methodology be prescribed whereby a vendor could demonstrate compliance.

**4 Cargo compartment – dimensions based on ergonomic design for SAR Tech tasks:** The inclusion of minimum cabin height and width requirements in the SOR is appropriate. A systematic analysis of the entire work envelope for the tasks to be performed must be carried out in order to derive the minimum requirements for cabin height and width. These techniques are identified as those typically used to ensure adequate cabin space in the background section of DAES TN 54-05-04 (DND, 2006b).

The SOR as worded does not offer supporting evidence to indicate that the tasks required of SAR Technicians may cause "long-term physiologic injury" nor does it suggest a mechanism for such injuries. Furthermore, no evidence is provided to indicate that cabin accommodation would reduce the incidence of the putative back injuries associated with manoeuvring heavy objects in a cramped cabin. Given that it may be possible to establish such evidence through further analysis, it is recommended that a retrospective study of injuries in the SAR Technician population be undertaken if the risk of particular classes of injury is to be used to support cabin spacing requirements.

**5 Cargo compartment – primary and secondary para/door for safe delivery of people and cargo/ min size:** It is recommended that a mandatory requirement for a ramp be explicitly identified in the SOR. Appropriate dimensions for the ramp could be determined via body envelope modelling techniques and identified in the SOR. In order to facilitate safe loading and unloading, it is recommended that the ramp be outfitted with a hydraulic lift capability such that it may be raised and lowered with heavy SAR equipment attached to it.

**6 Cargo compartment – bubble windows:** The inclusion of the SAR spotter bubble windows in the mandatory requirements is appropriate. The requirement that the SAR spotter station be ergonomically sound for the target population should also be mandatory. The requirement should specify the required field of view of the spotter windows and this definition should consider the relationship between the fields of view of the flying pilot and the SAR Team Lead. Consideration should be given to changing the rated requirements to mandatory requirements and to downgrading the window pressurization requirement to a rated requirement.

**7 Cargo compartment – dimensions to allow loading, standing and an aisle:** The stated requirement for a minimum cabin height of 83 inches in height (210.8 cm) is not supported. Given the importance of minimum cabin dimensions in discriminating between candidate aircraft, it is important that the definition of minimum requirements be based on a sound and comprehensive analysis of accommodation requirements. It is recommended that DND conduct an analysis of the work envelope of SAR Technicians across a complete range of tasks and roles. This analysis should be based on motion capture techniques and complete anthropometric data and should be conducted using either realistic mock-ups or modern software modelling techniques.

**8 Cargo compartment – carry standard SAR load plus 2-person workstation and allow use of spotter windows plus workspace:** The "standard SAR load" described in the SOR is not currently carried by either the CC-130 Hercules or the CC-115 Buffalo, and indeed cannot be carried by the CC-115 Buffalo but represents an attempt to define a SAR load that is sufficient for most SAR missions. The words "primary para door" should be replaced with the word "ramp." A side cargo door would represent an inefficient and unworkable configuration from a human factors perspective. The deployment of objects such as the toboggan from the side door is an inefficient manoeuvre and should be carried out only when the ramp is unserviceable or when training for this scenario. The height requirement identified in the SOR is not supported. A more comprehensive analysis of the space requirements for tasks carried out by SAR Technicians adjacent to the door should take into consideration the curvature of the fuselage and the complete scope of tasks; such an analysis would yield a more readily supportable estimate of space requirements.

**9 Cargo compartment – NATO pattern litter for 3 patients plus palletized SAR equipment:** Consideration should be given to the design of a modular roll-on, roll-off SAR system. The requirements to carry, load, and unload three patients on a NATO pattern litter would be supported for any Aeromedical Evacuation (AME) role, and any implementation should be in accordance with ASIC Advisory Publication 61/115/15. The need for a NATO standard pallet is not supported as a mandatory requirement in the SOR; a smaller pallet may be sufficient for SAR equipment. However, compatibility with a NATO standard pallet should be mandatory.

**10 Cargo compartment – cabin floor roller and securing system:** For consistency with other assessments in this report, the reference to a NATO standard pallet should be removed from this requirement. Cargo handling and securing provisions are required for the pallet system selected for the SAR equipment.

**11 Manoeuvrability:** Single-engine manoeuvre agility is not a conventional design criterion for transport category aircraft, nor is such performance typically tested or documented. Data for the specified manoeuvre is unlikely to be available. The critical parameter defining safe operations in confined mountainous terrain is the minimum sustained level flight turn radius. It is recommended that this requirement be quantified for a specific operating weight and density altitude.

The HLMC for manoeuvrability as written is insufficient to ensure procurement of an aircraft with suitable flying qualities for the SAR mission, and should be rewritten. Alternatively, such manoeuvres can be included in a preliminary SOI referenced by the SOR.

**12 Aircraft Certification:** It is recommended the wording of this requirement be amended to better reflect the intent of the existing HLMC while accommodating the needs of the TAA.

The wording of the requirement regarding obtaining an airworthiness clearance from the TAA should be amended to reflect the current version of the TAM.

**13 Fleet Size- quantity:** There are conflicting data on minimum number of aircraft required to meet the operational needs of FWSAR that must be resolved. The SOR states the requirement is 15 aircraft; two other references quote 17 and 19 aircraft, respectively.

It is recommended that fleet size sensitivity to operational availability and serviceability be investigated using a statistically valid method. In addition, the minimum level of aircraft operational availability and serviceability should be explicitly stated as a mandatory requirement in the SOR.

**14 Fleet Size – Location/basing:** The SOR should allow for some flexibility to investigate basing options as relatively small adjustments to basing can have a significant effect on the required minimum cruise speed and maximum range of the aircraft.

**15 Delivery:** NRC is not in the position to comment extensively on this HLMC as the delivery date requirements should be driven by the state of FWSAR capability at the time of the project launch and the forecasted state to the completion of deliveries. Available funding and the project funding profile will also impact the delivery dates, but both are outside the scope of NRC review. Nonetheless, on the basis that an off-the-shelf purchase is not well defined, it is difficult to make a reasonable estimate of the time required for industry to deliver a compliant aircraft. Consequently, the delivery schedule as currently written may not be achievable and should be reviewed in the context of other SOR amendments.

**Acronyms**

| | |
|---|---|
| AC | Advisory Circular (produced by FAA) |
| AC | Airworthiness Clearance |
| AGL | Above Ground Level |
| ADS-B | Automatic Dependent Surveillance - Broadcast |
| ALSE | Aviation Life Support Equipment |
| AME | Aeromedical Evacuation |
| AOI | Aircraft Operating Instructions |
| AWL | Above Water Level |
| BoC | Basis of Certification |
| BoSS | Body Sizing System |
| CAS | Chief of the Air Staff |
| CF | Canadian Forces |
| CFR | Code of Federal Regulations (USA) |
| COTS | Commercial Off the Shelf |
| CORA | Centre for Operational Research Analysis |
| CRS | Chief Review Services |
| DAES | Directorate of Aerospace Engineering Support |
| DND | Department of National Defence |
| DTA | Directorate of Technical Airworthiness |
| DTAES | Directorate of Technical Airworthiness and Engineering Support (DTA and DAES combined) |
| EO/IR | Electro-optical and infrared sensors |
| FAA | Federal Aviation Administration (USA) |
| FAR | Federal Aviation Regulations (USA) |
| FRL | Flight Research Laboratory |
| FWSAR | Fixed-Wing Search And Rescue |
| HLMC | High Level Mandatory Capability |
| IFR | Instrument Flight Rules |
| JRCC | Joint Rescue Coordination Centre |
| KIAS | Knots Indicated Airspeed |
| KMS | Knowledge Management System (NSS) |
| KTAS | Knots True Airspeed |
| LOS | Level of Service |
| MAJAID | Major Air Disaster |
| MHLH | Medium-Heavy Lift Helicopter |
| MOB | Main Operating Base |
| MOTS | Military Off-The-Shelf |
| MoU | Memorandum of Understanding |

| | |
|---|---|
| NATO | North Atlantic Treaty Organization |
| NRC | National Research Council |
| NSS | National Search and Rescue Secretariat |
| NVG | Night Vision Goggles |
| NVIS | Night Vision Imaging Systems |
| OAA | Operational Airworthiness Authority (DND) |
| OAC | Operational Airworthiness Clearance |
| PBN | Performance Based Navigation (ICAO) |
| PMO | Project Management Office |
| PWGSC | Public Works and Government Services Canada, Dept. of |
| RFP | Request for Proposal |
| RVSM | Reduced Vertical Separation Minima |
| SAR | Search and Rescue |
| SAR-IF | SAR Interagency Frequency |
| SAT | Strategic Air Transport |
| SMM | Standard Manoeuvre Manual |
| SOI | Statement of Operating Intent |
| SOIQ | Solicitation of Interest and Qualifications |
| SOR | Statement of Operational Requirements |
| SRR | Search and Rescue Region |
| SSI | Statement of Support Intent |
| TAA | Technical Airworthiness Authority (DND) |
| TAC | Technical Airworthiness Clearance |
| TAM | Technical Airworthiness Manual |
| TAT | Tactical Airlift Transport |
| TAWS | Terrain Awareness and Warning System |
| TCAS | Traffic Collision Avoidance System |
| TDE | Type design Examination |
| TRSET | Transport and Rescue Standardization Evaluation Team |
| VFR | Visual Flight Rules |
| YFR | Yearly Flying Rate |

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**Appendixes**

Appendix A – National Research Council Canada SOR Review Team Members

Appendix B –National Research Council Canada Review Team External Communications

## Appendix A

### National Research Council Canada SOR Review Team Members.

Dany Paraschivoiu, Ing.,MBA. - Order of engineers QC (1991) PMP – PMI (2005)
20 years experience in the aerospace industry mainly as project manager
Bombardier (Mirabel QC)
Boeing (Seattle WA)
Aerospatiale (Tarbes France)
Pilatus Aircraft (Stans Swiss)
L3 MAS (Ottawa ON)
DND DTAES (Ottawa ON)
Ecole Polytechnique - Mech/Aeronautical Engineering (1990) University of Ottawa - MBA (1994)
SOR Review Focus: Project Management

Malcolm Imray, P. Eng, M. Eng., B.Sc. FRL Airworthiness Engineer
20+ years Experience:
Airworthiness Engineer, DND-DTAES 2 yrs
Aeronautical Engineer/ FW Pilot, Sander Geophysics Ltd. 16 yrs
Full time commercial pilot, Peace Air Ltd. 2 yrs
Aerodynamics and Gas Turbine Analyst, GasTOPS Ltd. 2 yrs.
M.Eng. Aeronautical Engineering, 1986
B.Sc. Mechanical Engineering, 1983
SOR Review focus: Airworthiness

Jocelyn Keillor, Ph.D., Senior Research Officer, NRC IAR
1.5 Years, Group Leader, Advanced Interface Group, DRDC Toronto
8.5 Years, Defence Scientist, Human Factors, DRDC Toronto
Fellowship in Neuropsychology, University of Florida, 1999
Ph.D .Neuroscience, University of Waterloo, 1998
SAR related experience: 7 Years Experience leading R&D Projects for NSS, 7 Papers published in the Scientific Literature on Human Factors of SAR systems.
SOR Review focus: Human factors

Robert Erdos, BEng (Mech), MSc, DAR, PEng
Chief Test Pilot, NRC Flight Research Laboratory
16 years military pilot experience; 13 years NRC-FRL
Former operational SAR pilot, CH-113/A Labrador helicopter; 442 Squadron, CFB Comox
Graduate, US Naval Test Pilot School, 1991
Former Air Force rotary-wing SAR Test Pilot
3500 hrs fixed wing pilot in command (PIC); 4500 hrs PIC helicopter
SOR Review focus: Vehicle Technical Requirements;

Paul Kissmann, BEng, MA, QTP fixed wing
Graduate Empire Test Pilot School, Boscombe Down, England, 1996
FRL Research Test Pilot
24 years military experience; 2+ yrs NRC-FRL
6 years military flight test (AETE), 2 years Senior test pilot at AETE (all fleets)
Aerospace system course graduate and instructor (2-1/2 years)
SOR Review focus: Vehicle technical, operational and/or human factors requirements

Tim Leslie, BSc, MSc, FRL Research Pilot
Supervisor Flight Operations and Training, FRL.
18 years military pilot experience; 12 years NRC-FRL
Former DND Staff Officer Pilot Training; Chief of Plans and Support NATO AWACs
6500 hrs fixed wing pilot in command (PIC); 1500 hrs PIC helicopter
Former CF fixed-wing SAR pilot – CC-115 Buffalo with 442 Sqn as Standards and Squadron ICP
SOR Review focus: Vehicle Operational Requirements

## Appendix B

### National Research Council Canada Review Team External Communications

The following is a list of communications between the FRL review team and persons or organizations external to NRC. Each of these was authorized by PWGSC upon request from the FRL team lead.

| Date | Location | Correspondent |
|---|---|---|
| 18-20 Jan 2010 | CFB Trenton | Col Russell Williams, Commander 8 Wing |
| 18-20 Jan 2010 | CFB Trenton | Trenton JRCC Staff |
| 18-20 Jan 2010 | CFB Trenton | 424 Transport and Rescue Sqn Commanding Officer and staff. |
| 18-20 Jan 2010 | CFB Trenton | Transport and Rescue Standardization Evaluation Team (TRSET) staff |
| 25-29 Jan 2010 | CFB Comox | Col Lalumiére, Commander 19 Wing |
| 25-29 Jan 2010 | CFB Comox | 442 Transport and Rescue Sqn Commanding Officer and staff |
| 29 Jan 2010 | Ottawa | National Search and Rescue Secretariat (NSS), Executive Director and staff |
| 19 and 22 Feb 2010 | Ottawa | LCol Rob Coultard, Maj Phil Counsel, and Maj Harding, DND Directorate of Aerospace Requirements, FWSAR.<br><br>Susan Hale, DND Project Manager FWSAR<br><br>Mr.Brian Botting, Senior Industrial Benefits Manager, Industry Canada,<br><br>Mr. David Simpson, representing PWGSC |