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EGNOS Performance at System CDR

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Presentation overview

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Introduction

- System Performance requirements
- System Architecture

Performance Justification Methodology

- Methodology
- Tools

CPF CDR main performance results

System CDR main performance results

Conclusion

Introduction

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- In April 2002 EGNOS has passed its Critical Design Review
- A key element of this review was the justification of system performance foreseen to be achieved at this stage of the project.
- Indeed some requirements are expressed with very low probabilities (Integrity and Continuity) and demands special care
- Relevant methodology had to be put in place together with the adapted tools to support it

Introduction - Performance

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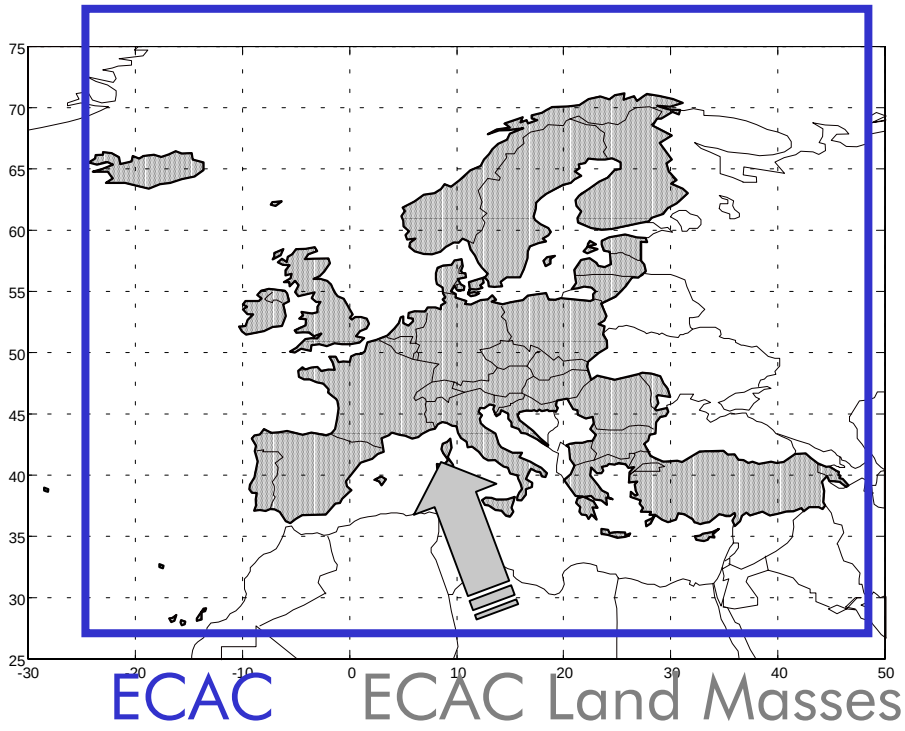
– EGNOS Performance requirement can be split into 4 categories which are Accuracy, Integrity, Continuity and Availability to be met on a specific service area

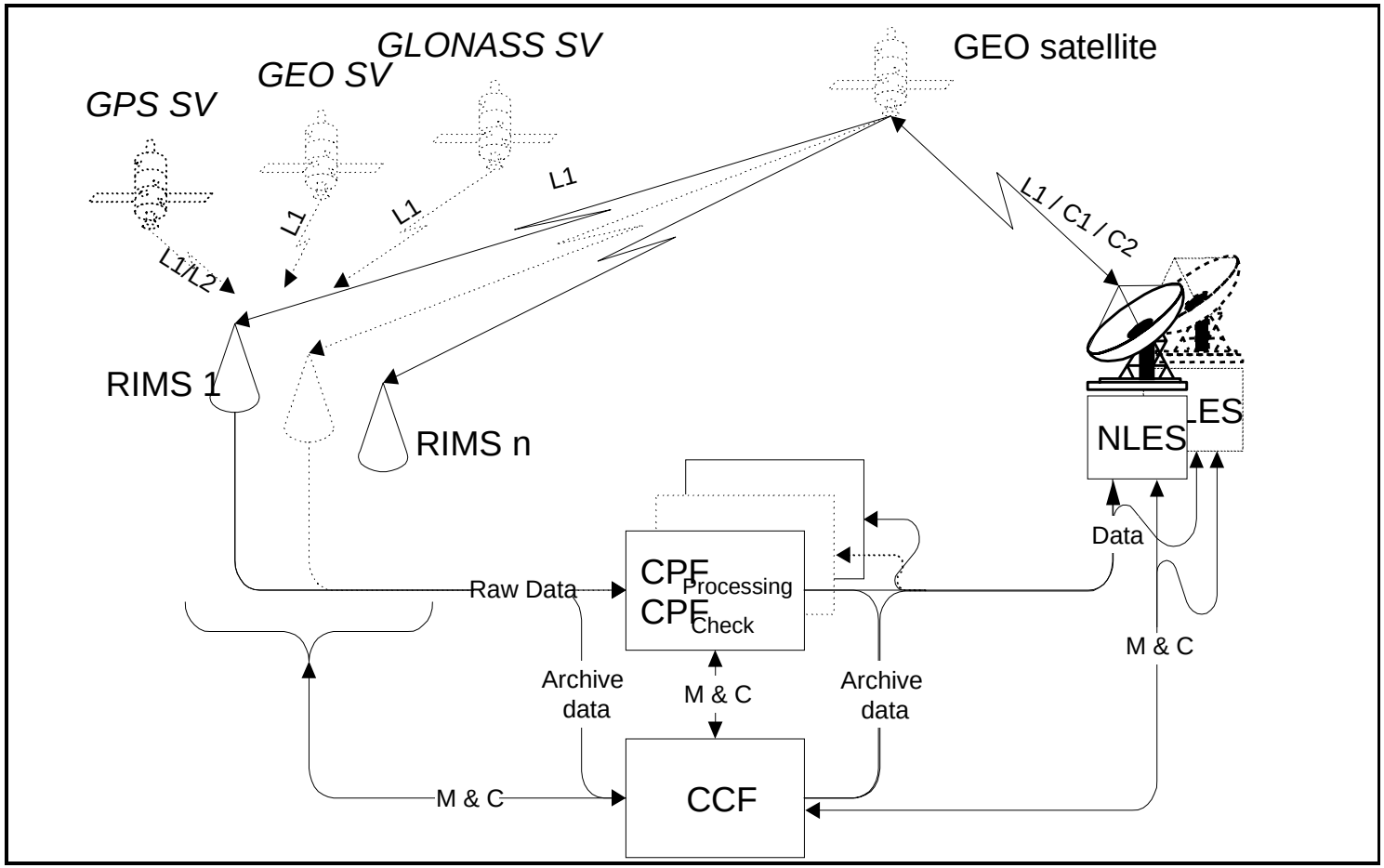
EGNOS AOC SYSTEM REQUIREMENTS	Level 2 (wo Iono corrections)	Level 3A (with all corrections including Iono)
XNSE 95%	100 m (H)	7.7 m (V) 7.7m (H)
Protected Alert Limit	556m (H)	20 m (V) 20 m (H)
Integrity Risk	10^{-7}/h	2.10^{-7} /appr.
Time to alert (2)	10 s	6 s
Continuity risk Navigation Service	10^{-5} /h	8.10^{-5} /appr.
Availability	0.999	0.95 (Objective 0.99)
Service Area	ECAC	ECAC land masses



ECAC ECAC Land Masses

Introduction- Architecture

EGNOS Performance relies first on a robust architecture



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Justification Methodology - Accuracy

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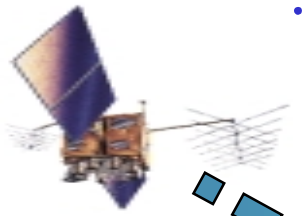

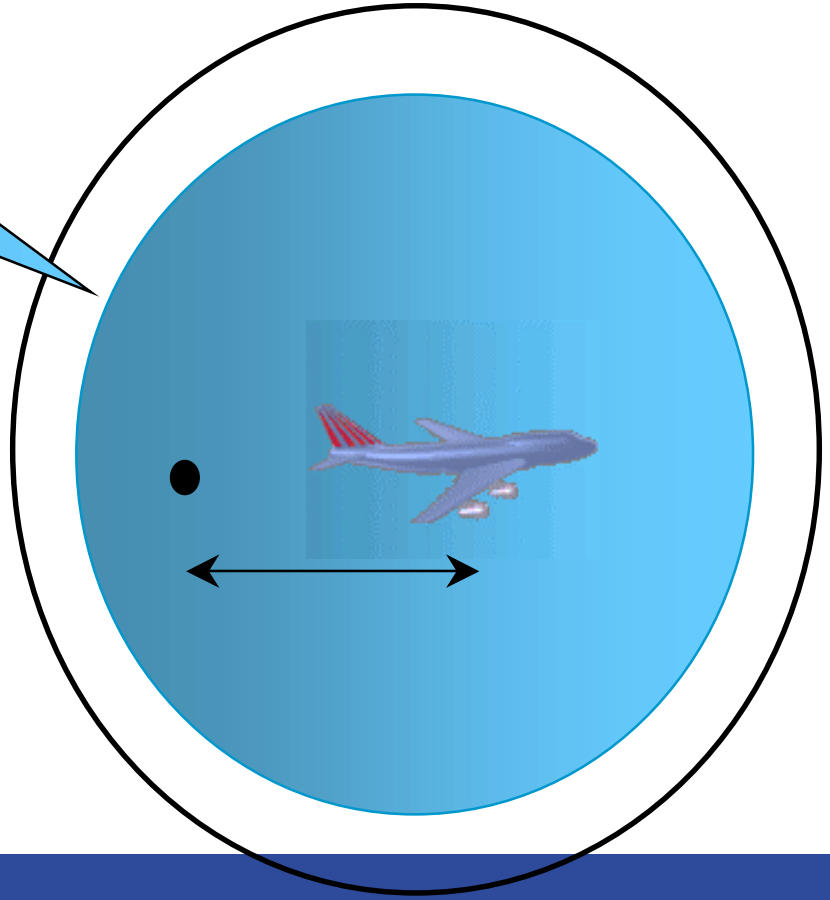

True Position

The **Accuracy** is the *"the error between true position and the estimated one"*

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Justification Methodology - Accuracy

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- **Accuracy expressed as a 95% statistics**
  Only nominal behaviour affects such type of figure
  Low event probability are drown in the statistics

- Accuracy is quantified under **nominal conditions** in terms of:
  - *RIMS Environment*
    Return from site surveys to define noise, multipath and interference levels
  - *Ionosphere Conditions*
    Provided by ESA with the support of Ionosphere European expert (IET)
  - *Satellite constellation*
    Nominal MOPS constellation (no failure)

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Justification Methodology - Availability

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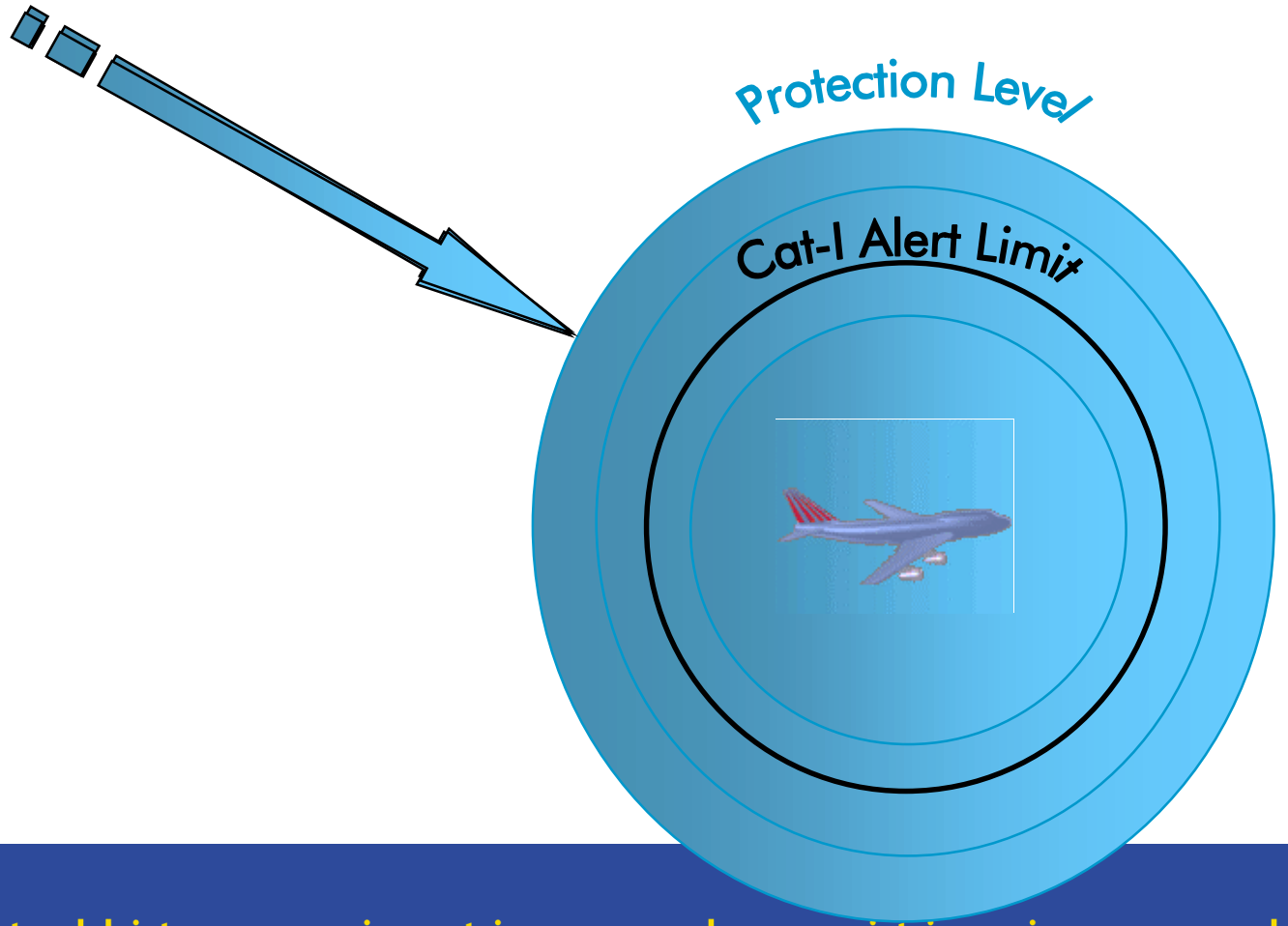
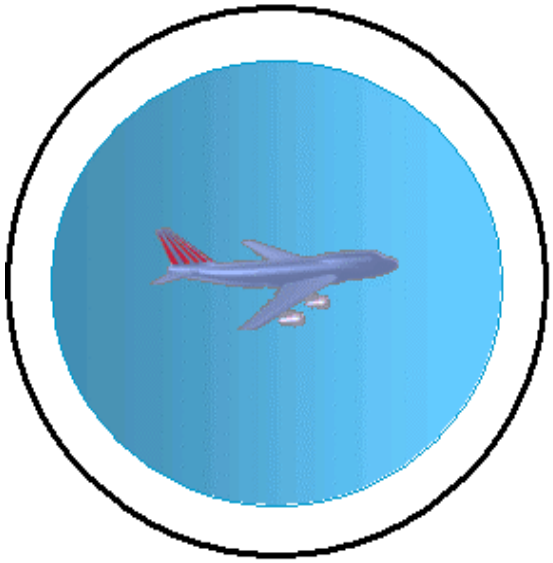
XPL Available: **Yes**



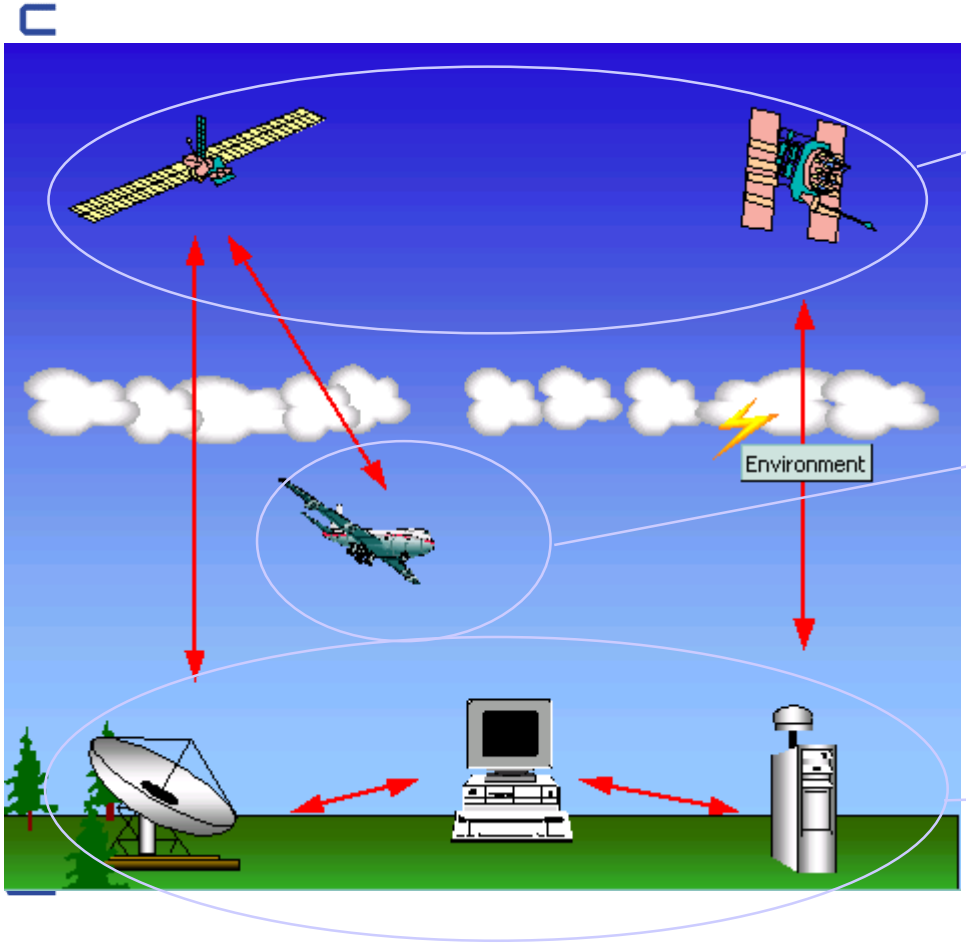
Justification Methodology - Availability

XPL Available: Yes

The **XPL Availability** is thus "*the proportion of time where the Protection Level is below the Alert Limit*"



Justification Methodology - Availability

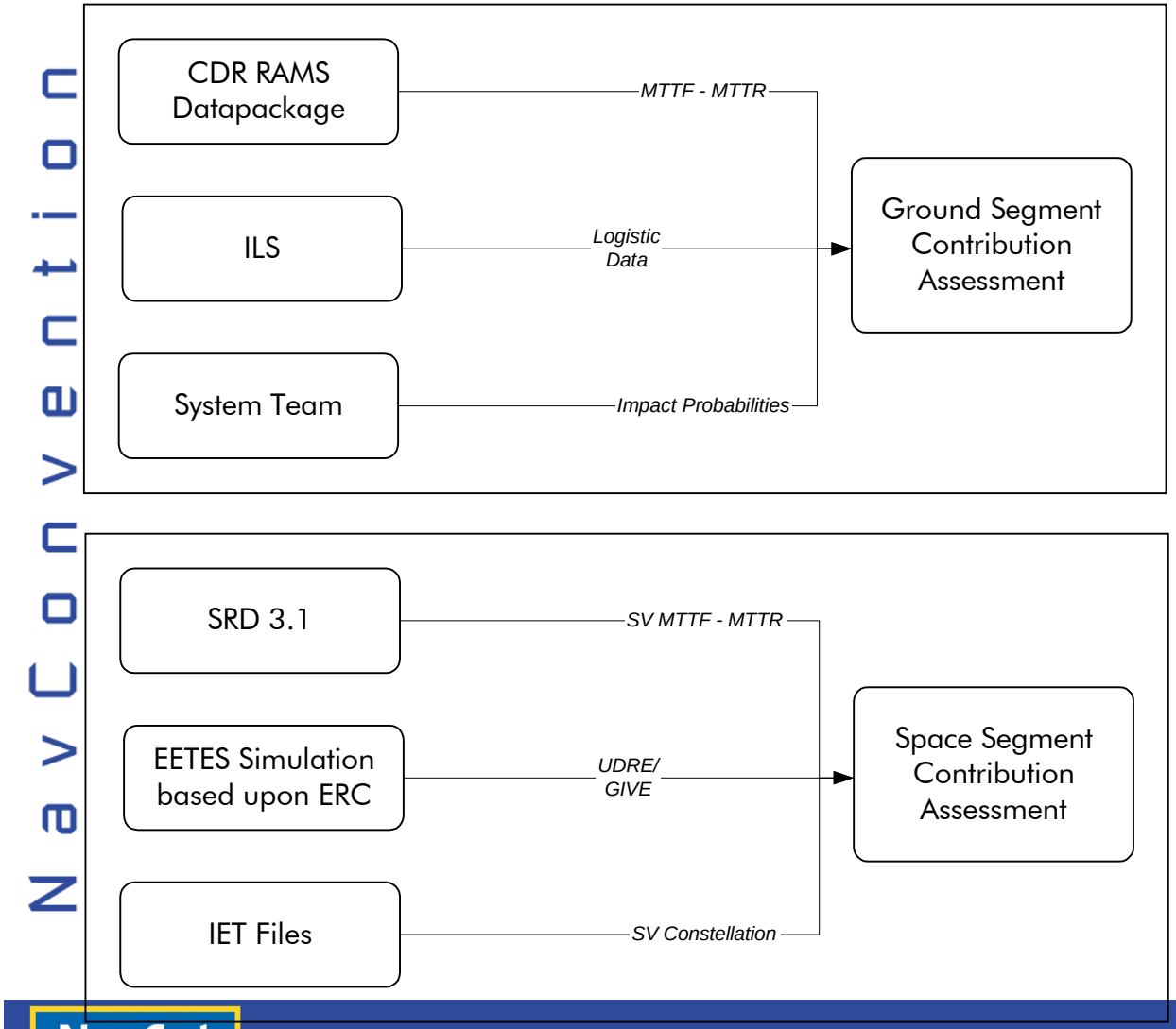


The Space Segment & Algos

The User Segment

The Ground Segment

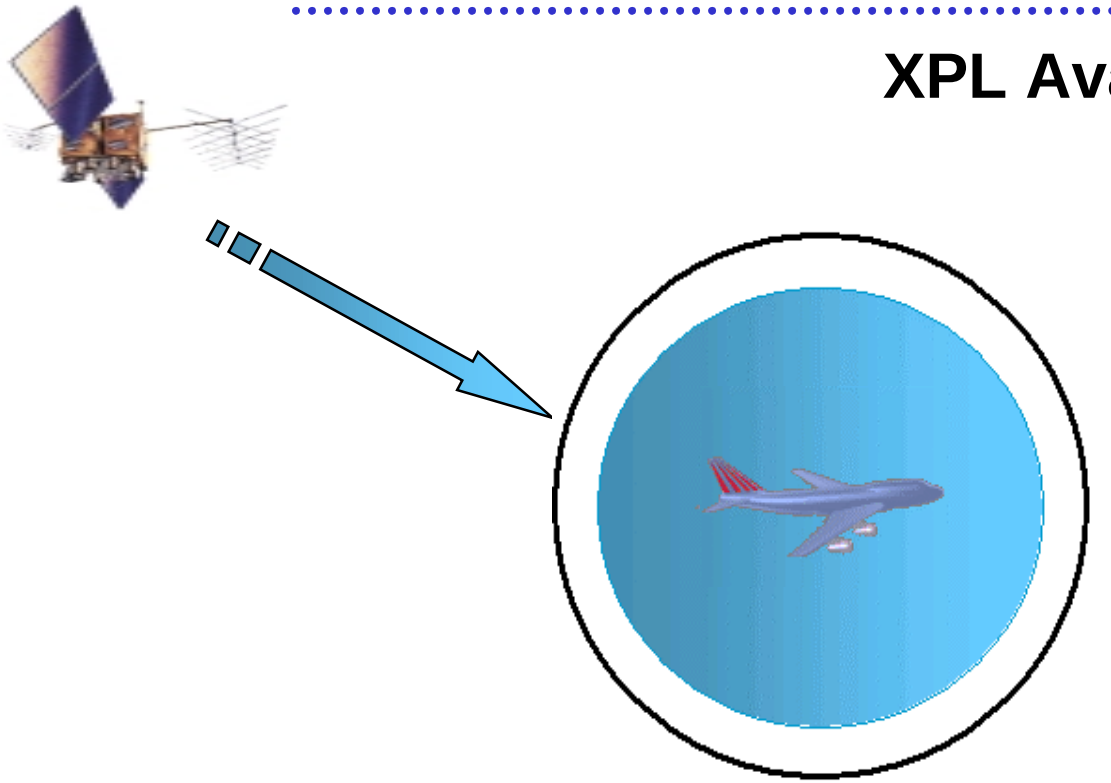
Justification Methodology - Availability



- Ground Segment Contribution
- Space Segment Contribution
- User segment contribution is based on applicable budgets defined in the MOPS

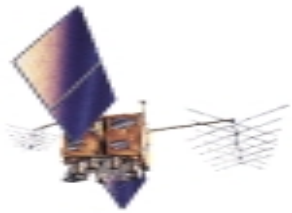
Justification Methodology - Continuity

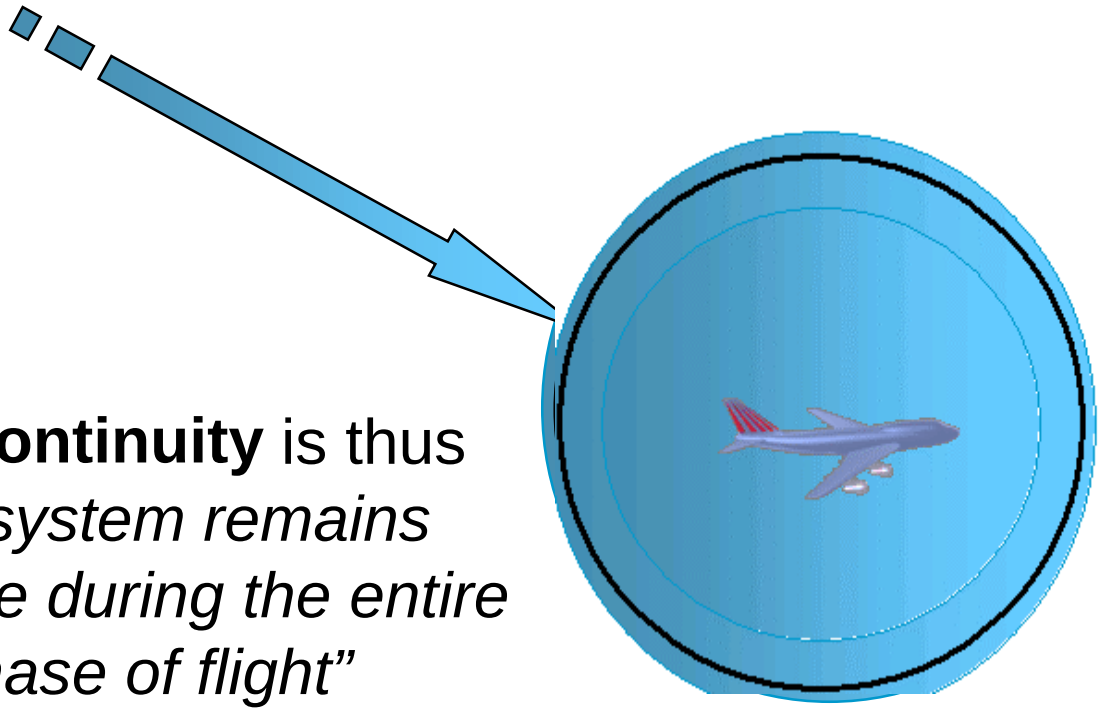
XPL Available: Yes



Justification Methodology - Continuity

XPL Available: No





The **Continuity** is thus "*the system remains available during the entire phase of flight*"

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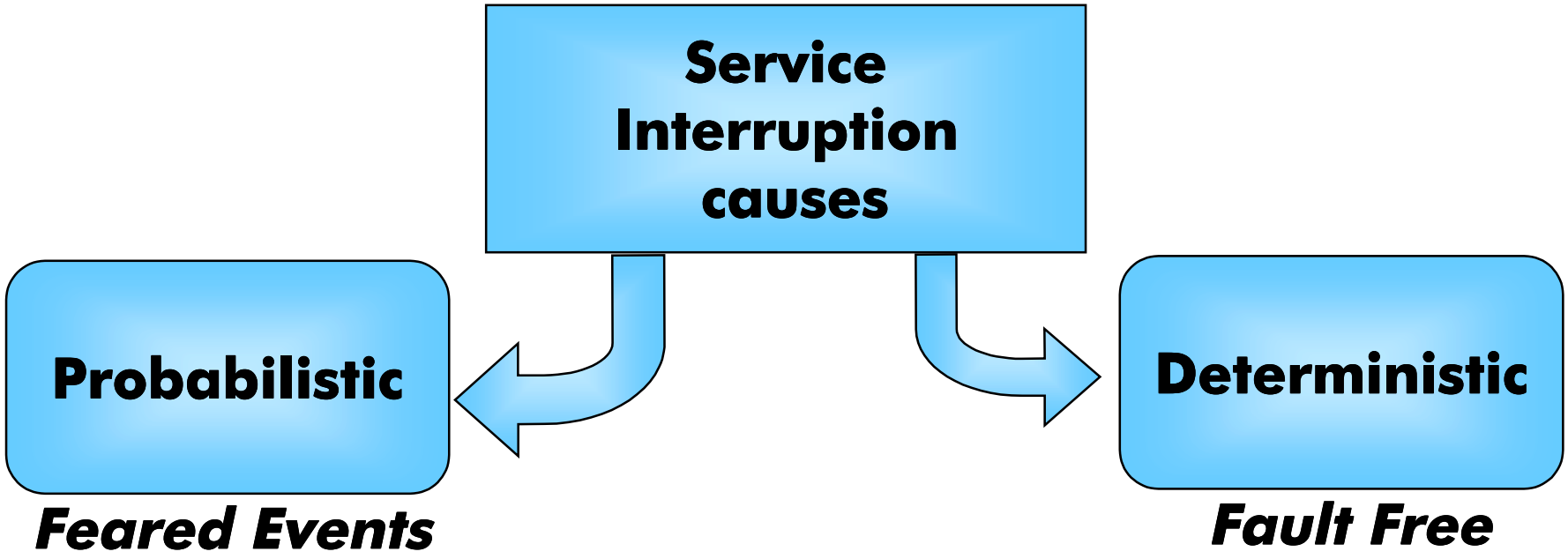
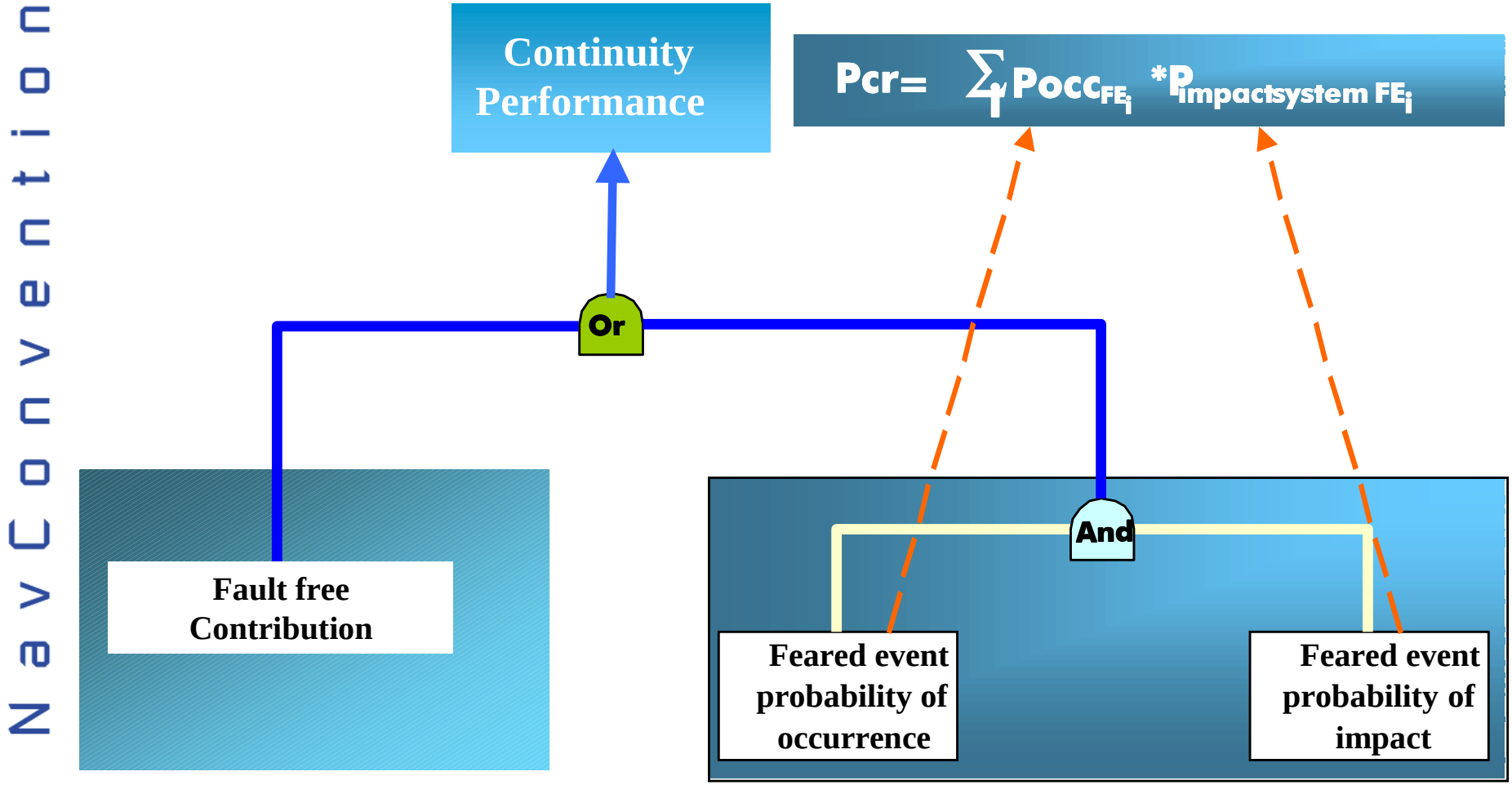
Justification Methodology - Continuity

- Requirement expressed with very low probability
  Service Level 2: 10^{-5} per hour
- Necessity to refine the models to include impact of low occurrence probability events (so called Feared Events)



Justification Methodology - Continuity



Justification Methodology - Integrity

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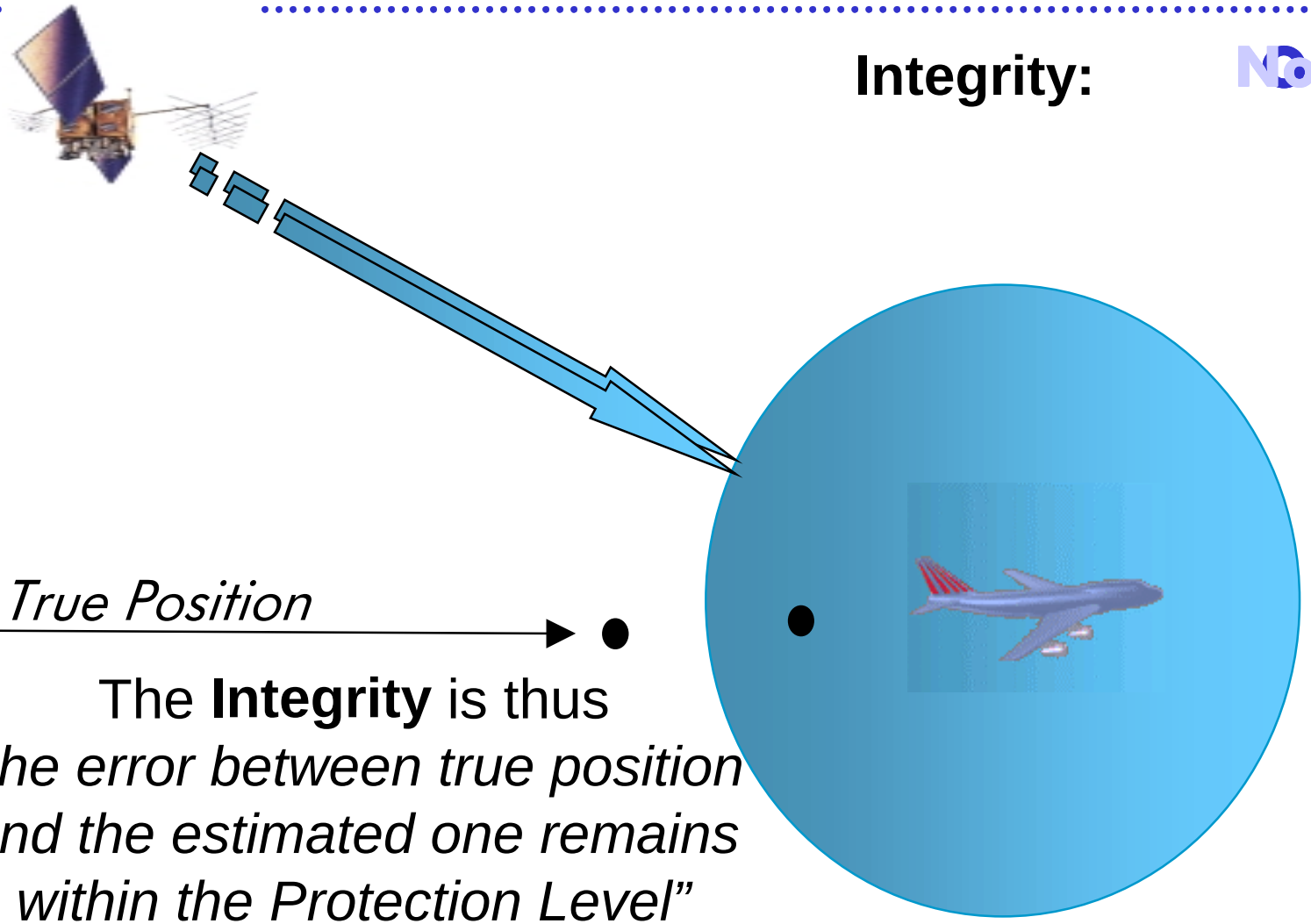
Integrity: NOK OK



True Position

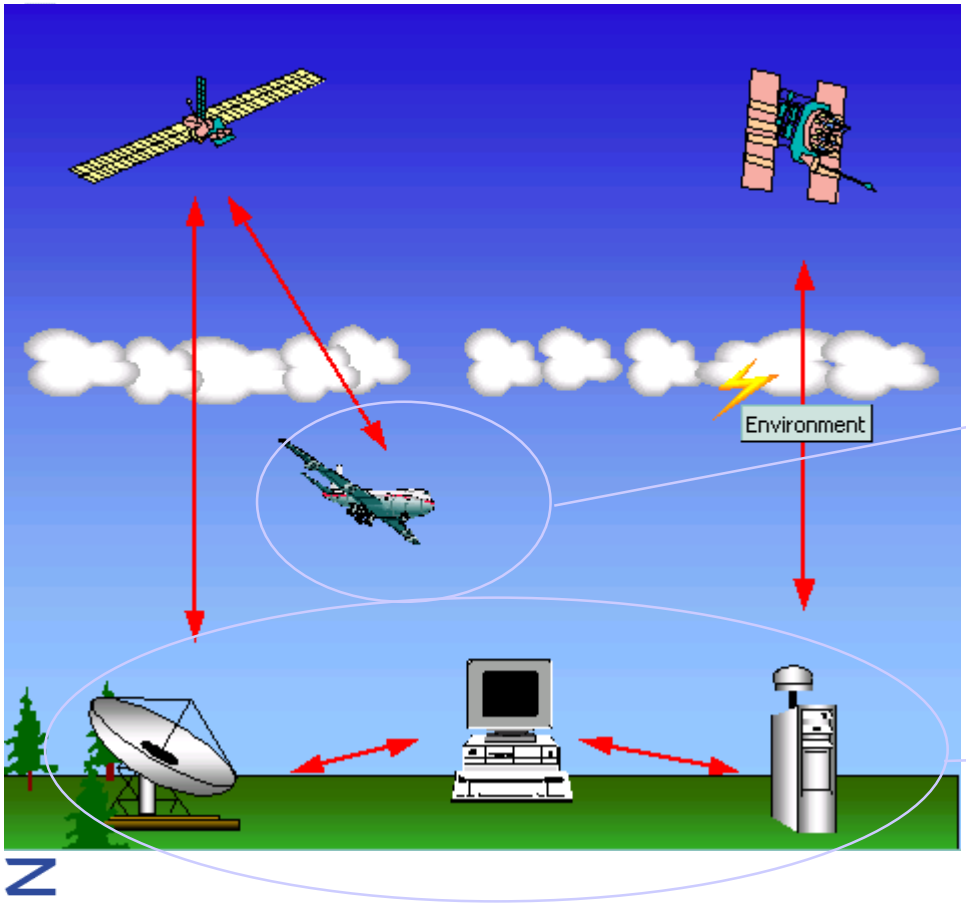
The **Integrity** is thus
"the error between true position and the estimated one remains within the Protection Level"

Justification Methodology - Integrity

Conservative Approach

- **Pseudo-range to position domain transfer**
  - integrity is assessed in the pseudo-range domain (i.e. integrity of the CPF Output)
  - This is a very conservative approach
    - *System Impact probability selected = 100%
    - *Estimation showed that System Impact is in between 0.4% and 4%
- **CPF anticipated models are more conservative than the simulations results**
- **Anticipated Occurrence Probabilities are more conservatives than estimation with Real Data**

Simulation Tools



Petri Net - FTA - FMECA
(RAMS Tool)

EGNOS Service Volume Simulator
(ESVS)

EGNOS End to End Simulator
(EETES)

CPF CDR Main Outcomes

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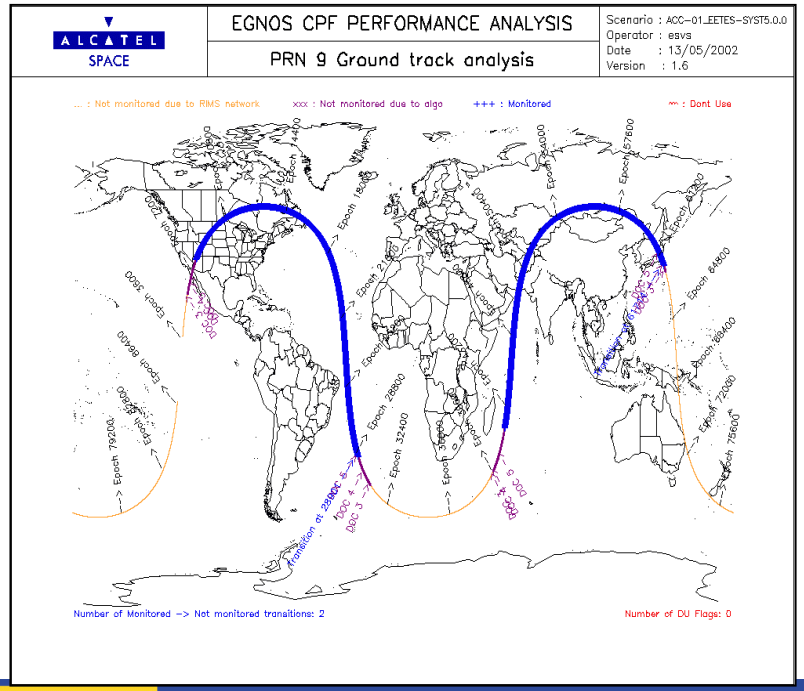
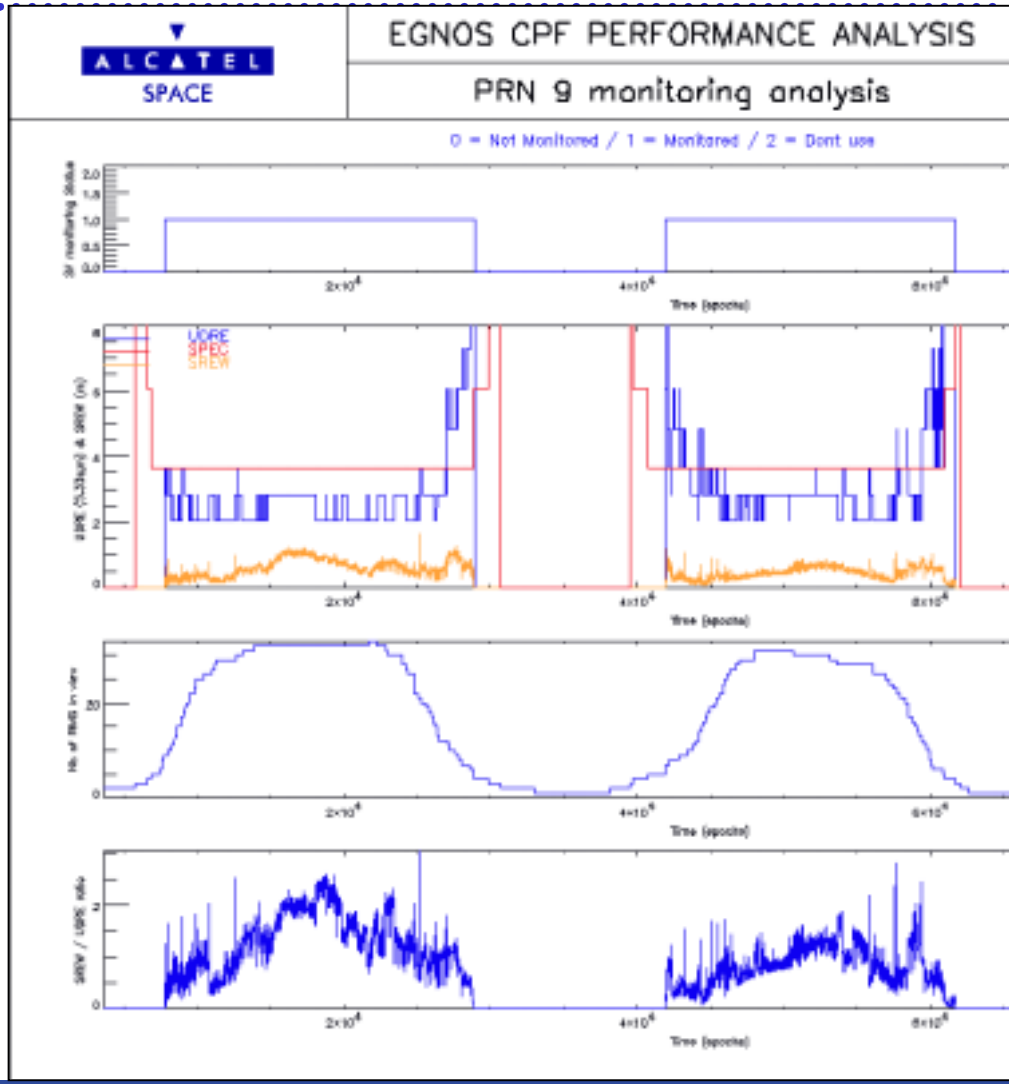
CPF Satellite Monitoring Capability *PRN09 Example*





CPF CDR Main Outcomes

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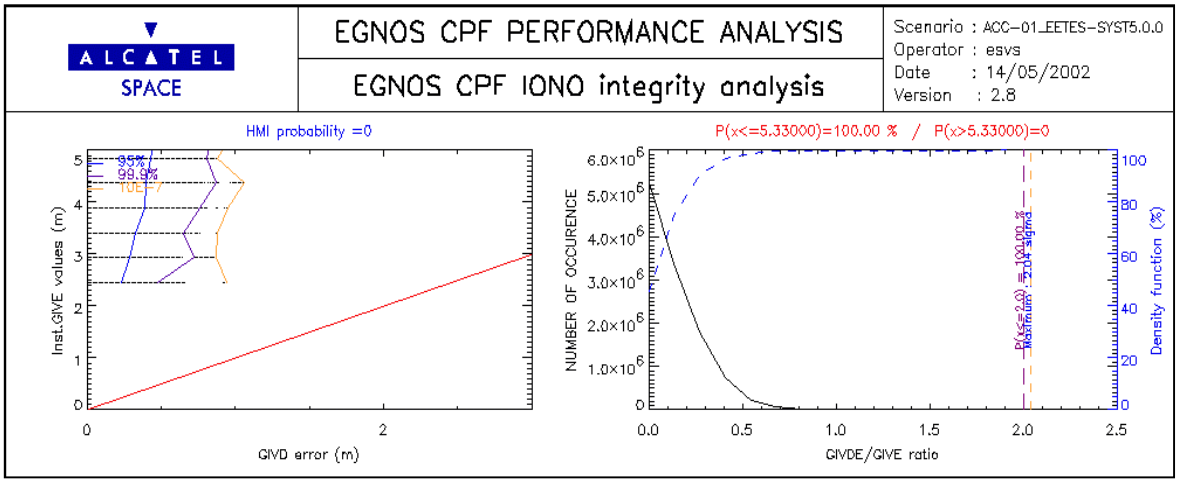
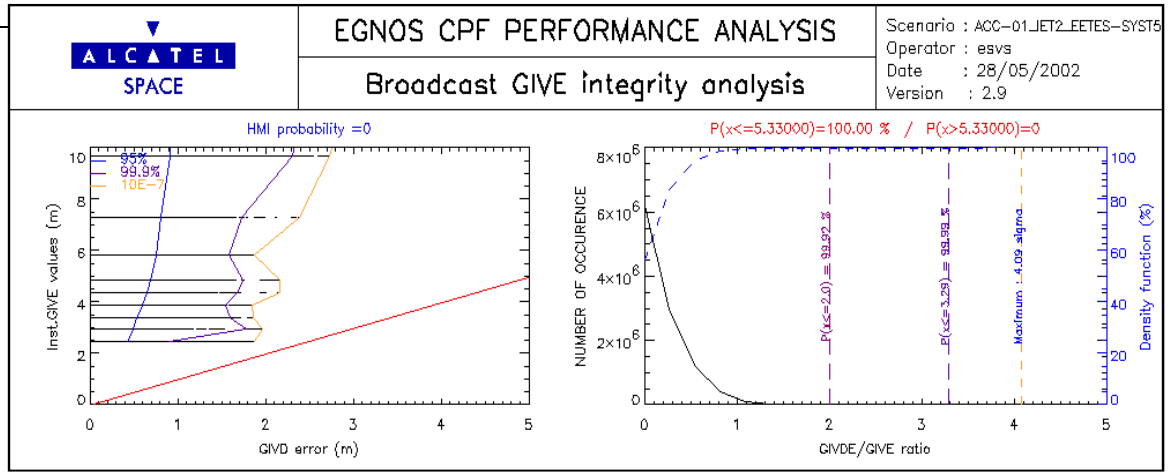
CPF GIVE Integrity Capability

Nominal Conditions
Large Margins



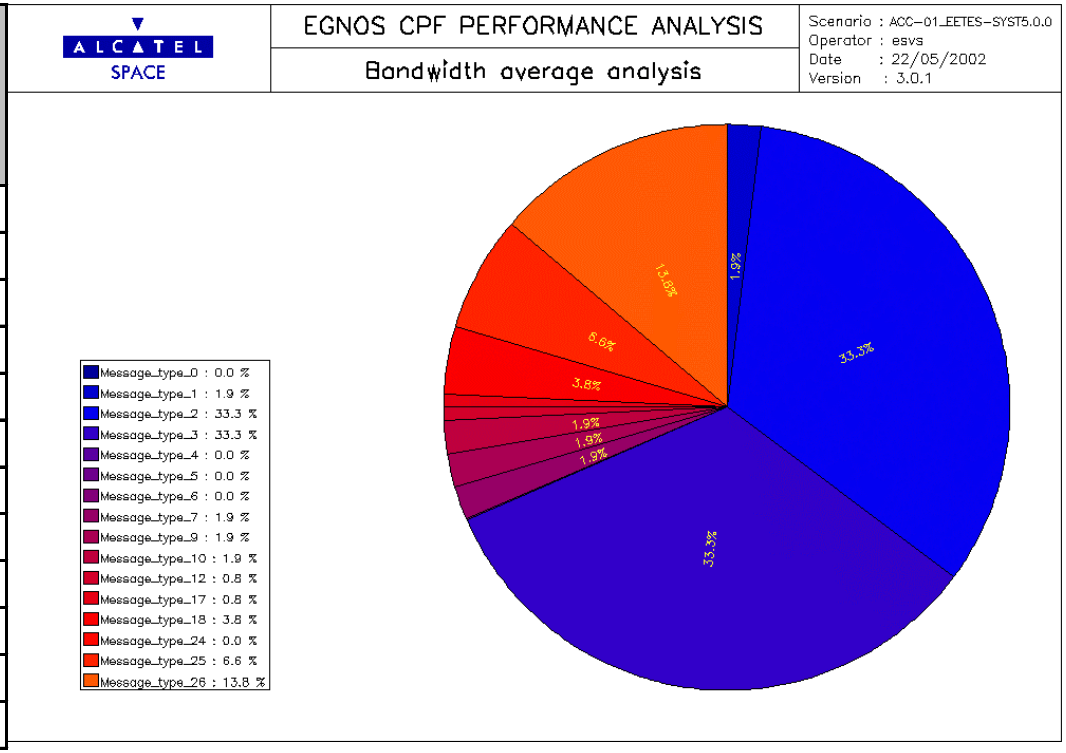
Extreme Conditions
Margins Reduced
but bounding
capabilities
maintained



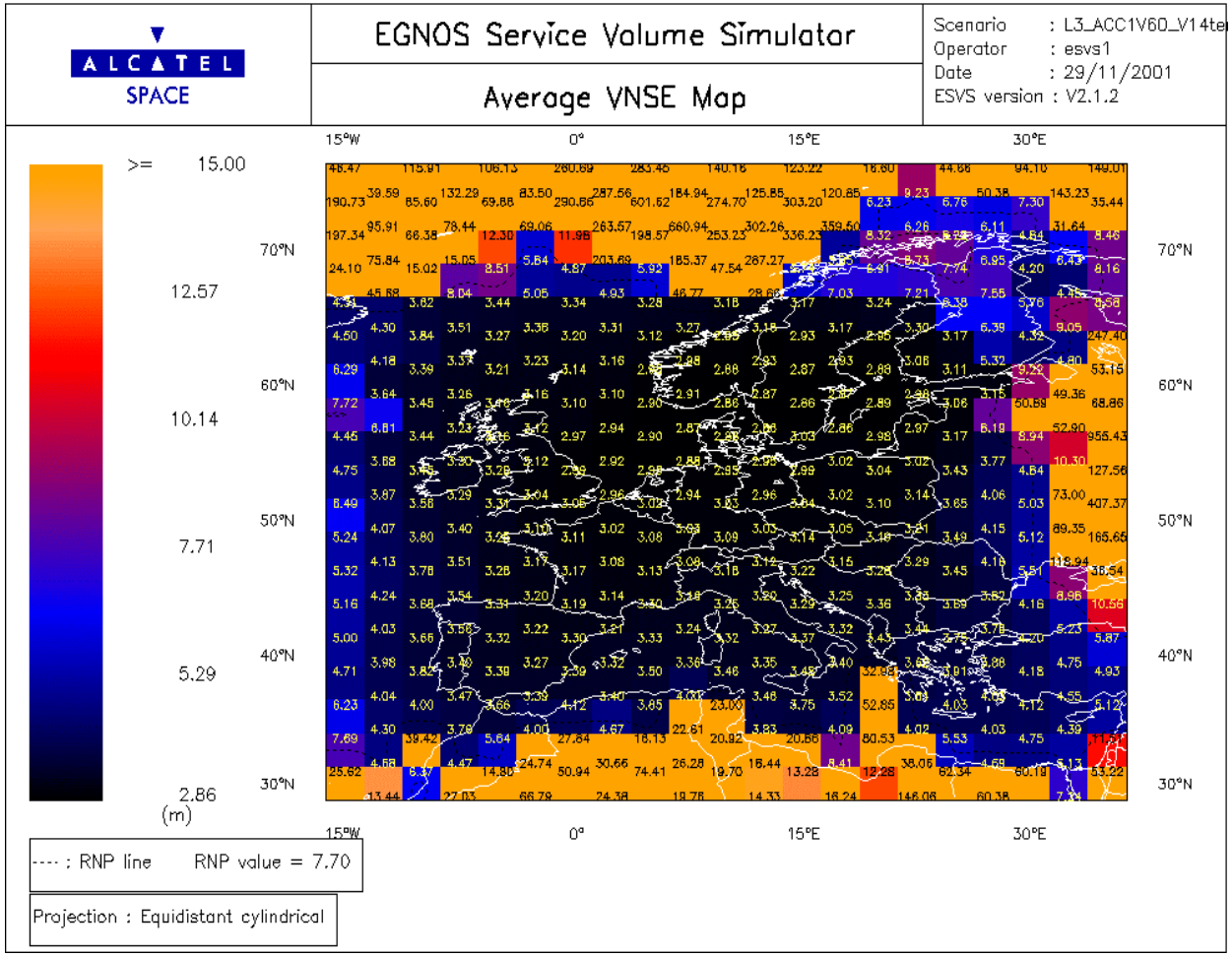
CPF CDR Main Outcomes

Compliance to Message MOPS Specifications
The Message is what is used by the system

Message type	Maximum update interval time specified in the MOPS	Compliance status to MOPS requirement
1	120 epochs	99.7 %
2,3,4,5+6	6 epochs	99.9 %
2	60 epochs	100%
7	120 epochs	99.7 %
9	120 epochs	99.7 %
10	120 epochs	99.7 %
12	300 epochs	99.9 %
17	300 epochs	100. %
18	300 epochs	100. %
25	120 epochs	99.8 %
26	300 epochs	99.8 %



System CDR Main Outcomes



System Accuracy

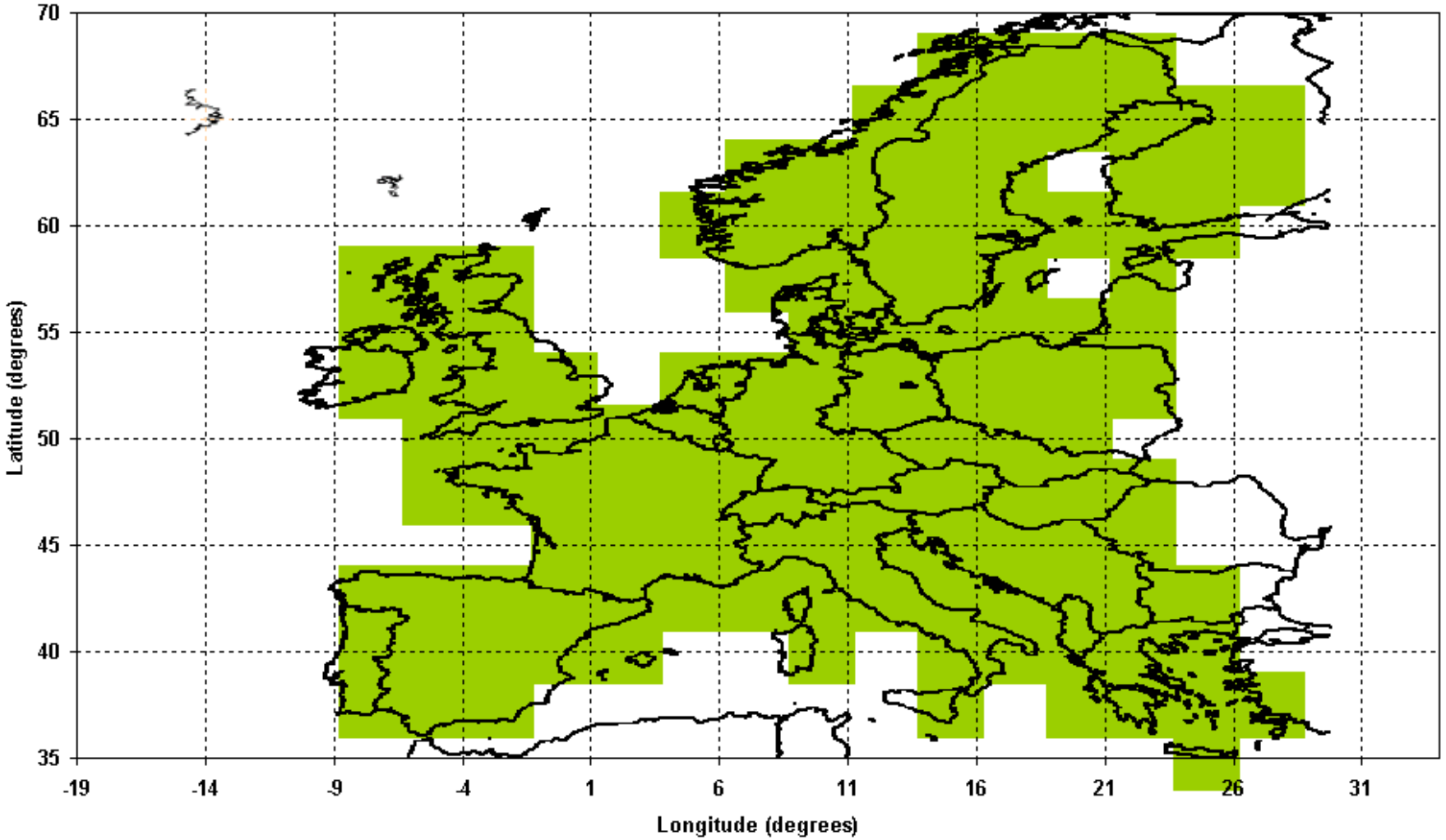
Horizontal (95%)
- 3.5 m (Average)
- 2.6 m (Min)

Vertical (95%)
- 2.9 m (Average)
- 3.9 m (Min)

Good performance on ECAC Land Masses

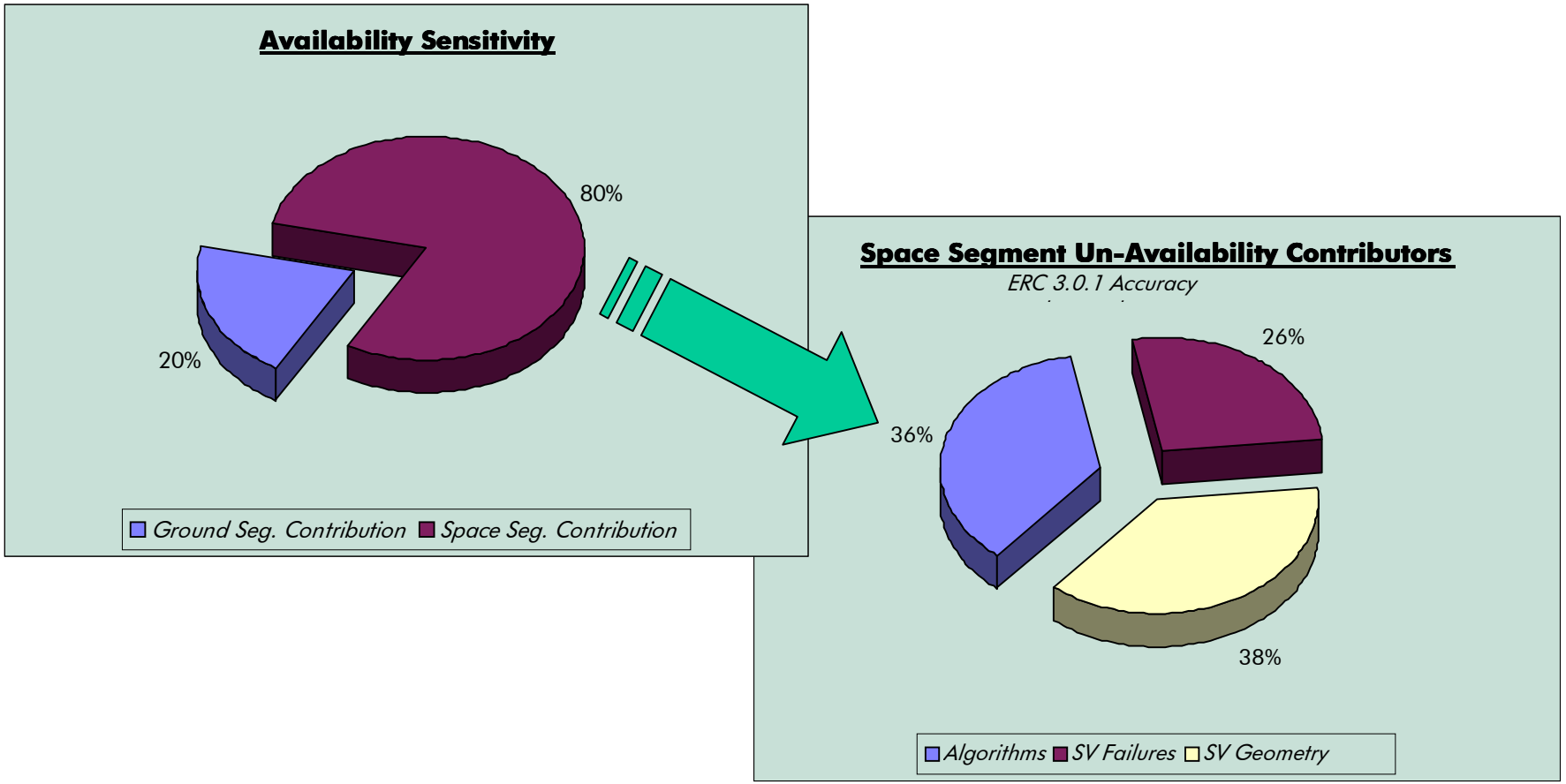
System CDR Main Outcomes

System availability



System CDR Main Outcomes

System availability contributor

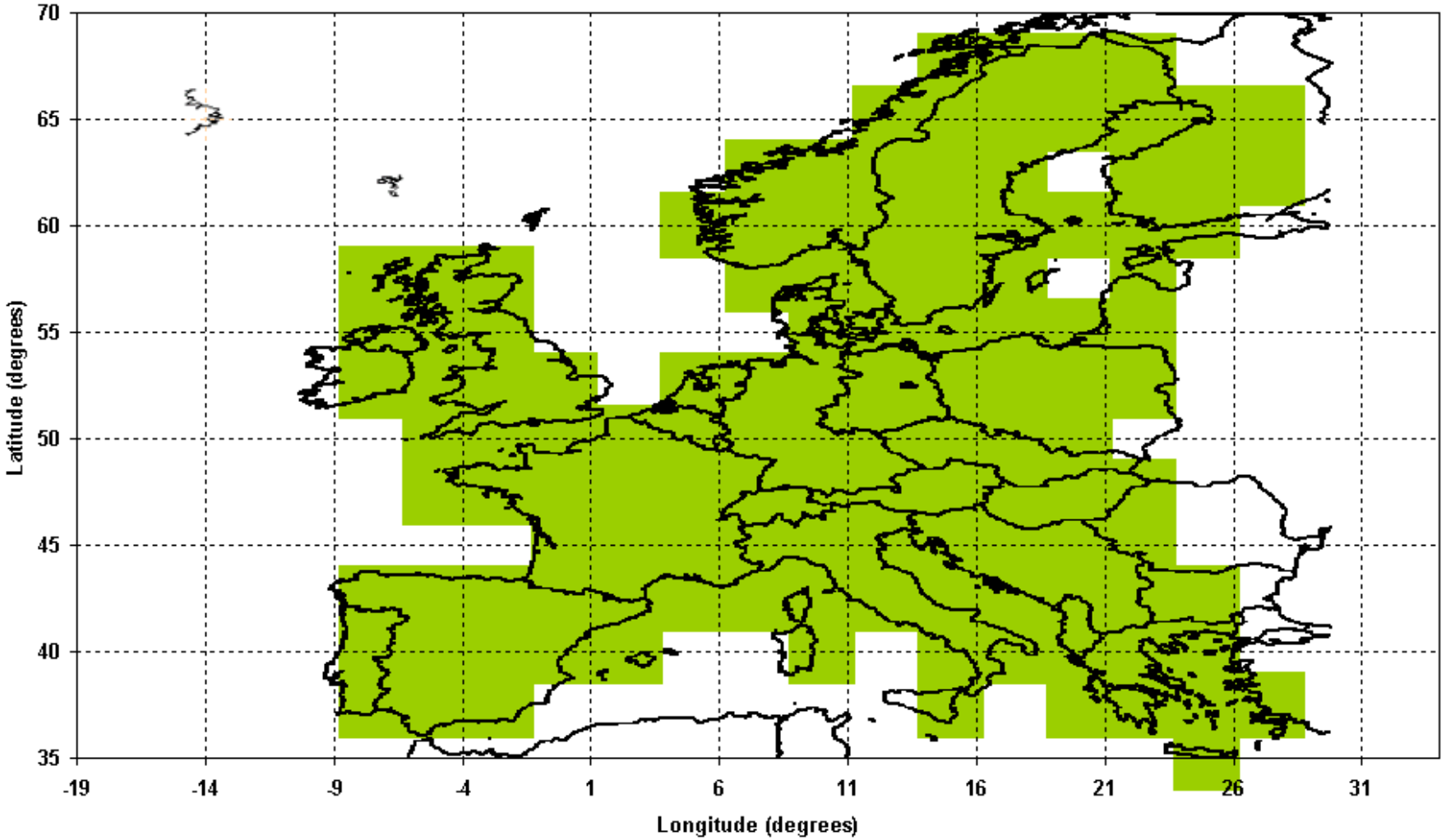


System Integrity

- Integrity Insured in Pseudo-range domain
  Mainly Based on CPF results
- After consolidation at System level conclusions are
  *Integrity Insured on the whole service area
  *Fault free contribution is negligible with respect to feared events
  *More than 97% of feared event contribution is due to
    >Excessive Multipath at RIMS level
    >Code Carrier Incoherence on the GEO satellite

System CDR Main Outcomes

System Continuity

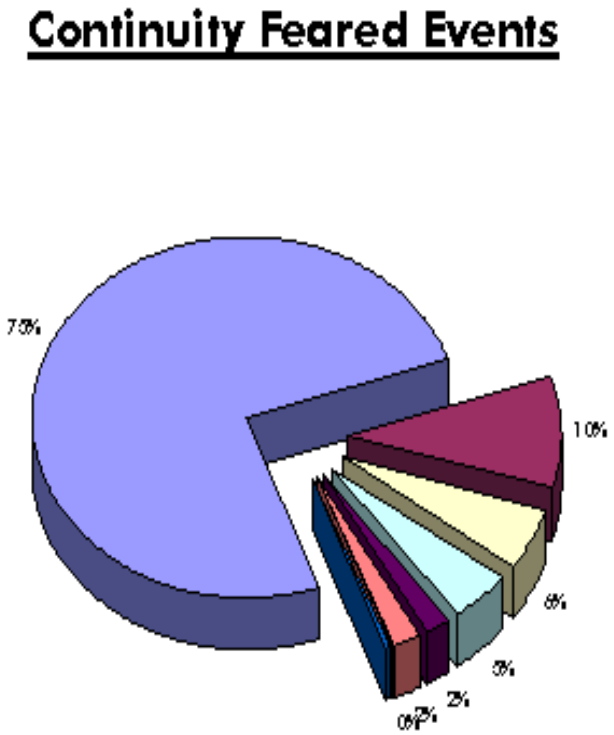


System CDR Main Outcomes

System Continuity contributor

Fault free represents 17% of the total budget

70% of the feared event budget is due to excessive multipath at RIMS level



Conclusion

The main outcomes of the analysis performed for EGNOS CPF and system Critical Design Review have been presented

Those results demonstrated during CDR that the proposed EGNOS design was able to fulfil EGNOS PDR commitments

- Integrity risk below specification on the whole ECAC area
- Continuity and availability compliance areas covers most of the ECAC land masses as required.

What shall be also underlined is the methodology used by EGNOS System Engineering team for performance justification.

This has been recognised as key contributor to a successful CDR completion.