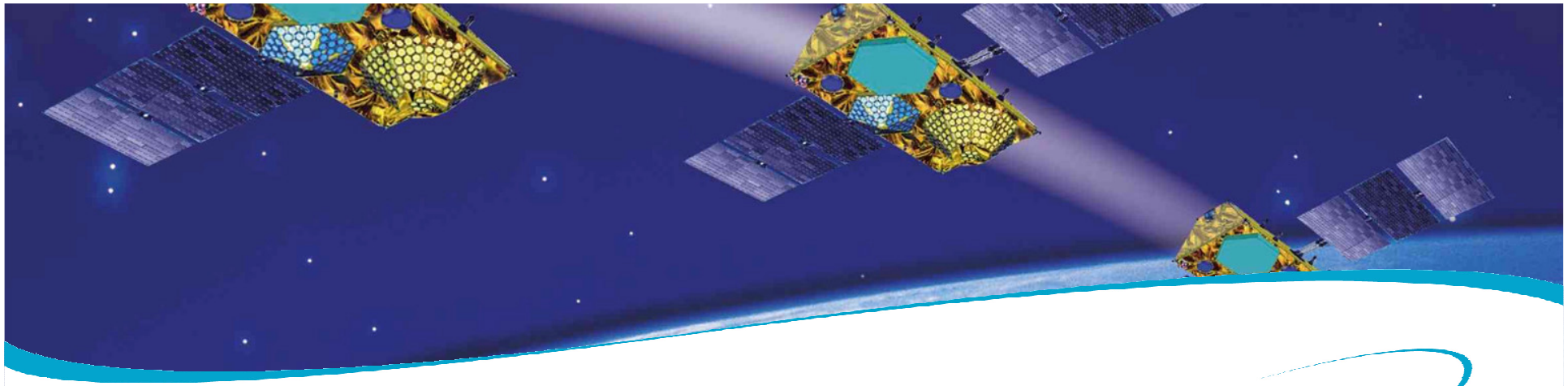

ICG-WG B

Multi constellation Regional System (MRS)
A step towards Multi constellation Interoperability

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Navigation Business Line

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Table Of Content

Introduction

MRS study held in the frame of ESA GNSS Evolution Program (EGEP) Period 1

The authors gratefully acknowledge the support of ESA.

However the opinions and potential future scenarios reflect those of Thales Alenia Space and GMV, and are not necessarily representative of ESA.

MRS Consortium

France | Spain | Italy | Germany | Norway | United Kingdom

MRS Concept

GNSS context is evolving ========> MRS concept

Multi-constellation INTEROPERABILITY

L1 / ~~L2P~~ / L2C / L5 L1 / L2 FDMA / L1 / L3 CDMA L1 / E5

Multi-frequency

Multi-broadcast

Regional concept in Europe

- Corrections / Regional integrity wrt GPS, GALILEO, GLONASS
- Natural Evolution of EGNOS, which :
  - Needs to evolve (no warranty of GPS L2P availability after 2018/2020)
  - Needs to manage obsolescence

MRS Missions

MRS missions

- Continuity with EGNOS Mission
  - EGNOS mission is the starting point for MRS mission definition
- Aeronautical Users
  - Well known mission with evolutions

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MRS missions

- Continuity with EGNOS Mission
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- Aeronautical Users
  - Well known mission with evolutions

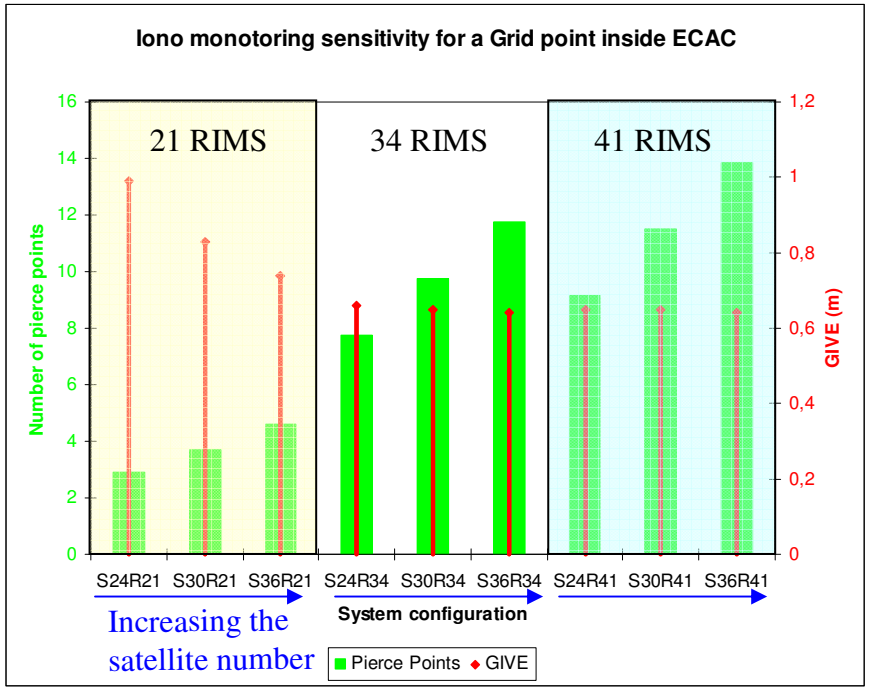
GNSS Context Evolutions + Aeronautical Mission Evolutions
= Opportunities for new Missions

- Non aeronautical users
  - Emerging services such as Liability Critical Applications (LCA)

MRS Mission Opportunities

MRS Mission Opportunities for Aeronautical users – SoL Services

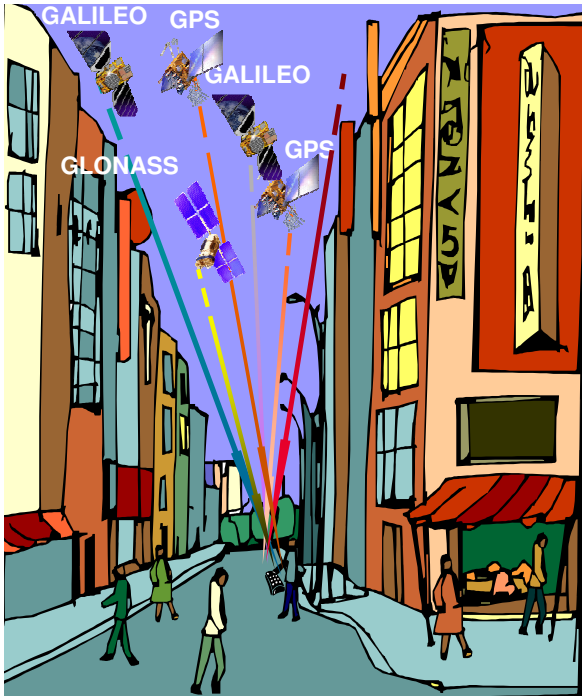
- Ionosphere monitoring improvement
- SoL Service robustness enhancement
  - Robustness towards constellation failure
  - Logistic Delays may be relaxed
- Service performance improvement
  - Continuity improvement
  - Robust LPV200
  - Dual frequency service
- Service Area Extension
  - Arctic, North Africa, Eastern Europe
  - Specific need at high latitude (North of ECAC)
    - Adapted Broadcast (MEO Broadcast)
    - Handling of specific ionosphere characteristics



MRS Mission Opportunities

MRS Mission Opportunities for non-aeronautical users

- Multi modal concept addressing non aeronautical users
  - Maritime, train, road,…

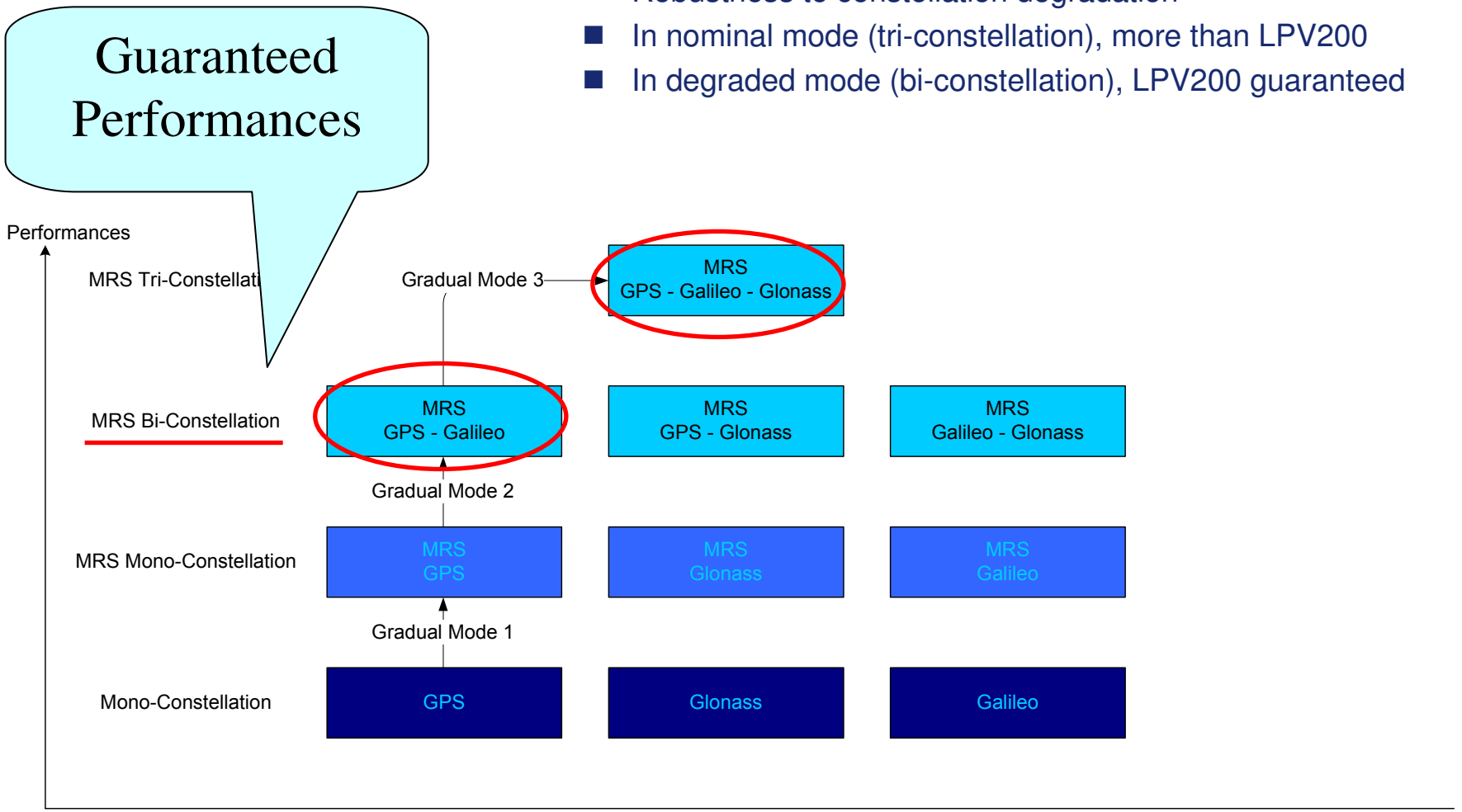


- Integrity provision in non aero users environment
  - Through multi constellation / frequency monitoring capability
  - Through multi broadcast using MEO Broadcast or Data Server
- Association with mechanisms relevant for “Liability”
  - Security (Authentication,...)

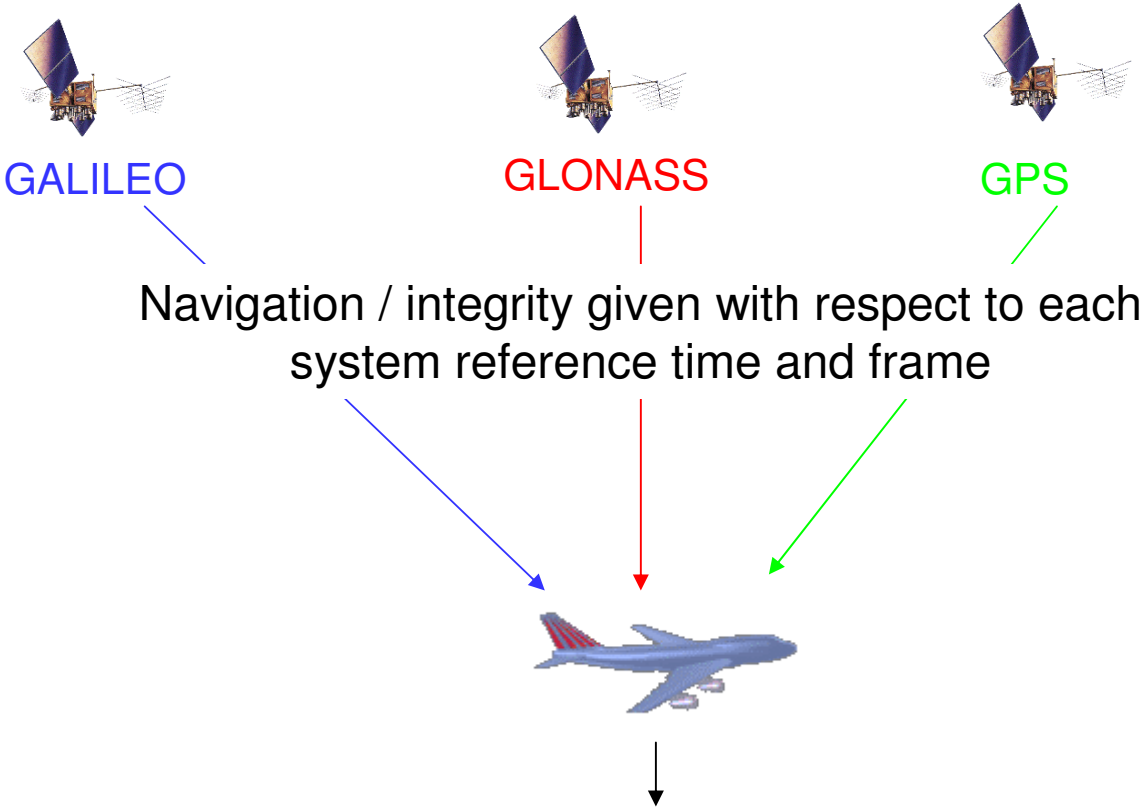
Gradual mode approach

Ensures

- Robustness to constellation degradation
- In nominal mode (tri-constellation), more than LPV200
- In degraded mode (bi-constellation), LPV200 guaranteed

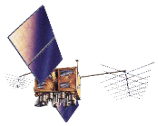


Constellations interoperability

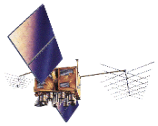


MRS enabling constellations interoperability

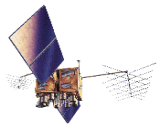
With MRS



GALILEO



GLONASS

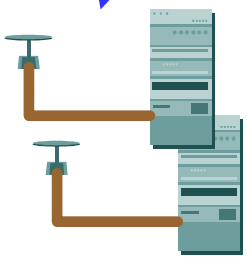


GPS

MRS broadcast mean

Navigation / integrity given with respect to each system reference time and frame

Overlay ensuring the link between different systems



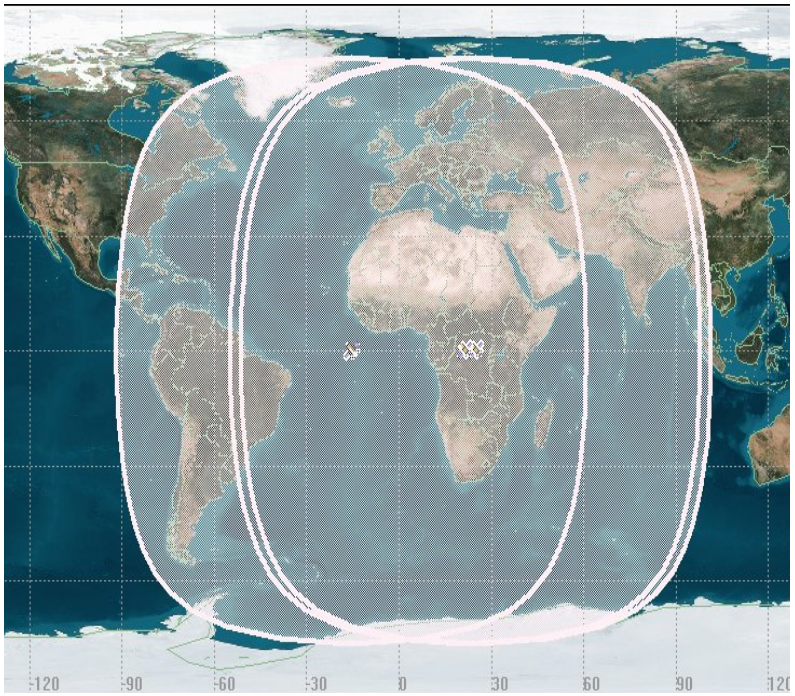
MRS reference stations

Optimises user performances

Uplink Station

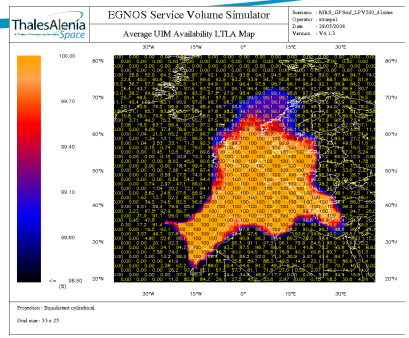
MRS Control Center

Sub System : Broadcast Means

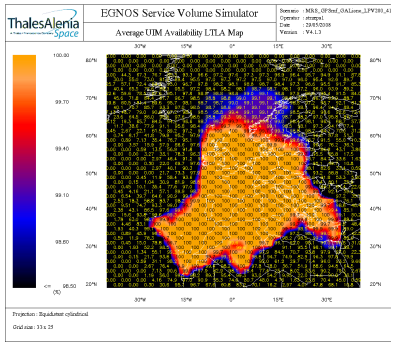


- GEO transparent payload L1 and L1/L5 Signal In Space
  - mainly dedicated to aeronautical users, but some land users can use these SIS
- MDAS : MRS Data Access Server
  - dedicated to non aeronautical users
  - can be interfaced with various broadcast means (ie, terrestrial networks)
- Galileo MEO Signal in Space
  - For aeronautical users : to cover high latitudes area.
    - Use of ERIS channel
  - For non aeronautical users: MEOs visibility is better than GEO.
    - Use of ERIS channel
    - Use of E6
- Other broadcast means may also be envisaged : HEO, IGSO…

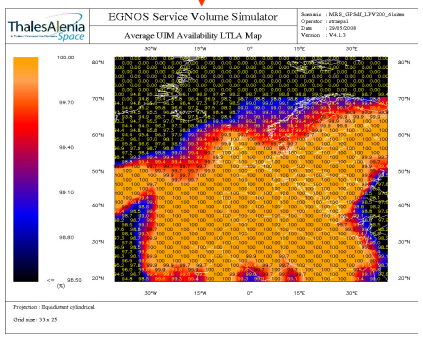
MRS Benefits in Europe - SoL Service : LPV200



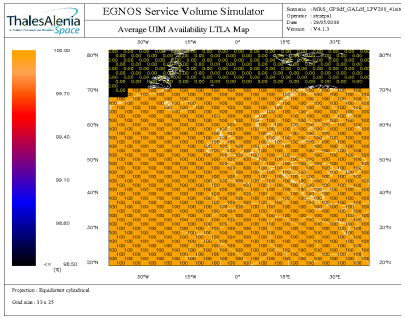
(Reference Case)
Processing of GPS Only:
Broadcast of GPS augmentation in L1 only



Processing of GPS + GALILEO
Ionosphere Monitoring improvement
Broadcast of GPS augmentation in L1 only



Processing of GPS only:
Broadcast of GPS augmentation
Dual frequency User L1+L5
SBAS L5 Standard w/o Galileo



Processing of GPS+GAL
Broadcast of GPS+GAL augmentation
Dual frequency User L1+L5
SBAS L5 Standard with Galileo

GIC/RAIM Combinations

Current situation :

- Standardised SoL GIC does not consider RAIM (for Precision approach)
- Potential use of RAIM is studied in the frame of US GEAS initiative (for aviation)

Objective for MRS Study:

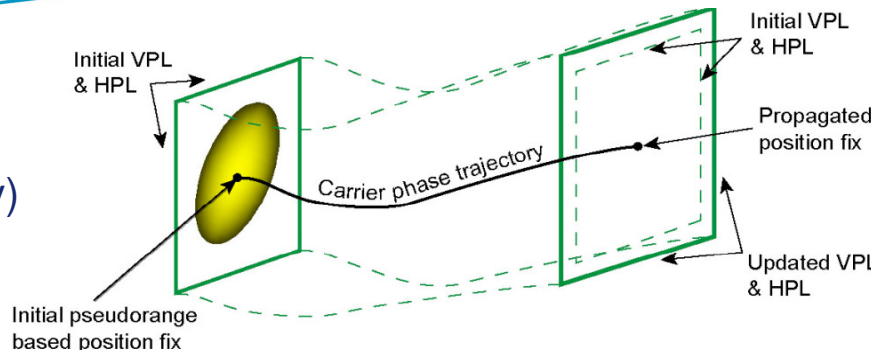
- Assessment of GIC/RAIM combinations suitable
  - For Aeronautical users (ie GEAS kind,…)
  - For Ground users (other solutions under analysis)

GIC/RAIM Combinations

Aeronautical users

- Assessment of Relative-RAIM (GEAS Study) based on GPS real data

  (for bi frequency users – 2020/2030)



- APV-II seems reachable in a multi-constellation scenario
- Ground segment constraints may be relaxed :
  - only when the "legacy" L1 aviation SOL service can be suppressed (> 2030)
  - In this case, no backup is available if the user looses L1 or L5 frequency

Ground users

- GIC allocated to signal-in-space monitoring
- RAIM allocated to environment monitoring

MRS Way Forward

Short term way Forward : ESA GNSS Evolution Program (EGEP) Period II

- Test Beds Experimentations (similar to ESTB at the beginning of EGNOS)
- EGNOS V3 Definition Phase to consolidate MRS Study outcomes

Future MRS system implementation steps (keeping L1 legacy service)

	1st Step	2nd Step	3rd Step
SOL	■L1 only service improvement (LPV 200) ■Ionosphere monitoring improvement using growing Galileo constellation ■Optional : Bi constellation monitoring (GPS, GAL), *pending GAL is included in MOPS standard*	■Bi constellation L1 / L5 monitoring (GPS, GAL), dual frequency operations ■GPS L5 signals use to maintain the GPS augmentation service if GPS L2P(Y) becomes unavailable	■tri constellation monitoring (GPS, GAL, GLO), dual frequency operations
LCA	■Design compatible with LCA service provision ■LCA early services for demonstration	■LCA additional services on new signals (GPS L5, L1C)	■LCA additional services on GLO L1/L3 CDMA new signals

Worldwide interoperability

First stage (MRS system step 1, 2 & 3), based on existing SBAS "backbone"

- MRS concept (European SBAS) is regional but many SBAS exists around the world, that would allow provision of nearly worldwide service (*see article ION ITM session B2 by Todd Walter*), taking benefits of :
  - Bi-frequency
  - Addition of reference stations in the southern hemisphere
  - Multi-constellation
  - Multi-broadcast (e.g. allowing high latitudes coverage)
- User standards to evolve
- Uses existing satellite blocks in open service and taking benefit of growing constellations

Second stage, based on advanced integrity concepts like those studied in GEAS and existing ground infrastructure (e.g. MRS)

- Integrity burden to be re-allocated between User (RAIM), Space (e.g. on-board integrity monitoring) and Ground segments
- New User standards to be developed
- Could take benefit of future satellite blocks with integrity service (GPS III, …)

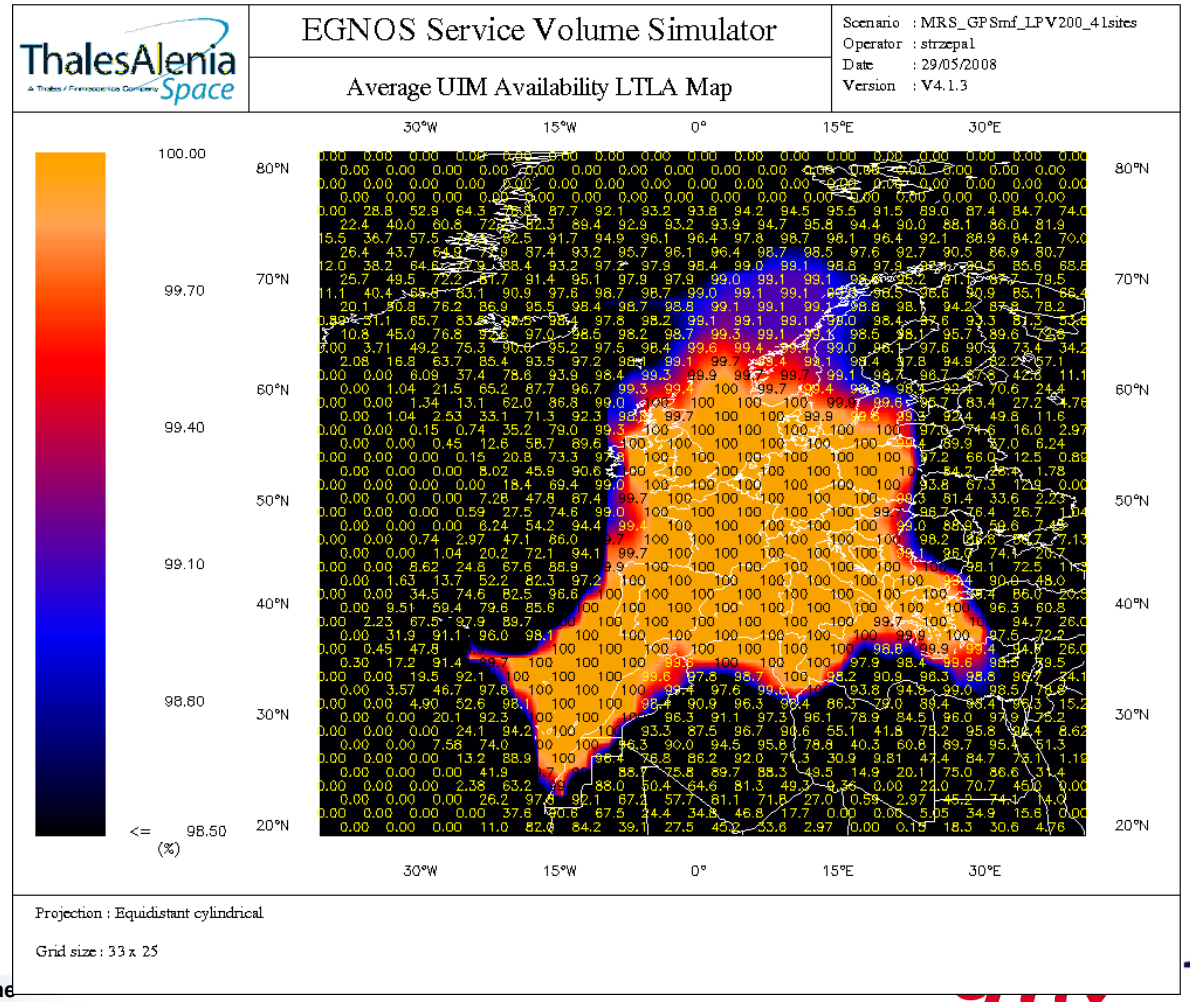
Thank you for your attention !

Any question ?

Back Up slides

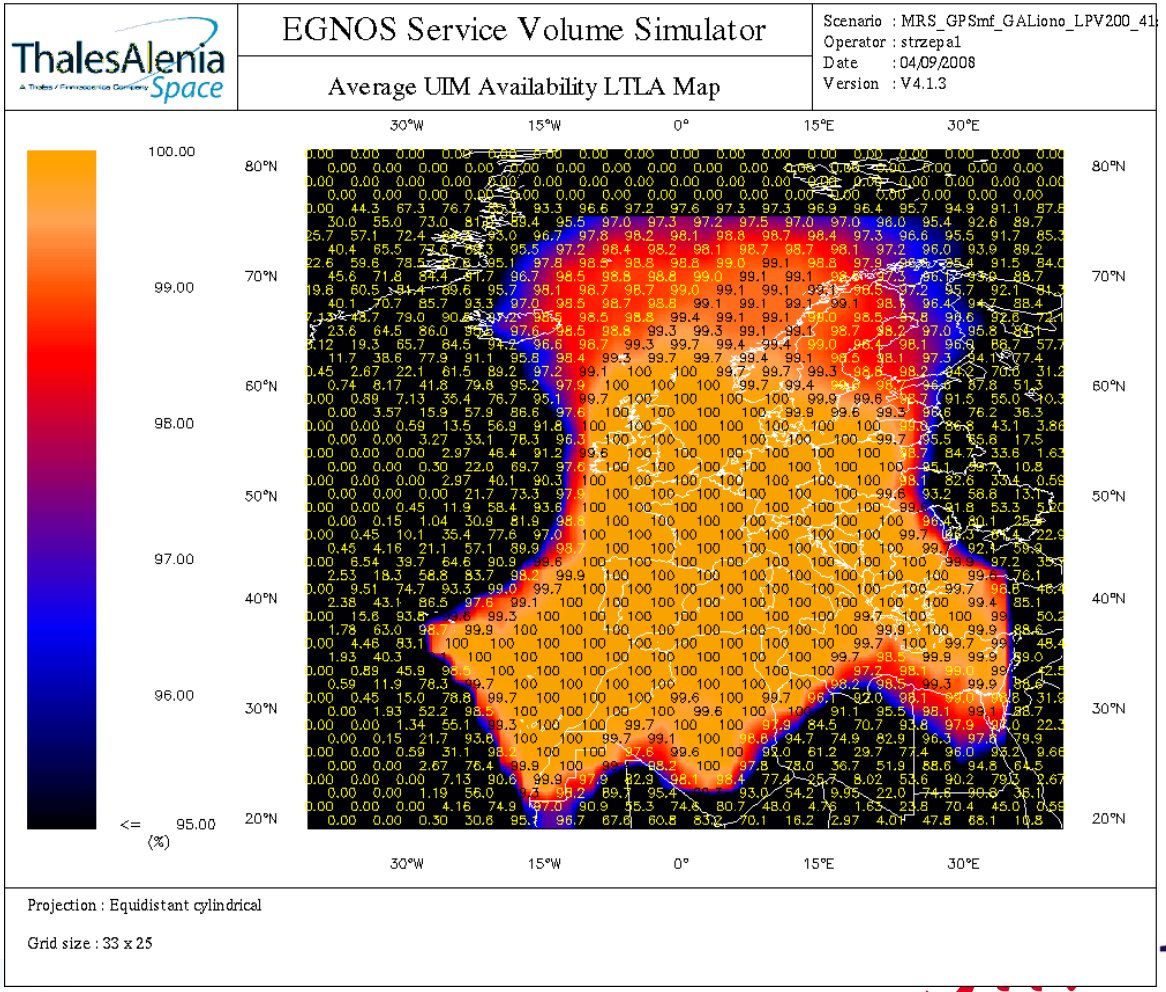
MRS Benefits - SoL Service : LPV200

(Reference Case) Processing of GPS Only: Broadcast of GPS augmentation in L1 only



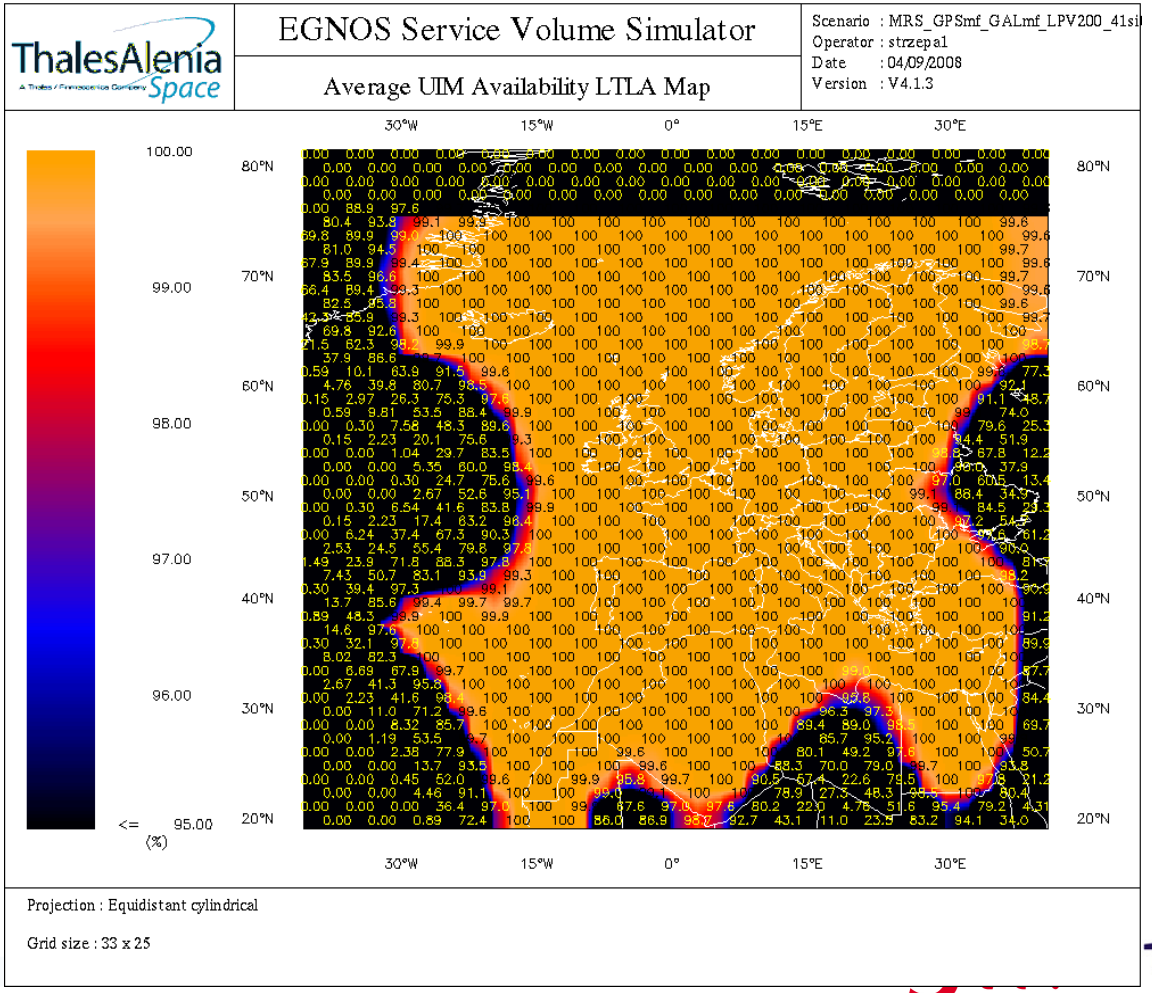
MRS Benefits - SoL Service : LPV200

Processing of GPS + GALILEO for Iono – Broadcast of GPS augmentation in L1 only



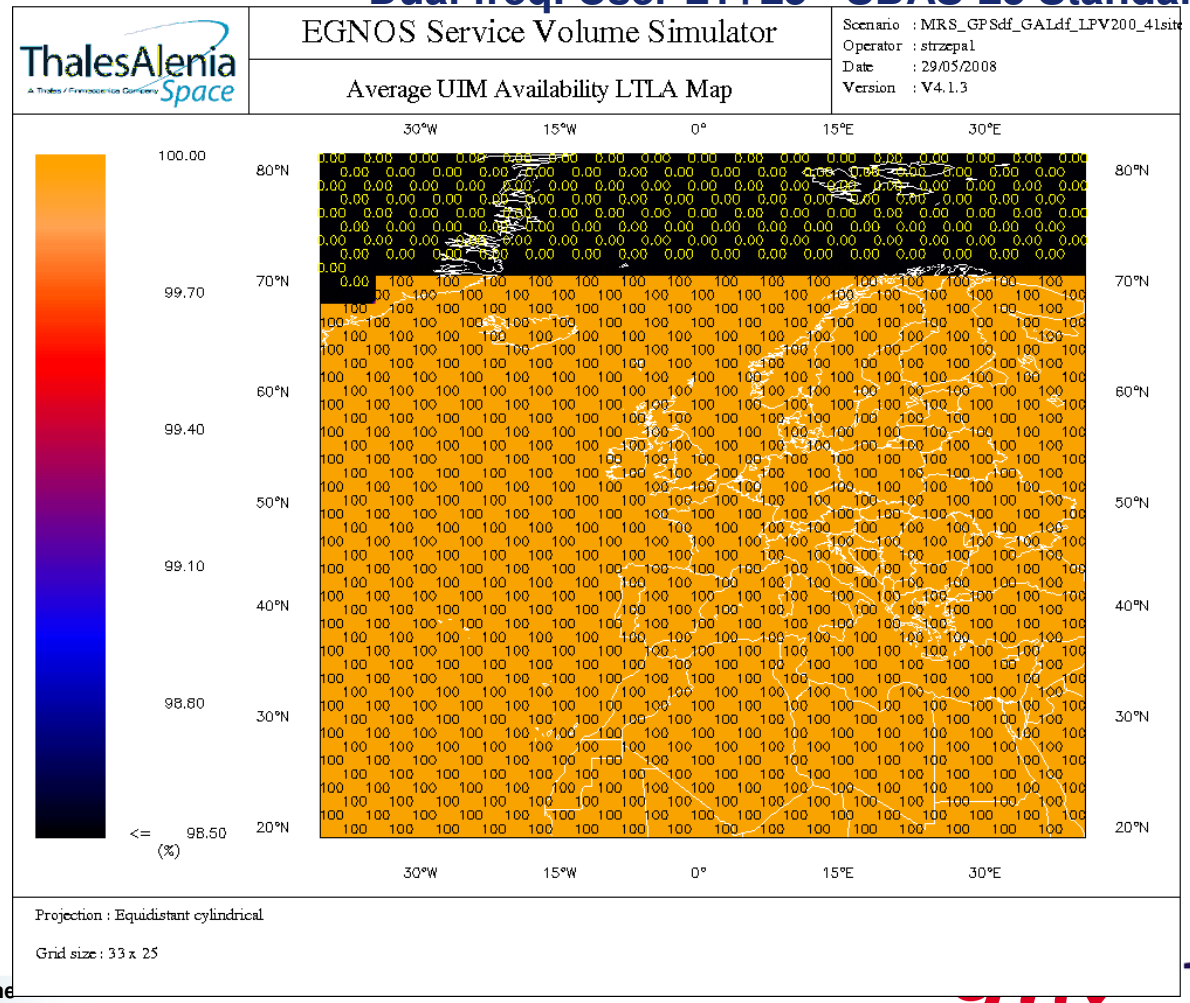
MRS Benefits - SoL Service : LPV200

Processing of GPS+GAL
Broadcast of GPS+GAL augmentation in L1 only (adapting DO229D standard)



MRS Benefits - SoL Service : LPV200

Processing of GPS+GAL
Broadcast of GPS+GAL augmentation
Dual freq. User L1+L5 - SBAS L5 Standard with Galileo



MRS Benefits - SoL Service : LPV200

Processing of GPS
Broadcast of GPS augmentation
Dual freq. User L1+L5 - SBAS L5 Standard without Galileo