ASSAP Action Item #47:

Propose Strawman Values of NIC, NACp, and NACv as a function of SIL that meet the Application Requirements

RTCA SC-186 WG-4 Meeting
ASSAP Subgroup

By: Joel M. Wichgers
e-mail: jmwichge@rockwellcollins.com
Phone: (319) 295-0068

November 6, 2006

Rockwell Collins
Building trust every day

Presentation Outline

- **Motivation**
  - **Possible Strategy to Improve Availability of Surveillance Data to support ASA Applications**
  - **This is one of the first steps to assess this. It is not clear yet, if there is any significant operational availability provided.**
- **Disclaimer!!!!!**
  - **The "strawman" values identified herein need further analysis before they are endorsed by the author.**
    - However, before we do more detailed analysis, we need to quickly assess if there is any significant operational availability to be gained.
- **Initial Strawman Values of NIC, NACp, and NACv as a function of SIL are identified**

Motivation *(Page 1 of 2)*

- **ASSAP may receive Traffic Track data that has significantly higher SIL than is required to perform the active application(s)**
  - **SIL received for some traffic targets may be 3 (indicating 10^{-7} /hr. horizontal integrity) and the active application(s) may only require a SIL of 1 (indicating 10^{-3} /hr. integrity)**
  - **When SIL indicates a higher integrity than needed for the application, is it possible to assess compliance against a different set of minimum "quality thresholds"?**
    - If so, it "may" enhance the application availability.

Enhance Availability of Surveillance Data to Support the Quality Necessary for ASA Applications

Motivation *(Page 2 of 2)*

- **As an example:**
  - **e.g., If an application only needs a 10^{-3} (SIL=1) integrity containment bound of 1 NM (NIC=5), when the reported SIL is 3 (10^{-7}) and NIC=4 (2NM) is that sufficient?**
  - **The simplistic approach of comparing a 99.99999% containment bound against a 99.9% requirement threshold is very conservative, and may result in reducing the operational availability of the ASA surveillance applications**
  - **Comparing against quality thresholds that differ based upon the SIL <u>may</u> enhance application availability**
    - OPEN QUESTION: Is the operational availability significant?
    - This presentation is a first step to answering that open question.

Enhance Availability of Surveillance Data to Support the Quality Necessary for ASA Applications

Action Item #47

- **Action Log for #47 States: "Joel will provide some preliminary NIC/NAC/SIL threshold values for the initial 5 ASA applications based on his proposed alternative 3."**
- **Recall: "Proposed Alternative 3" *(from WP addressing action item #31)***
  - Reference Paper: ASSAP-WP07-xx_Wichgers_Scaling_Discussion_AI#31_2006-08-10)
  - **If the SC-186 community wants to maximize application availability of the received traffic information, then rather than scaling the received quality, I propose that the following be "considered":**
    - Write Surveillance Application Rqmts. based upon received traffic information
      - For example, traffic quality is sufficient application (A_1) when any of the following are valid:
        - When SIL = 0, quality is insufficient
        - When SIL = 1, NIC >= X_1, NAC_P >= Y_1, NAC_V >= Z_1
        - When SIL = 2, NIC >= X_2, NAC_P >= Y_2, NAC_V >= Z_2
        - When SIL = 3, NIC >= X_3, NAC_P >= Y_3, NAC_V >= Z_3
      - Advantage: Keeps the problem in the surveillance community to make reasonable assumptions about application needs versus the reported quality.
        - Many of the surveillance application requirements are based upon good engineering judgment, especially the initial situational awareness applications.
      - Concern: delay in re-evaluating application requirements in the ASA MASPS.

Recall ADS-B Quality Parameters
NIC = Navigation Integrity Category

NIC (Note 1)	Horizontal and Vertical Containment Bounds	Comment
0	$R_C \geq 37.04$ km (20 NM)	Unknown Position Integrity
1	$R_C < 37.04$ km (20 NM)	RNP-10 containment radius
2	$R_C < 14.816$ km (8 NM)	RNP-4 containment radius
3	$R_C < 7.408$ km (4 NM)	RNP-2 containment radius
4	$R_C < 3.704$ km (2 NM)	RNP-1 containment radius
5	$R_C < 1852$ m (1 NM)	RNP-0.5 containment radius
6	$R_C < 1111.2$ m (0.6 NM)	RNP-0.3 containment radius
7	$R_C < 370.4$ m (0.2 NM)	RNP-0.1 containment radius
8	$R_C < 185.2$ m (0.1 NM)	RNP-0.05 containment radius
9	$R_C < 75$ m and VPL < [112 m]	e.g., WAAS HPL, VPL
10	$R_C < 25$ m and VPL < [37.5 m]	e.g., WAAS HPL, VPL
11	$R_C < 7.5$ m and VPL < [11 m]	e.g., LAAS HPL, VPL

Note: "Comment" column has been proposed to be deleted in the NIC and SIL change proposals for DO-289, DO-242A, DO-260A, and DO-282

Disclaimer!!!

- **Disclaimer!!!!!**
  - **The "strawman" values identified herein need further analysis before they are endorsed by the author.**
- **Two Methods used to Develop Potential ASA Application Surveillance Requirements as a Function of SIL**
  - **First Method: Based upon applying statistics to the existing ASA MASPS requirements**
    - Simplifying assumptions (e.g., distributions are well-behaved)
  - **Second Method: Based upon "engineering judgment"**
    - These strawman values would need more comprehensive investigation before they are endorsed by the author
- **However, before we do more detailed analysis, we need to quickly assess if there is any significant operational availability to be gained.**

First Method

Apply Statistics to Existing ASA MASPS Requirements

First Order Analysis Approach

- **The ASA MASPS "requirements" were treated as "golden" and statistics was used to see if alternate requirements relationships were also satisfied.**
  - **Ideally, there is a tradeoff of surveillance quality (not only NIC, NACp, SIL, NACv, but also latency, update rate, etc.)**
  - **However, this first order approach is limited to scaling the maximum Rc associated with the required NIC, as a function of SIL**
    - NACp and NACv have not been changed
  - **Horizontal Distribution Scaling Factors are based on the Rayleigh Distribution (ratio of number of sigmas to achieve a given probability)**
  - **It may be possible to up-scale the NACp for applications that only require 99% confidence, rather than down-scaling the NIC.**
    - This analysis has scaled the requirements for Rc and hence affected the NIC

- **Note: It may be possible to re-assess the ASA MASPS requirements for the situational awareness applications, and judge that accuracy (NACp) is sufficient, rather than an integrity containment bound.**
    - However, this was viewed to be outside the scope of this analysis.

Discussion

- **Integrity bounding is concerned with the probability in the "tails" of the distribution**
  - **Concerned with "fat tailed" distributions**
- **NIC is meant to encompass both "fault-free" and "faulted" performance [Containment Bound]**
  - **The tails of the distribution are significantly influenced by faulted performance**
- **Typically, it is conservative to "down" scale**
  - **Basic conversion factors are arguably conservative for down scaling from $(1-10^{-x})$ to $(1-10^{-y})$ where x > y [e.g., scaling $(1-10^{-7})$ to $(1-10^{-5})$]**
- **Typically, it is <u>not</u> conservative for "up" scaling**
  - **Basic conversion factors are NOT conservative for up scaling from $(1-10^{-x})$ to $(1-10^{-y})$ where x < y**
    - However, it is possible to select an appropriate scaling factor to address "up" scaling, although, it is not needed for this paper

This method is just 'conservatively' "down" scaling

Selection of Scaling Factor

- **To select scaling factor, it would be nice to:**
  - **Know the shape of the error distribution**
    - However, that is NOT required. We just need to select an appropriate scale factor that it bounds probability of exceeding the limit
  - **The Horizontal position error distribution for GPS is**
    - "Roughly" Rayleigh distributed for "Fault Free" performance
      - It is theoretically a Gaussian in two dimensions
    - What about "Faulted" performance
      - Not a well-behaved function, as it depends on the failure mode
      - Can overbound with the right selection of scale factor
  - **The Vertical position error distribution for GPS is**
    - "Roughly" Gaussian distributed for "Fault Free" performance
      - It is theoretically Gaussian
    - What about "Faulted" performance
      - Not a well-behaved function, as it depends on the failure mode
      - Can overbound with the right selection of scale factor
  - **Initial Analysis has assumed that Horizontal Scaling Factor can be determined using a Rayleigh Distribution**
    - Can be applied to GPS or FMS sources (believed to be conservative)

Guassian and Rayleigh Distributions

α	$1 - \alpha$	Gaussian Distribution [Minimum $R_{(1-\alpha)}$]	Rayleigh Distribution [Minimum $R_{(1-\alpha)}$]
5% or (0.05)	95%	1.9600 σ	2.4477 σ
1% or (10^{-2})	99%	2.5758 σ	3.0349 σ
0.1% or (10^{-3})	99.9%	3.2905 σ	3.7169 σ
0.001% or (10^{-5})	99.999%	4.4170 σ	4.7985 σ
4.8×10^{-6}	99.99952%	4.573 σ	not needed
0.00001% or (10^{-7})	99.99999%	5.34 σ	5.6777 σ

Note: 4.8×10^{-6} per hour is conservatively equivalent to 2×10^{-7} / 150 seconds (i.e., multiply 2×10^{-7} by 24 exposure periods of 150 seconds).

Guassian and Rayleigh Distributions

Conversion from $(1-\alpha_1)$ to $(1-\alpha_2)$	Conversion Factors	
	Gaussian Distribution	Rayleigh Distribution
95% to 99%	2.5758 / 1.9600 = 1.3142	3.0349 / 2.4477 = 1.2399
95% to 99.9%	3.2905 / 1.9600 = 1.6788	3.7169 / 2.4477 = 1.5185
$(1-10^{-3})$ to $(1-10^{-2})$	2.5758 / 3.2905 = 0.7828	3.0349 / 3.7169 = 0.8165
$(1-10^{-5})$ to $(1-10^{-2})$	2.5758 / 4.4170 = 0.5832	3.0349 / 4.7985 = 0.6325
$(1-10^{-5})$ to $(1-10^{-3})$	3.2905 / 4.4170 = 0.7450	3.7169 / 4.7985 = 0.7746
$(1-10^{-7})$ to $(1-10^{-2})$	2.5758 / 5.34 = 0.4824	3.3049 / 5.6777 = 0.5822
$(1-10^{-7})$ to $(1-10^{-3})$	3.2905 / 5.34 = 0.6162	3.7169 / 5.6777 = 0.6546
$(1-10^{-7})$ to $(1-10^{-5})$	4.4170 / 5.34 = 0.8272	4.7985 / 5.6777 = 0.8451

Scale factor is determine by a ratio of number of standard deviations

ASSA and FAROA – Method #1

- ASA MASPS Requirements are highlighted in Yellow
- Scaled Rc for SIL=2 and SIL=3, to be equivalent to the Rc of the ASA MASPS requirement @ SIL=1.

SIL	NIC	NAC_P	NAC_V
0	N/A	N/A	N/A
1	NIC ≥ 9 (R_C < 75m)	$NAC_P \geq 9$ (EPU<30m)	$NAC_V \geq 2$ (3 m/s)
2	NIC ≥ 9 (R_C< 97m)	$NAC_P \geq 9$ (EPU<30m)	$NAC_V \geq 2$ (3 m/s)
3	NIC ≥ 9 (R_C<115m)	$NAC_P \geq 9$ (EPU<30m)	$NAC_V \geq 2$ (3 m/s)

Notes:

1. Rationale: A horizontal containment radius of 75 meters with a 99.9% confidence (SIL=1), can equivalently be satisfied with a containment radius of: a) 96.8 meters (75 / 0.7746) with a 99.999% confidence (SIL=2), or b) 114.6m (75 / 0.6546) with 99.99999% confidence (SIL=3).
2. When SIL=0, it satisfies degraded quality if $NAC_P \geq 8$ (i.e., 92.6m).

- No benefit from statistical scaling, because of the quantization levels.
  - To get to NIC=8, Rc needs to get to 185.2m.

Enhanced Visual (EV) Approach – Method #1

- ASA MASPS Requirements are highlighted in Yellow.
- Scaled Rc for SIL=2 and SIL=3, to be equivalent to the Rc of the ASA MASPS requirement @ SIL=1.

SIL	NIC	NAC_P	NAC_V
0	N/A	N/A	N/A
1	NIC ≥ 7 (R_C < 0.2NM)	NAC_P ≥ 7 (EPU<0.1NM)	NAC_V ≥ 1 (10 m/s)
2	NIC ≥ 7 (R_C< 0.26NM)	NAC_P ≥ 7 (EPU<0.1NM)	NAC_V ≥ 1 (10 m/s)
3	NIC ≥ 7 (R_C<0.31NM)	NAC_P ≥ 7 (EPU<0.1NM)	NAC_V ≥ 1 (10 m/s)

Notes:

1. Rationale: A horizontal containment radius of 0.2NM with a 99.9% confidence (SIL=1), can equivalently be satisfied with a containment radius of: a) 0.258NM (0.1NM / 0.7746) with a 99.999% confidence (SIL=2), or b) 0.306NM (0.2NM / 0.6546) with 99.99999% confidence (SIL=3).

- No benefit from statistical scaling, because of the quantization levels.
  - To get to NIC=6, Rc needs to get to 0.6 NM.

Conflict Detection (CD) – Method #1

- **ASA MASPS Requirements are highlighted in Yellow.**
  - **Assumes Baro Altitude for vertical**
- **Scaled Rc to be equivalent to the Rc of the ASA MASPS requirement.**

SIL	NIC	NAC_P	NAC_V
0	N/A	N/A	N/A
*	NIC ≥ 7 (R_C < 0.5NM)	$NAC_P \geq 5$ (EPU<0.5NM)	$NAC_V \geq 2$ (3 m/s)
1	NIC ≥ 6 (R_C < 0.6NM)	$NAC_P \geq 5$ (EPU<0.5NM)	$NAC_V \geq 2$ (3 m/s)
2	NIC ≥ 6 (R_C< 0.8NM)	$NAC_P \geq 5$ (EPU<0.5NM)	$NAC_V \geq 2$ (3 m/s)
3	NIC ≥ 6 (R_C<0.86NM)	$NAC_P \geq 5$ (EPU<0.5NM)	$NAC_V \geq 2$ (3 m/s)

Notes:

* Requirements is 10^{-2}/hr.

1. Rationale: A horizontal containment radius of 0.5NM with a 99% confidence, can equivalently be satisfied with a containment radius of: a) 0.61NM (0.5NM/0.8165) with a 99.9% confidence (SIL=1), b) 0.79NM (0.5NM / 0.6325) with a 99.999% confidence (SIL=2), or c) 0.86NM (0.5NM / 0.5822) with 99.99999% confidence (SIL=3).

- **Modest benefit (highlighted in green) from statistical scaling, because of the quantization levels.**
  - **To get to NIC=6, Rc needs to get to 0.6 NM. To get to NIC=5, Rc needs to get to 1NM.**

EV Acquisition – Method #1

- **ASA MASPS Requirements are highlighted in Yellow.**
  - **Assumes Baro Altitude for vertical**
- **Scaled Rc to be equivalent to the Rc of the ASA MASPS requirement.**

SIL	NIC	NAC_P	NAC_V
0	N/A	N/A	N/A
*	NIC ≥ 5 (R_C < 1NM)	NAC_P ≥ 5 (EPU<0.5NM)	N/A
1	NIC ≥ 5 (R_C < 1.2NM)	NAC_P ≥ 5 (EPU<0.5NM)	N/A
2	NIC ≥ 5 (R_C< 1.6NM)	NAC_P ≥ 5 (EPU<0.5NM)	N/A
3	NIC ≥ 5 (R_C<1.7NM)	NAC_P ≥ 5 (EPU<0.5NM)	N/A

Notes:

* Requirements is 10^{-2}/hr.

1. Rationale: A horizontal containment radius of 1NM with a 99% confidence, can equivalently be satisfied with a containment radius of: a) 1.22NM (1NM/0.8165) with a 99.9% confidence (SIL=1), b) 1.58NM (1NM / 0.6325) with a 99.999% confidence (SIL=2), or c) 1.72NM (1NM / 0.5822) with 99.99999% confidence (SIL=3).

- **No benefit from statistical scaling, because of the quantization levels.**
  - **To get to NIC=4, Rc needs to get to 2 NM.**

Conclusions for Method #1

- **Appears that there is little benefit from this method as applied by the receiver (user of transmitted information)**
  - **For the initial 5 basic "situational awareness" applications**

- **There may be value in statistical scaling applied by the transmit function, that has access to the source reported quality factors (e.g., HPL)**
  - **This could reduce the transmitted NIC, if it was known that the applications in a given airspace would only need a given value of integrity containment.**
  - **However, this would drive changes to the STP and Link MOPS, and I do not expect that SC-186 will want to entertain such ideas unless there is a very significant operational availability enhancement.**
    - Outside the scope of the ASSAP group

Second Method

Engineering Judgment

(additional analysis needed to validate strawman values)

Method #2 – Engineering Judgment

- **ASA MASPS Requirements for EV Acquisition and Conflict Detection (CD) are 99%**
  - **If the 99% ASA MASPS integrity risk requirements are correct, then these applications requirements should be able to be satisfied with just a NACp check, when a "valid" position is reported (i.e., no NIC or SIL check should be required).**

EV Acquisition & CD – Method #2

- **EV Acquisition:**
  - **Two thresholds: "Good" within +/- 15 degrees, and "Degraded" within +/- 30 degrees**

SIL	NIC	NAC_P	NAC_V
N/A	N/A	$NAC_P \geq 5$ (EPU<0.5NM) and equivalent bearing uncertainty < 30deg. (+/- 15 deg.)	N/A

Note:

1. EV Acquisition application only defined out to 10NM from own-ship. Recommend that the +/- 15 deg. accuracy be the criteria for displaying all airborne traffic as "good", and +/- 30 deg. Be the accuracy criteria for displaying airborne traffic as "degraded".

- **CD**

SIL	NIC	NAC_P	NAC_V
N/A	N/A	$NAC_P \geq 5$ (EPU<0.5NM)	$NAC_V \geq 1$ (10 m/s)

ASSA and FAROA – Method #2

- **ASA MASPS Requirements for ASSA and FAROA**
  - **Have two thresholds "Good" and "Degraded"**
  - **Good**

SIL	NIC	NAC_P	NAC_V
0	N/A	N/A	N/A
1	$NIC \geq 9$ ($R_C < 75m$)	$NAC_P \geq 9$ (EPU<30m)	$NAC_V \geq 2$ (3 m/s)
2	$NIC \geq 8$ (R_C <185.2m)	$NAC_P \geq 9$ (EPU<30m)	$NAC_V \geq 2$ (3 m/s)
3	$NIC \geq 8$ (R_C <182.2m)	$NAC_P \geq 9$ (EPU<30m)	$NAC_V \geq 2$ (3 m/s)

  - **"Degraded": Surveillance data is degraded where there is a higher position uncertainty, but still provides degraded SA**
    - ASSA and FAROA surface traffic targets could get confusing if they are shown relative to the map in significantly different positions than they actually are located.

SIL	NIC	NAC_P	NAC_V
N/A	N/A	$NAC_P \geq 8$ (EPU<92.6m)	N/A

EV Approach – Method #2

SIL	NIC	NAC_P	NAC_V
0	N/A	N/A	N/A
1	NIC ≥ 7 (R_C < 0.2NM)	NAC_P ≥ 7 (EPU<0.1NM)	NAC_V ≥ 1 (10 m/s)
2	NIC ≥ 6 (R_C < 0.6NM)	NAC_P ≥ 7 (EPU<0.1NM)	NAC_V ≥ 1 (10 m/s)
3	NIC ≥ 6 (R_C < 0.6NM)	NAC_P ≥ 7 (EPU<0.1NM)	NAC_V ≥ 1 (10 m/s)

Presentation Conclusion

- **Strawman values of NIC, NACp, and NACv have been developed as a function of SIL**
- **Two methods were used to establish these strawman**
  - **Method 1: Applying Statistics to Existing ASA MASPS Rqmts.**
  - **Method 2: Engineering Judgment**
- **Motivation**
  - **Possible Strategy to Improve Availability of Surveillance Data to support ASA Applications**
  - **This is one of the first steps to assess this. It is not clear yet, if there is any significant operational availability provided.**
- ***Note: The "strawman" values identified herein need further analysis before they are endorsed by the author.***