PRELIMINARY ANALYSIS OF REQUIREMENTS FOR CAT IIIB LAAS *

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BIOGRAPHY

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ABSTRACT

The FAA is in the early stages of performing analyses leading to the specification for a Performance Type 3 (PT 3) Local Area Augmentation System (LAAS) Ground Facility (LGF) capable of supporting Category IIIb (CAT IIIb) precision approach and landing operations. This paper presents a preliminary examination of integrity, continuity and availability requirements for a PT 3 LGF. The requirements for PT 3 are more stringent than for PT 1 (supports CAT I), particularly with regard to integrity performance. Consequently, the probabilities of missed detection for PT 3 ranging source fault monitors are found to be somewhat smaller than for PT 1. However, the exposure time for the more stringent integrity requirements is shorter than for PT 1. Therefore, the probability of failure of a ground reference receiver during the exposure time for PT 3 is actually less than was previously assumed. As a result, new smaller values of parameters used in aircraft protection level computations are proposed. An initial allocation of continuity requirements is made based on rationale similar to that for PT 1. However, the multiple reference consistency check (MRCC) used in the LGF to compare corrections among reference receivers must meet requirements for both continuity and integrity. The analysis indicates that the PT 3 MRCC threshold needs to be set higher than for PT 1, in order to meet the more stringent integrity requirement for wrong exclusion of a reference receiver. The higher MRCC threshold leads to the achievement of lower continuity risk, allowing a reallocation of continuity requirements to other risk areas. Predicted availability of GPS satellite geometry to meet PT 3 requirements is found to be 0.994 for the originally proposed Vertical Alert Limit (VAL) of 5.3 m. However, if PT 3 VAL can be kept at the 10-m level used for PT 1, availability is predicted to be 0.999.

INTRODUCTION

Background

The Federal Aviation Administration's (FAA's) Global Positioning System (GPS) Local Area Augmentation System (LAAS) ground facility (LGF) is intended to provide performance capable of supporting various precision approach and landing operations. A performance type (PT) defines a specific level of required accuracy, integrity and continuity for the ground (and airborne) equipment. On the other hand, an approach and landing operation category (CAT) is characterized by a decision altitude/height (DA/H) and the extent to which auto-land is provided. The relationship between PT of the LGF and CAT of operation supported is given in Table 1 [1]. The most stringent requirements are associated with PT 3 because it provides guidance for CAT IIIb auto-land through touchdown and rollout. The FAA has already published a specification for the PT 1 LGF [2] and is in the early stages of developing a specification for the PT 3 LGF.

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Table 1. Operational Categories Supported by LAAS Performance Types

Performance Type	Operational Category	DA/H (ft)	Auto-land
1	I	≥ 200	Not necessarily
2	II	≥ 100	Visually monitored
2	IIIa	≥ 50	Visually monitored
3	IIIb	none	Fully automatic

Purpose and Organization of Paper

This paper presents a preliminary analysis of requirements associated with a PT 3 LGF capable of supporting CAT IIIb landings. Integrity is examined first because performance is significantly more demanding for PT 3 than for PT 1. Several topics related to continuity are discussed next. For additional insight the paper also presents predicted availability of GPS satellite constellation geometry needed to meet several variations of PT 3 requirements. The paper then summarizes some prospective areas where the future PT 3 LGF specification may need to be more stringent than is the specification already published for the LAAS PT1 LGF. The paper concludes with identification of some areas where further analysis is needed. It should be emphasized that the analysis in this paper is preliminary and subject to change, particularly in response to revisions of the PT 1 specification and other work that affects the interpretation of PT 3 requirements.

INTEGRITY ANALYSIS

Integrity Requirements

Integrity requirements for the LAAS signal in space (SIS) are shown in Table 2 [1]. Note that relative to PT 1 the allowable integrity risk decreases by nearly two orders of magnitude for PT 2 and PT 3. However, some relief is provided by a much shorter exposure time, corresponding to application of the more stringent risk to only the final stages of the operation. Note that for PT 3 the integrity risk must be provided over an exposure time of 15 s for vertical guidance (same as for PT 2), but 30 s for lateral guidance. This results from use of lateral guidance for rollout after touchdown in a PT 3 operation.

Table 2. LAAS Signal In Space Integrity Requirements [1]

Performance Type	Exposure Time (s)	Integrity Risk
1	150	$2x10^{-7}$
2	15	10^{-9}
3	Vertical 15 Lateral 30	10^{-9}

Integrity Risk Allocation Tree

Figure 1 shows a proposed integrity risk allocation tree for PT 3. This tree closely resembles the corresponding tree for PT 1 in [2]. Since the broadcast corrections are used for both vertical and lateral guidance, the tree assumes the more demanding lateral guidance exposure time of 30 s. Allocations at the top level, second level and left side of third level have already been specified elsewhere (as indicated by the referenced paragraph numbers). Furthermore, Integrity Risk due to VHF Data Broadcast (VDB) Message Corruption is left at the value specified for PT 1, even though the corresponding performance would be a factor of 150 / 30 = 5 better over the shorter exposure time for PT 3. It is proposed to decrease the allocation to the other failures from $1x10^{-8}$ per 150 s approach (PT 1) to $1x10^{-10}$ per 30 s (PT 3). Because of the difference in exposure times this represents a decrease of only a factor of 20 and is not believed to be problematic. The above rationale leaves the bulk of the $7.5x10^{-10}$ allocated to Cases Not Covered by Protection Level Integrity Risk for allocation to Failures in Ranging Sources ($6.0x10^{-10}$). Assuming 12 ranging sources, monitors for each of six fault modes receive an allocation of $6.0x10^{-10}$ / 72 = $8.33x10^{-12}$ per satellite. The lowest level in the tree shows the fault monitor missed detection probability (P_{md}) needed to achieve the allocated integrity risk. The values shown will be derived later in the paper after first considering the Protection Level Integrity Risk for ease of exposition.

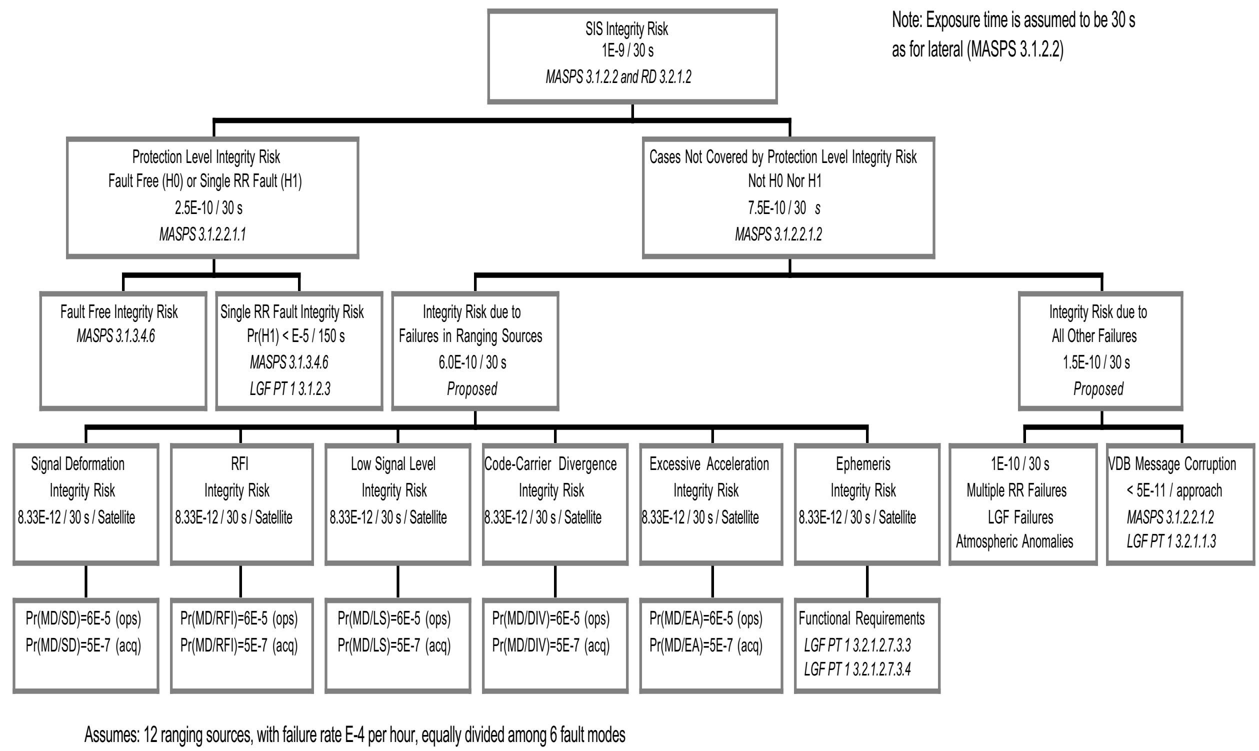

Figure 1. Integrity Risk Allocation (30 s Exposure Time)

Protection Level Equations and Parameters

The aircraft computes protection levels that bound the position error with a required probability. Protection levels are computed under two hypotheses: 1) the fault-free hypothesis (H_0) or 2) the hypothesis that the jth ground reference receiver has failed ($H_{1,j}$). Each protection level is compared to an alert limit, which is the maximum position error that can be exceeded with the probability provided by the protection level bound. Although protection levels are computed in both vertical and lateral dimensions, only vertical protection levels will be discussed in this paper because meeting the alert limit is more difficult in the vertical dimension. Equations for the vertical protection levels are given in [1] as

$$VPL_{H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} S_{i,vert}^2 \sigma_i^2} = K_{ffmd}\sigma_v \tag{1}$$

$$VPL_{H1,j} = \left|\sum_{i=1}^{N} S_{i,vert} B_{i,j}\right| + K_{md}\sigma_{vert,H1} \tag{2}$$

where N is the number of satellites in the position solution, $S_{i,vert}$ is the vertical coefficient for the ith satellite in the solution, $B_{i,j}$ is the B value for the ith satellite and jth reference receiver and

$$\begin{aligned} \sigma_i^2 &= \sigma_{pr\_gnd,i}^2 + \sigma_{other,i}^2 ; \\ \sigma_{other,i}^2 &= \sigma_{air,i}^2 + \sigma_{iono,i}^2 + \sigma_{tropo,i}^2 \end{aligned} \tag{3}$$

$$\sigma_{vert,H1}^2 = \sum_{i=1}^{N} S_{vert,i}^2 \left(\frac{M_i \sigma_{pr\_gnd,i}^2}{M_i - 1} + \sigma_{other,i}^2 \right) \tag{4}$$

where M_i is the number of reference receivers providing corrections for the ith satellite.

The fault-free protection level (VPL_{H0}) essentially limits the satellite geometry so that the vertical alert limit (VAL) is not exceeded due to rare, but fault-free errors. On the other hand, the protection level $VPL_{H1,j}$ uses real time B values which attempt to estimate the error in the average correction due to a fault in the jth reference receiver's measurement of the correction for the ith satellite. For each type of protection level the required bounding probability of the total vertical error is provided by the missed detection multiplier (K_{ffmd} or K_{md}) under the assumption that the error has a Gaussian distribution with the corresponding standard deviation.

Allocation of the total protection level integrity risk to the H_0 and H_1 protection levels and the computation of K_{ffmd} and K_{md} are detailed in Appendix E of [1]. Therein, an equal allocation of the total risk among the H_0 hypothesis and the M H_1 hypotheses is assumed. The resulting equations for P_{ffmd}, K_{ffmd} and P_{md}, K_{md} are

$$P_{ffmd} = \frac{P_{vpl}(MI)}{(M+1)P(H_0)} = \frac{1.25\times10^{-10}}{(M+1)P(H_0)} \; ;$$
$$K_{ffmd} = Q^{-1}\left(\frac{P_{ffmd}}{2}\right) \tag{5}$$

$$P_{md} = \frac{M\times P_{vpl}(MI)}{(M+1)P(H_1)} = \frac{M\times1.25\times10^{-10}}{(M+1)P(H_1)} \; ;$$
$$K_{md} = Q^{-1}(P_{md}) \tag{6}$$

where Q(x) is the single sided tail probability of a Gaussian distribution beyond x, and $P_{vpl}(MI)$ is the total probability of Misleading Information allocated to H_0 and H_1 in the vertical dimension. An equal allocation between vertical and lateral [1] has been assumed to give the result for PT 3 as $P_{vpl}(MI) = 2.5\text{x}10^{-10} / 2 = 1.25\text{x}10^{-10}$.

For determining P_{ffmd} it is assumed that the a priori probability of the fault-free condition $P(H_0) \sim 1$. The resulting values for K_{ffmd} are computed in [1] and repeated in Table 3 for later use in this paper.

Table 3. Values of Fault-Free Missed Detection Multiplier K_{ffmd} for PT 3

M = 3		M = 4	
P_{ffmd}	K_{ffmd}	P_{ffmd}	K_{ffmd}
$1.56\text{x}10^{-11}$	6.641	$1.25\text{x}10^{-11}$	6.673

The calculation of P_{md} involves the a priori probability of a single reference receiver fault $P(H_1)$. Note the probability of a fault of one particular reference receiver is $P(H_1)$ / M. To meet PT 1 requirements $P(H_1)$ must not exceed 10^{-5} per approach [1]. Values of K_{md} assuming $P(H_1) = 10^{-5}$ are calculated in [1] and repeated in the first row of Table 4. However, the integrity requirement exposure time for PT 1 is 150 seconds, while for PT 3 it is either 30 s (lateral) or 15 s (vertical). Thus, it is suggested that $P(H_1)$ used in the calculation of K_{md} for PT 3 can be decreased by a factor of 150 / 30 = 5 for lateral and 150 / 15 = 10 for vertical. The resulting values of P_{md} to achieve the same integrity risk are correspondingly higher by the same factors than those computed in [1]. The second and third rows in Table 4 show the results for K_{md} assuming the shorter exposure times for PT 3.

Table 4. Values of Missed Detection Probability P_{md} and Multiplier K_{md} for PT 3

Exposure Time	M = 3		M = 4	
	P_{md}	K_{md}	P_{md}	K_{md}
150 s [1]	$9.4\text{x}10^{-6}$	4.28	$1.0\text{x}10^{-5}$	4.27
30 s (lateral)	$4.7\text{x}10^{-5}$	3.91	$5.0\text{x}10^{-5}$	3.89
15 s (vertical)	$9.4\text{x}10^{-5}$	3.73	$1.0\text{x}10^{-4}$	3.72

Ranging Source Monitor Missed Detection Probabilities

The performance of the ranging source monitors is characterized by a missed detection probability for a certain size error. Derivation of the required missed detection probability will be discussed here. The maximum allowable pseudorange error (MERPR) to be missed with the associated probability will be discussed in the next section of the paper. The following analysis is a simplified version of that described in [3] to obtain the corresponding results for PT 1. In general the P_{md} is found from the following relationship

$$P_{md} = \frac{\text{Risk}}{P_{fault}} \tag{7}$$

where P_{fault} is the a priori probability of fault and Risk is the required integrity risk. The a priori satellite failure rate is assumed to be 10^{-4} per hour. Assuming equal likelihood of each of the six fault modes gives an a priori probability of 10^{-4} / 6 = $1.7\text{x}10^{-5}$ per hour. The two circumstances that must be considered are: 1) presence of a latent fault when the satellite is initially acquired and 2) occurrence of a fault during operational use of the satellite. A mean time to respond of 1 hour is assumed giving an a priori probability of latent fault of 1 / (1 / ($1.7\text{x}10^{-5}$)) = $1.7\text{x}10^{-5}$. The P_{md} required for acquisition is

$$P_{md}(\text{acquisition}) = \frac{8.33\times10^{-12}}{1.7\times10^{-5}} = 5\times10^{-7} \tag{8}$$

For operations, the exposure time is 30 seconds (lateral). The a priori probability of fault is (30 / 3600)($1.7\text{x}10^{-5}$) = $1.4\text{x}10^{-7}$. The P_{md} required for operations is therefore

$$P_{md}(\text{operations}) = \frac{8.33\times10^{-12}}{1.4\times10^{-7}} = 6\times10^{-5} \tag{9}$$

It should be pointed out that the above values of P_{md} derived for PT 3 are somewhat more demanding than the corresponding values of P_{md}(acquisition) = $1.1\text{x}10^{-4}$ and P_{md}(operations) = 10^{-3} for PT 1 [2].

Ranging Source Monitor Maximum Allowable Error in Pseudorange (MERPR)

Since the ranging source monitors operate in the range domain, a method is needed to translate a bound on the error in the pseudorange correction to a bound on the resulting error in the position domain. The LGF does not know what combination of ranging sources is being used by the aircraft. Therefore, it does not know exactly how much the error on each satellite is amplified when it is translated into the position domain. However, it may be assumed that VPL_{H0} is implemented in the aircraft and thus, the standard deviation of the vertical error due to errors from all satellites, σ_V, is correspondingly limited (refer to equation (1)). Based on this knowledge it is shown in [4] that a suitable MERPR can be defined as proportional to σ_i

$$MERPR_i = F\sigma_i \tag{10}$$

Recall from equation (3) that σ_i includes ground, airborne, tropospheric and ionospheric errors. The smaller these errors are, the worse the geometry allowed by VPL_{H0} could be, and thus, the smaller MERPR should be. However, the ground system does not have knowledge of the tropospheric and ionospheric residual errors at the aircraft. Furthermore, it is not desirable to place a limit on how small the airborne error could be. Therefore, to be conservative it will be assumed (as was done for PT 1 in [2]) that all errors except the ground contribution are zero giving

$$MERPR_i = F\sigma_{pr\_gnd,i} \tag{11}$$

MERPR was derived for two cases in [4]. Undetected ranging errors on all satellites at once (MERPRAS) and an undetected error on only one satellite at a time (MERPROS). The MERPROS case is of most interest here and the corresponding equation is derived in [4] as

$$MERPROS_i = K_{ffmd}\sqrt{1-\left(\frac{K_{mdffs}}{K_{ffmd}}\right)^2}\,\sigma_{pr\_gnd,i} \tag{12}$$

where K_{mdffs} is the multiplier corresponding to an allowance for errors on the N – 1 fault-free satellites. Two values of K_{mdffs} are illustrated. K_{mdffs} = 0 corresponds to no allowance for the fault-free satellite errors. K_{mdffs} = 4.89 corresponds to an allowance for the fault-free satellite errors equal to the missed detection probability of $5\text{x}10^{-7}$ for acquisition. For M = 4, using the value of K_{ffmd} = 6.67 from Table 3 gives

$$MERPROS_i = 6.67\sigma_{pr\_gnd,i}\ ;\ K_{mdffs} = 0 \tag{13}$$

$$\mathrm{MERPROS_i} = 6.67\sqrt{1-\left(\frac{4.89}{6.67}\right)^2}\,\sigma_{pr\_gnd,i}$$

$$= 4.54\sigma_{pr\_gnd,i}\ ;\ K_{mdffs} = 4.89 \quad (14)$$

Figure 2 shows the resulting values of $\mathrm{MERPROS_i}$ as a function of satellite elevation angle, assuming $\sigma_{pr\_gnd,i}$ meets the ground accuracy designator C4 requirement [2].

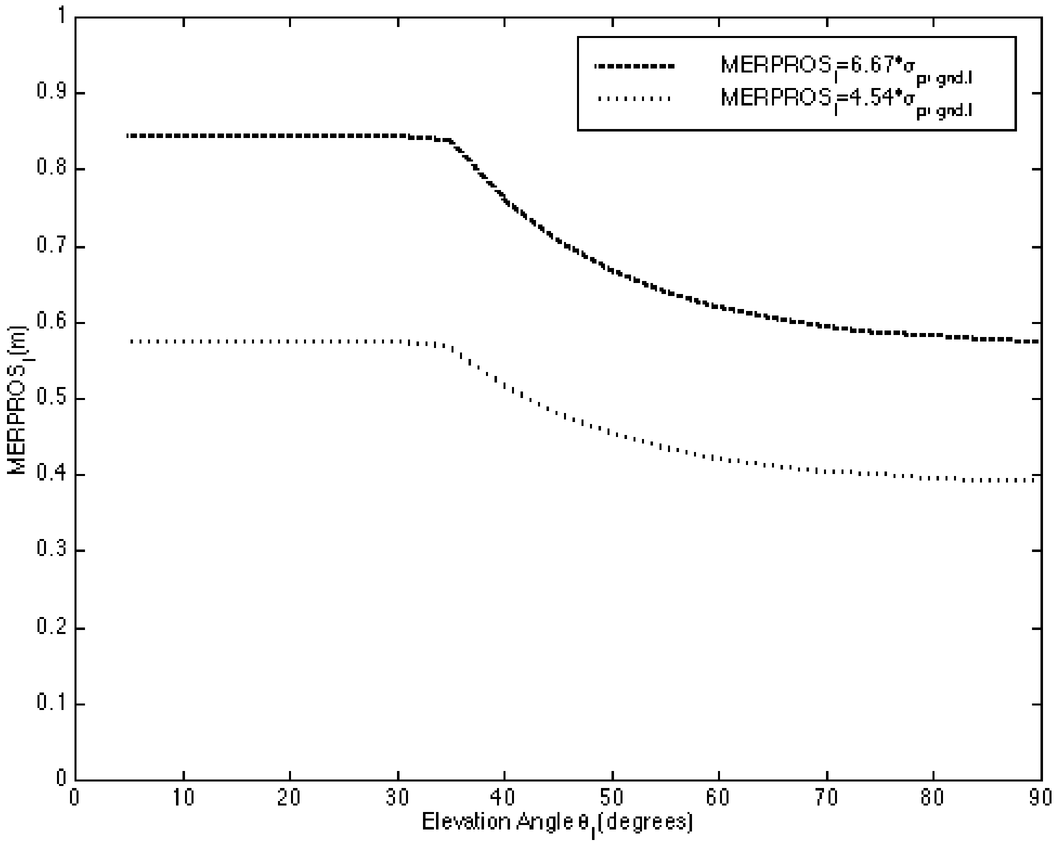

Figure 2. Graph of MERPROS as Function of Elevation

CONTINUITY ANALYSIS

Initial Allocation

For PT 3 the continuity risk exposure times are 15 s for vertical and 30 s for lateral (same as integrity exposure times). Since the continuity risk allocations for lateral and vertical are almost identical, the analysis will be illustrated for the longer lateral exposure time of 30 s. Figure 3 shows an initial (will be subsequently revised) continuity risk allocation tree for PT 3 lateral guidance. All allocations in the tree are already specified in the LAAS MASPS [1] or LGF specification [2] except those at the very lowest level. This level corresponds to the allocation of $2.0\text{x}10^{-7}$ risk among RR & Other Fault Free Detects, Sigma pr_gnd Fault Free Detection and B Value Fault Free Detection. An initial allocation is proposed based on rationale similar to that used to develop the corresponding tree for PT 1 (Appendix G of [2]). This rationale allocates roughly 1/10 th of the total risk to Sigma pr_gnd Fault Free detection and divides most of the risk roughly equally between the other two monitors. Note that the resulting continuity risk allocated to B Value Fault Free Detection is $1.0\text{x}10^{-7}$.

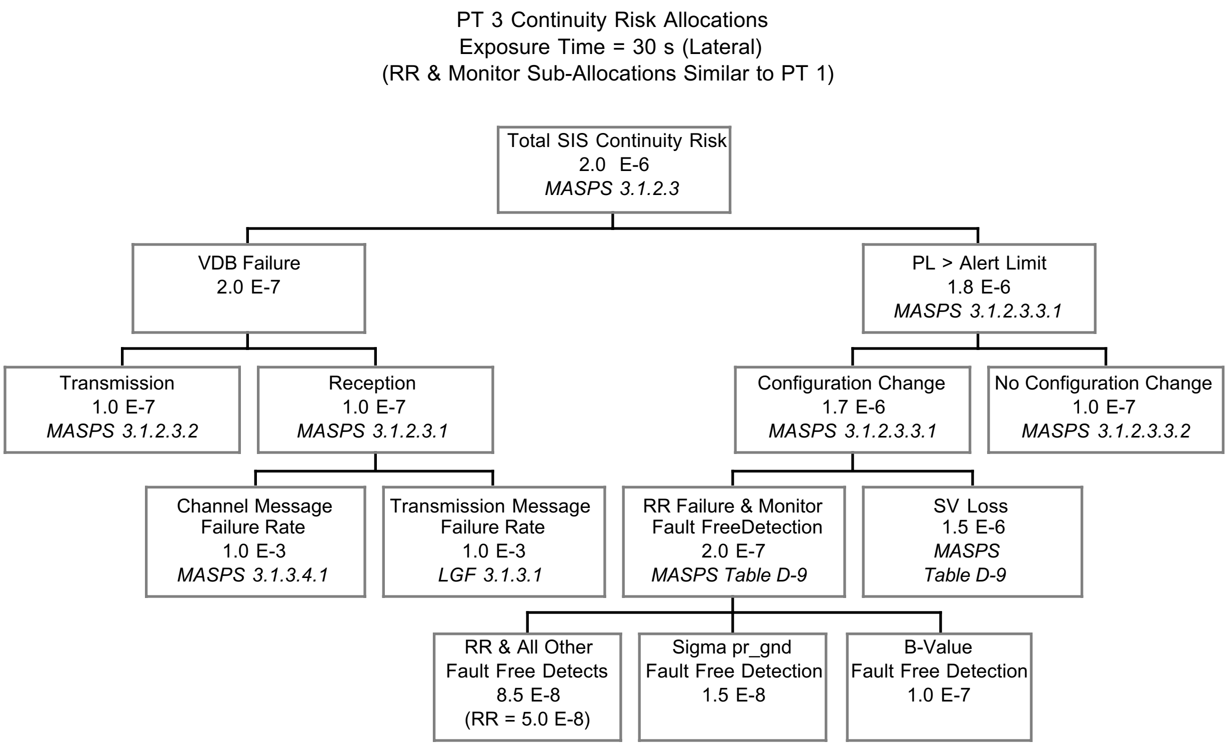

Figure 3. Initial Continuity Risk Allocation Tree

MRCC Analysis

B value monitoring in the LGF is sometimes referred to as the Multiple Reference Consistency Check (MRCC) and has been analyzed extensively in previous work [5]. On an individual satellite basis, a B value is computed for the hypothesis that a particular reference receiver is faulted. The B value estimates the error contribution in the average correction from all receivers due to the supposedly faulted receiver. This error is estimated by checking the consistency of the correction from the suspect receiver with the corrections from the other receivers. If the inconsistency in the corrections exceeds a threshold T_B, a B value detection occurs. If the satellite is being tracked by more than two receivers, an attempt can be made to exclude the faulty receiver and continue using corrections for the satellite from the remaining receivers. In addition to the probability of not detecting a faulty receiver at all, the integrity risk is impacted by the probability the wrong receiver is excluded (P_{WE}). Increasing the threshold T_B decreases P_{WE}, but increases the minimum detectable error. However, decreasing T_B increases the continuity risk due to fault-free detections. Therefore, it is desirable to choose the smallest value of T_B that meets both continuity risk and integrity risk requirements. Recall that the initial continuity risk allocation for B value fault-free detections is 1.0×10^{-7}. It is desirable to have P_{WE} in the LGF be comparable to P_{md} from the H_1 protection level equations in the aircraft. Referring back to Table 4 and assuming M = 3 reference receivers gives the required $P_{WE} = 4.7 \times 10^{-5}$.

An analysis similar to that in for PT 1 [5] was repeated for PT 3 and the results are given in Table 5. Note that a threshold of $T_B = 5.7\sigma_B$ meets the continuity risk requirement but does not provide small enough P_{WE}. However, increasing the threshold to $T_B = 6.7\sigma_B$ meets the integrity risk requirement. The corresponding continuity risk achieved (1.5×10^{-10}) is much smaller than the initial allocation of 1.0×10^{-7}.

Table 5. Threshold (T_B) Needed to Satisfy Requirements for Continuity Risk (CR) and Probability of Wrong Exclusion (P_{WE})

T_B/σ_B	CR[1] /decision/sat	CR[2] total/30 s	P_{WE}
5.7	$1.4x10^{-8}$	$1.0x10^{-7}$	$4.9x10^{-4}$
6.7	$2.1x10^{-11}$	$1.5x10^{-10}$	$4.7x10^{-5}$

[1] Independent decision ~ every 150 s due to carrier smoothing

[2] (Column 2)x36x30/150 (assuming 6 critical satellites, code and code rate B value checks) and M = 3 reference receivers.

Revised Continuity Risk Allocation

The above analysis suggests that the continuity risk allocation for B value fault-free detections can be decreased from the initial allocation ($1x10^{-7}$). A new allocation of $1x10^{-8}$ is proposed, since this value is a conservative limit on continuity risk actually achieved ($1.5x10^{-10}$) due to meeting the more stringent integrity requirement. A correspondingly revised continuity risk allocation tree for PT 3 is given in Figure 4. The excess risk $1x10^{-7} - 1x10^{-8} = 9x10^{-8}$ is reallocated equally between RR & Other Fault Free Detects and Sigma pr_gnd Fault Free Detection.

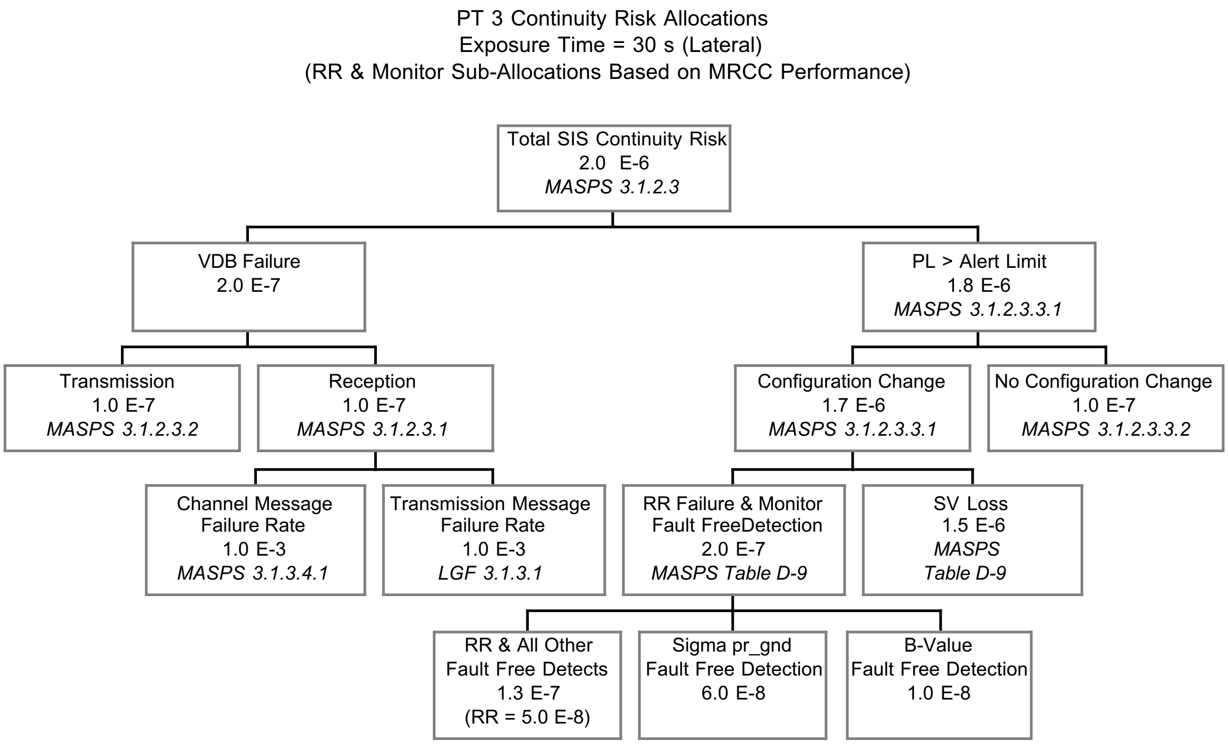

Figure 4. Revised Continuity Risk Allocation Tree

Continuity Risk Associated With Protection Level H1

Recall from the discussion on integrity that a protection level $VPL_{H1,j}$ is computed in the aircraft to bound the vertical position error under the hypothesis that the jth reference receiver is faulty. Recall also from equation (2) that $VPL_{H1,j}$ uses the B values ($B_{i,j}$) for each satellite i for which the jth reference receiver is producing differential corrections. Even if there is no fault on the jth reference receiver, the $B_{i,j}$ values undergo random fluctuations that can cause an alert due to $VPL_{H1,j}$ exceeding VAL. The impact of such fault-free alerts on continuity risk is captured in a predictive form of VPL_{H1} given by [1]

$$PVPL_{H1} = K_{ffd}\sigma_{B,vert} + K_{md}\sigma_{vert,H1} \qquad (15)$$

where the multiplier K_{ffd} determines the level of position error that will be exceeded with the probability of fault-free detection given M reference receivers and

$$\sigma^2_{B,vert} = \sum_{i=1}^{N} S^2_{i,vert} \frac{\sigma^2_{pr\_gnd,i}}{M_i - 1} \qquad (16)$$

$PVPL_{H1}$ is compared to VAL to ensure that the satellite geometry will allow enough margin between VAL and $K_{md}\sigma_{vert,H1}$ for an acceptable fault-free detection probability from the random B value component of the $VPL_{H1,j}$. The required continuity risk is based on the value for PL > Alert Limit for the No Configuration Change case (refer to Figure 4). Corresponding values for K_{ffd} are derived in [1].

$PVPL_{H1}$ is not used for PT 1 (it does not appear in [6]), but will be used for PT 3 because continuity risk is of more concern during the final phase of a CAT IIIb landing. While the values for K_{ffd} derived in [1] are still believed to be correct, smaller values for K_{md} have been proposed earlier in this paper and would change the impact of using $PVPL_{H1}$. As a limiter of satellite geometry, $PVPL_{H1}$ can be more stringent than VPL_{H0}. Thus, the availability results in the next section are based on using $PVPL_{H1}$, rather than VPL_{H0}. Recall that the maximum allowable undetected error from the ranging source integrity monitors was derived from the geometry limit provided by VPL_{H0}. However, since $PVPL_{H1}$ may be more stringent, further work should be done to determine if larger values of MERR can be derived from a generalized relationship between ranging error and position error ensured by the $PVPL_{H1}$ geometry limit.

AVAILABILITY ANALYSIS

The availability of satellite geometry for PT 3 is computed using the $PVPL_{H1}$ criterion equation (15). Figure 5 shows the results with vertical scale ranging from 0.9999 at the bottom to 0.0 at the top of the graph. Individual bars indicate the daily average availability at 25 locations in the U.S., including Hawaii, Alaska and Puerto Rico. The right-most bar in each group is the average over all locations. Four groups of bars are shown. The first two groups of results (starting from the left) correspond to VAL = 5.3 m. as in [1]. Note that for K_{md} = 4.27 (as computed in [1]), the PT 3 availability average over all locations is about 0.9935. Decreasing K_{md} to 3.72 (as proposed above in this paper) produces a slight improvement in the average availability to 0.9958. A proposal has been advanced to keep VAL for PT 3 at the 10-m level used for PT 1 [7]. The last two groups of results predict PT 3 availability for VAL = 10 to be 0.9990 for K_{md} = 4.27, with a slight improvement to 0.9992 for K_{md} = 3.72.

SUMMARY OF POTENTIAL CHANGES FOR PT 3

LGF Specification [2]

- New Integrity Risk Allocation Tree (Appendix G) P_{md} decreases from 1.1×10^{-4} to 5.0×10^{-7} (acquisition) and from 10^{-3} to 6.0×10^{-5} (operations)
- MERPR – Maximum Allowable Undetected Error in Ranging Source (Tables 3-3 and 3-4) $5.8\sigma_{pr\_gnd}$ increases to $6.7\sigma_{pr\_gnd}$ and $4.9\sigma_{pr\_gnd}$ decreases to $4.54\sigma_{pr\_gnd}$
- B Value Check (3.2.1.2.7.5.6.1 & 3.2.1.2.7.6.1.1) T_B increases from $5.6\sigma_B$ to $6.7\sigma_B$ (30 s exposure time) to meet integrity performance
- New Continuity Risk Allocation Tree (Appendix G)

LAAS MOPS [6]

- Since exposure time reduced from 150 s (CAT I) to 30 s (CAT III lateral) smaller values of K_{md} in protection level equations may be used (than in MASPS Table 3-13 [1]).

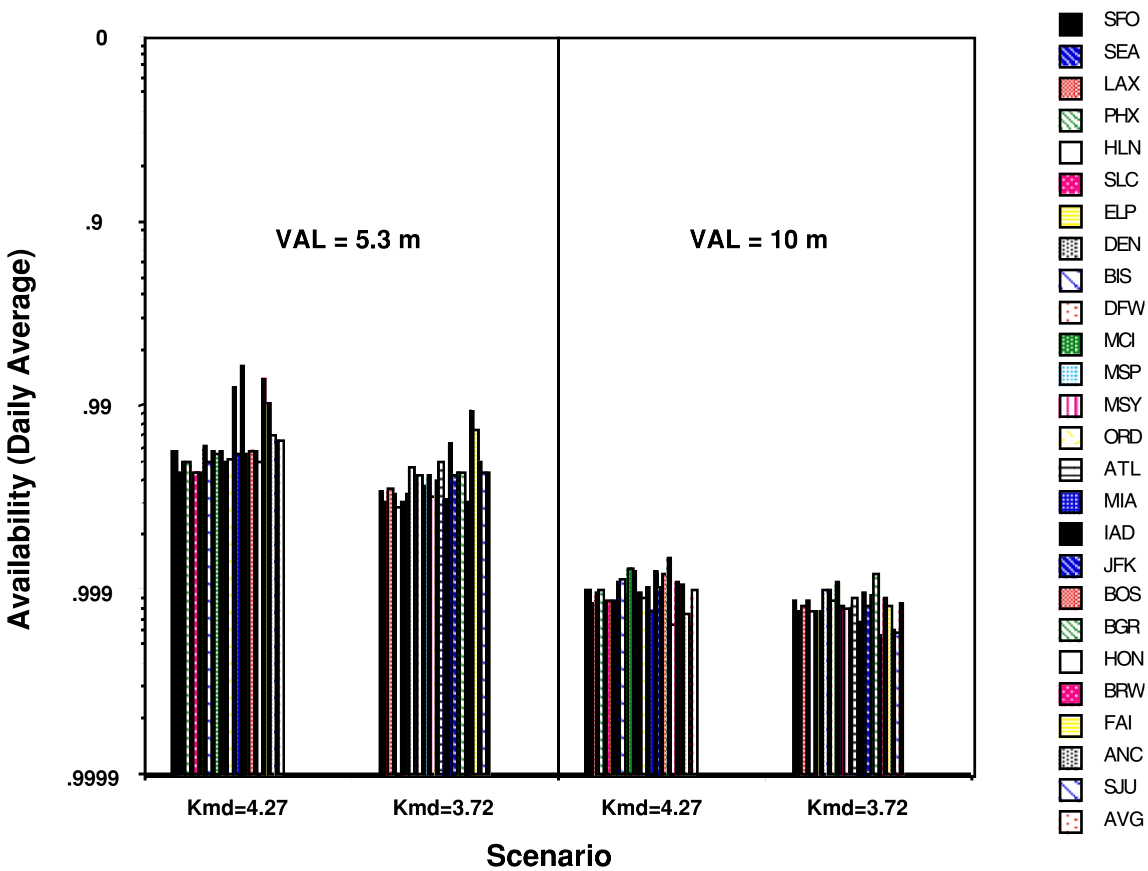

Figure 5. PT 3 Availability – PVPL$_{H1}$, M = 4, K$_{ffd}$ = 5.50
(Courtesy of Tom Hsiao)

FURTHER TOPICS FOR ANALYSIS

- Use predictive protection levels to limit satellite geometry, allowing larger values of MERPR.
- Monitoring for satellite ephemeris errors by the LGF.

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