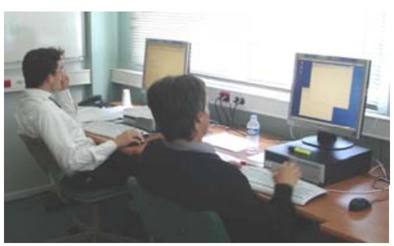
ThalesAlenia Space
A Thales / Finmeccanica Company

Galileo Mission Segment

End To End Simulator

First Usage, Lessons Learned and Perspectives

SESP 2008



THALES

1 – ETE INTRODUCTION

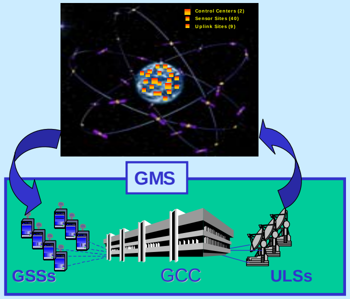
2 – ETE USAGE LOGIC & RESULTS

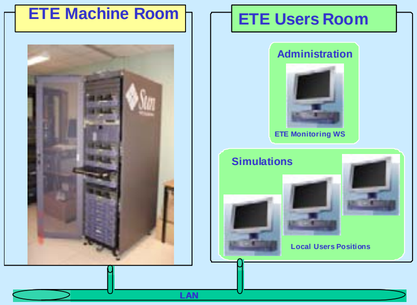
3 – ETE LESSONS LEARNED

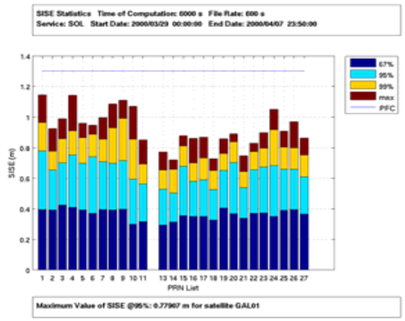
4 – ETE EVOLUTIONS

5 – CONCLUSION

6 – QUESTIONS ?

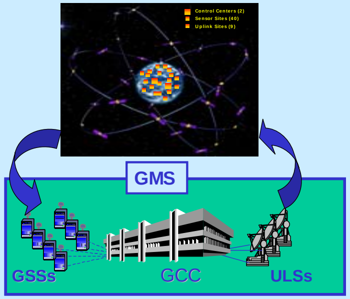




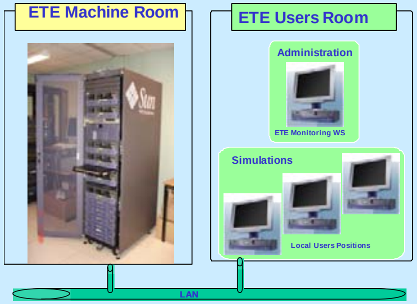


1 – ETE INTRODUCTION

- The Galileo System and the GMS
- The GMS & the End To End Simulator
- The ETE platform



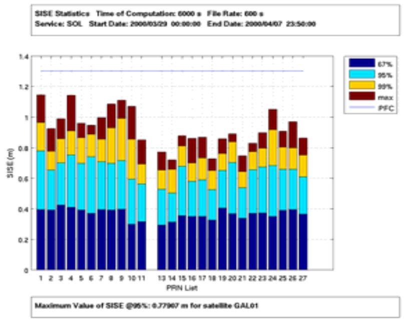
2 – ETE USAGE LOGIC & RESULTS



3 – ETE LESSONS LEARNED

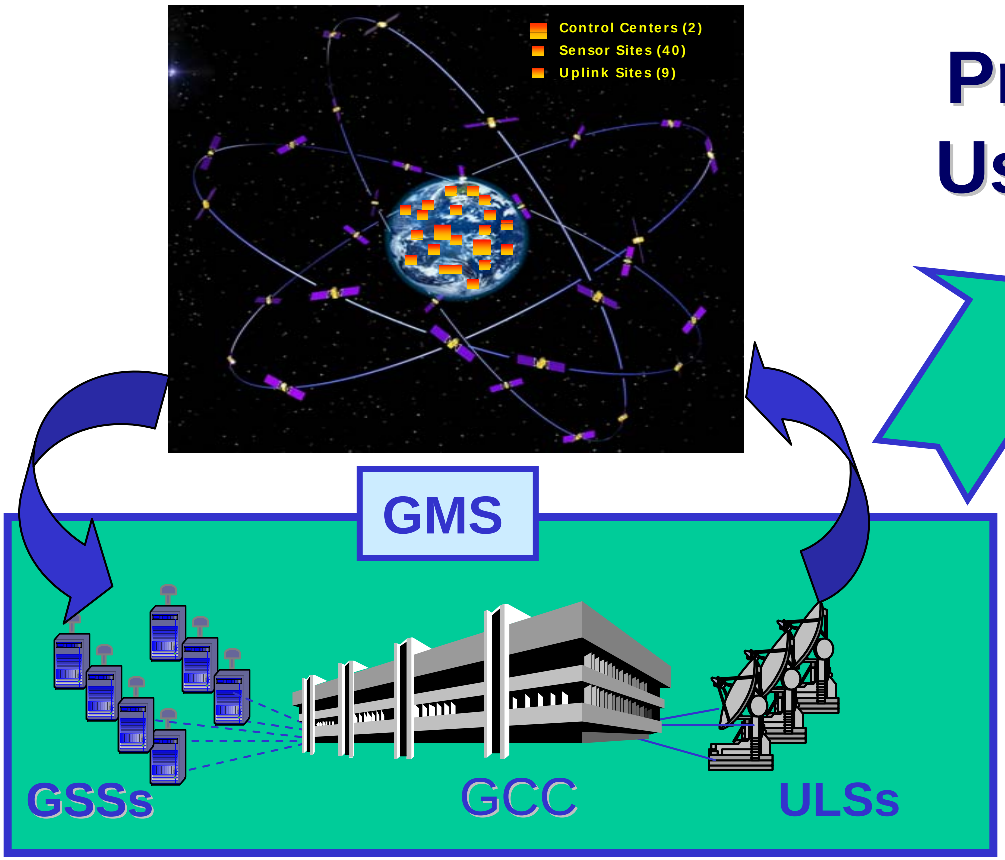
4 – ETE EVOLUTIONS

5 – CONCLUSION



6 – QUESTIONS ?

The Galileo System and the GMS



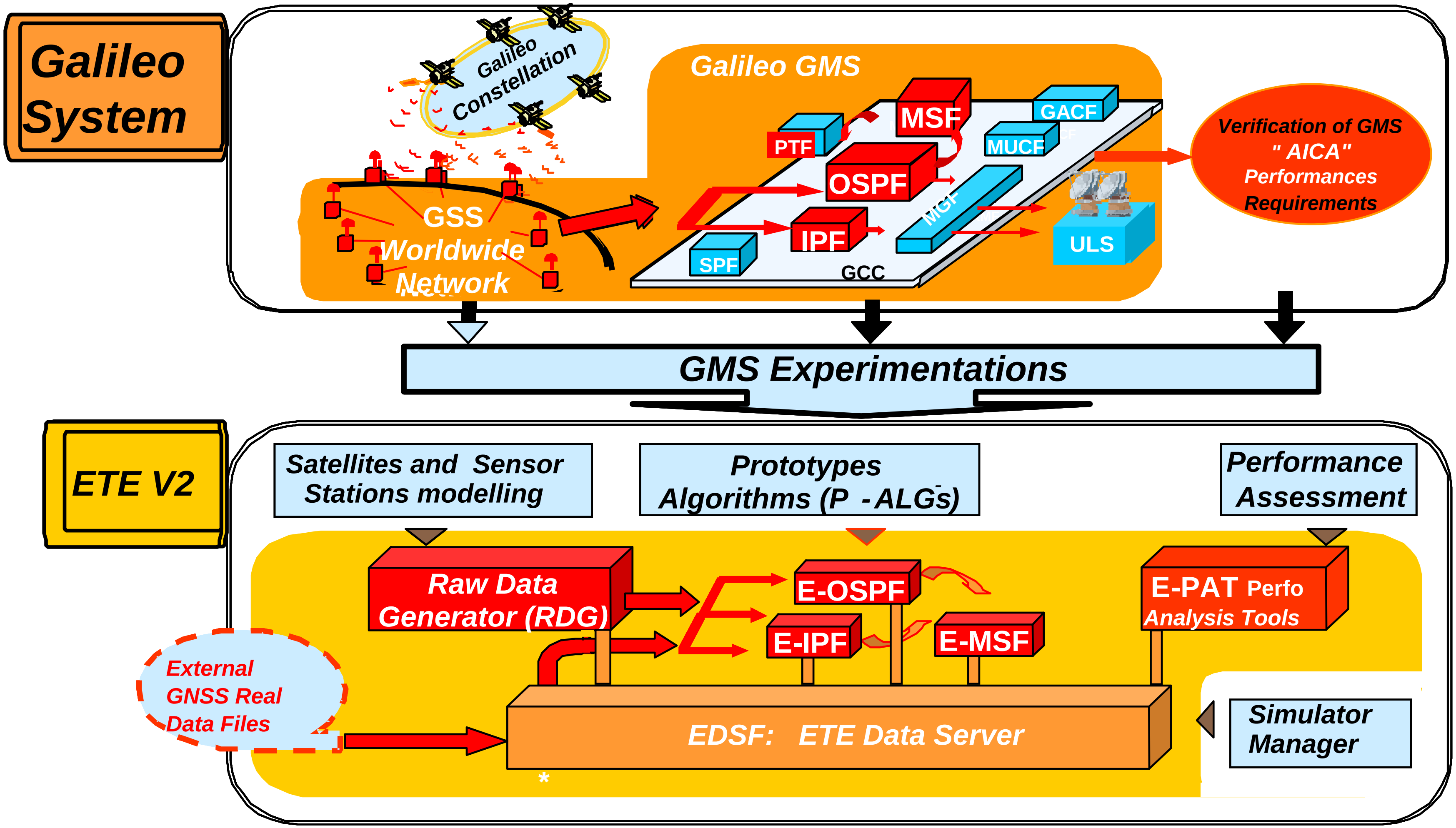
Provide Galileo Users with SIS :

- Accuracy
- Integrity
- Continuity
- Availability

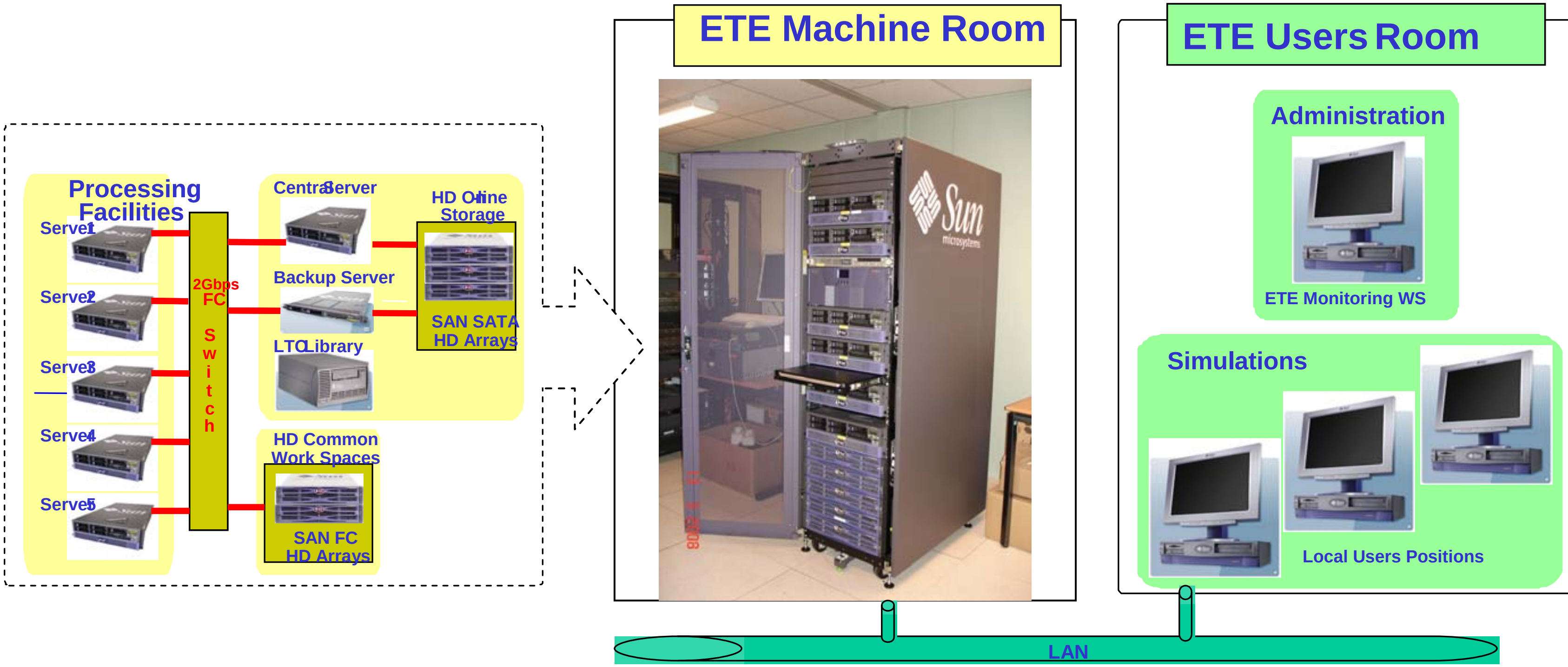
"AICA" Performances

-1- ETE INTRODUCTION

GMS & End To End Simulator



The ETE Platform



7 Quadri & Octo processors Servers (Opterons 64b)	**•Linux cluster over SAN Technology 5 Disk Arrays of 12 Disks each one**
• 100 Giga flops/s • 200 Giga Bytes of RAM	**• 2 Gbit/s Fibre channel • 20 TeraBytes of disk**

1 – ETE INTRODUCTION

2 – ETE USAGE LOGIC & RESULTS

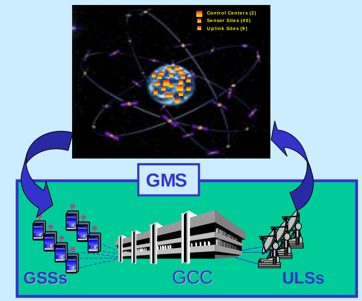
- GMS Experimentation progress Status
- GMS Reference Scenario (GRS) used
- Type of results produced
- Logic of ETE usage

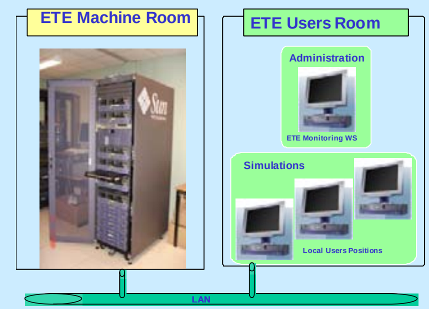
3 – ETE LESSONS LEARNED

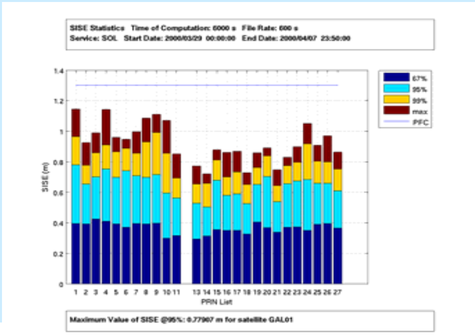
4 – ETE EVOLUTIONS

5 – CONCLUSION

6 – QUESTIONS ?







- **Short-term objective of the ETE V2 version was to allow Thales GMS Performance Team to:**
  - verify the main GMS performance requirements at GMS CDR stage
  - get the first qualification credits on AICA Performances requirements for further GMS qualification.

- **The presentation is not devoted to detail the successful results achieved at CDR in term of performances but rather to present:**
  - the type and the representativeness of results, which have been produced.
  - the usage of the ETE by the final User (I.e. GMS Performance team).

GMS Reference Scenario (GRS)

- **The GRS (GMS Reference Scenario) → RDG synthetic data sets**

- **40 GRS generated:**

  - **16 Background scenarios and**
    - representing the nominal steady-state behaviour of the system for AICA Performances verification.
    - typical duration of 13 calendar days.

  - **24 Feared Event scenarios.**
    - extreme case with low probability of abnormally functioning for safety-of-life (IC) requirements verification
    - typical duration of 5 calendar days.

-2- ETE USAGE LOGIC & RESULTS

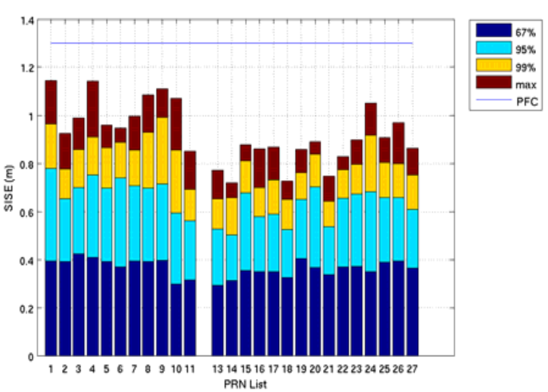
Type of results produced by ETE

Synthetic graphical results with Pass Fail Criteria (PFC) w.r.t the compliance of the key AICA Performances, according to the GRS input used.

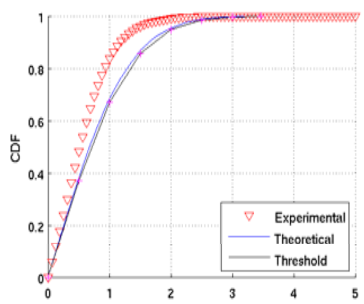
Below results examples show (from left to right) the assessment of the:

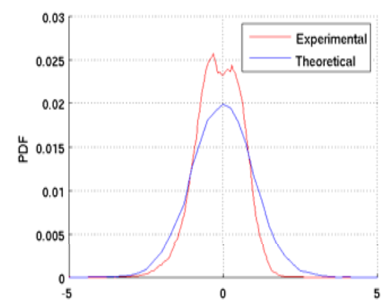
- **Accuracy performance of each satellites** : SIS Error ranging
- **Integrity performance of a given satellites**:
  - ✓ SIS Monitoring error over bounding in a Background scenario
  - ✓ SIS Monitoring error over bounding in a Feared Event scenario

SISE Statistics Time of Computation: 6000 s File Rate: 600 s
Service: SOL Start Date: 2000/03/29 00:00:00 End Date: 2000/04/07 23:50:00



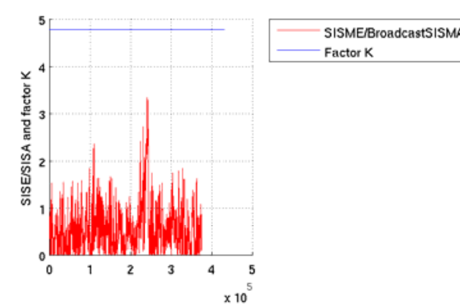
Maximum Value of SISE @95%: 0.77907 m for satellite GAL01





Pass/Fail Criterion Test : OK
Number of independent samples = 18422
Verification up to: 3.46 sigma

BROADCAST SISMA Overbounding Test for PRN1 in Feared Event configuration

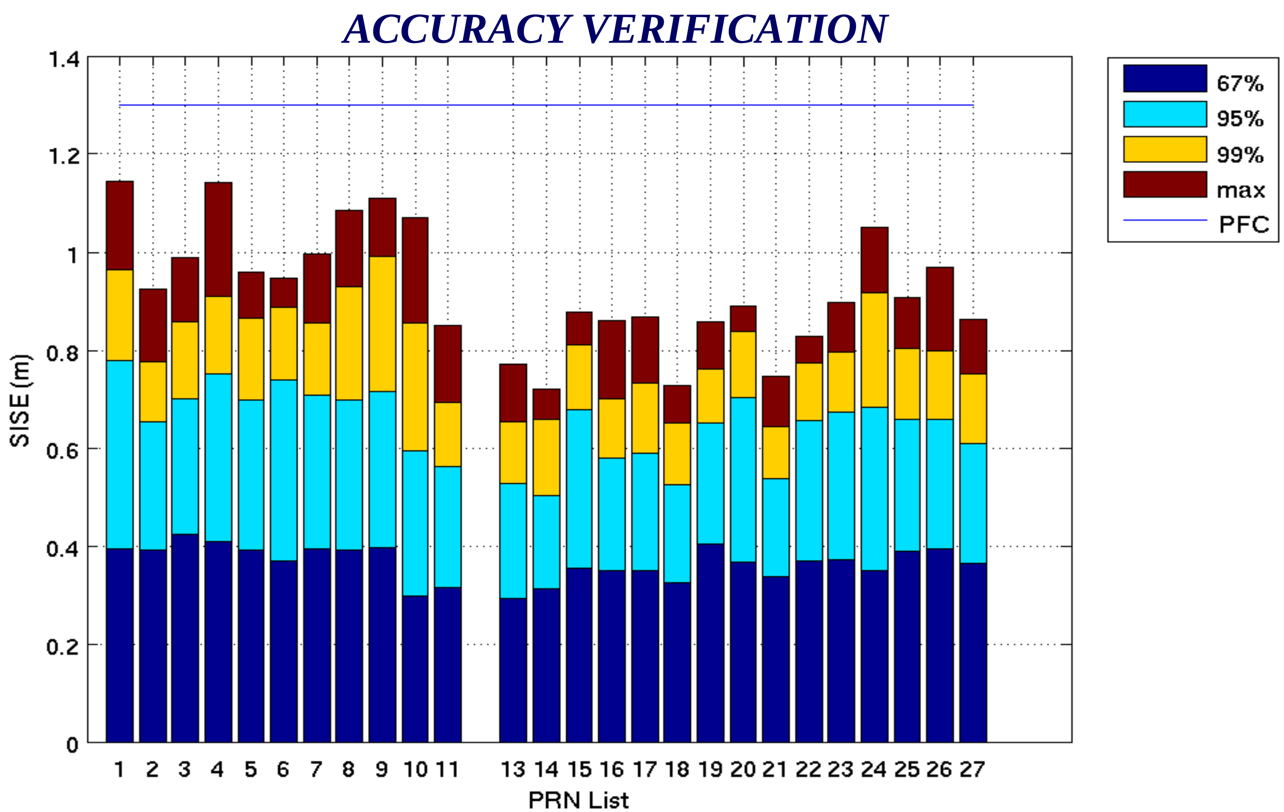


Pass/Fail Criterion Test for Feared Event: OK
Factor K = 4.7741

-2- ETE USAGE LOGIC & RESULTS

Type of results produced by ETE

SISE Statistics   Time of Computation: 6000 s   File Rate: 600 s
Service: SOL   Start Date: 2000/03/29 00:00:00   End Date: 2000/04/07 23:50:00



Maximum Value of SISE @95%: 0.77907 m for satellite GAL01

Logic of ETE usage

1) <u>Dataset production and verification activities:</u> Usage of ETE V1 with RDG & EPAT in standalone mode (6 months)

- Generation of 40 GRS → 250 simulated calendar days and 3 TB of data with a generation time of about 3 weeks for the whole of the GRS.
- Corrective versions or work-arounds requests for all RDG blocking anomalies (among the 90 models managed by the RDG)
- Tuning of the 30,000 parameters (calibration).
- Up to 6 regenerations of each GRS to reach a correct tuning

<u>2) GMS Performance Simulations activities</u>:

- Usage of ETE V1 with GMS Prototype Algorithms (P-ALGs) running in standalone (6 months)
    - Unitary tests of 4 P-ALGs in different stage of development
    - Corrective versions or Work-arounds requests for P-ALGs blocking anomalies
- Usage of ETE V2 in connected mode
    - first running GRS partial session involving P-ALGs two by two
    - then running GRS global session (GRS) with interactions between all the P-ALGs

1 – ETE INTRODUCTION

2 – ETE USAGE LOGIC & RESULTS

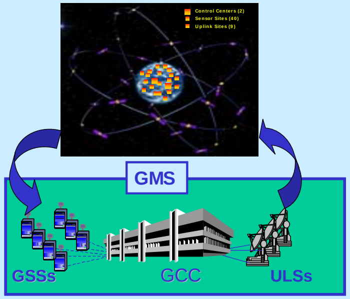
3 – ETE LESSONS LEARNED

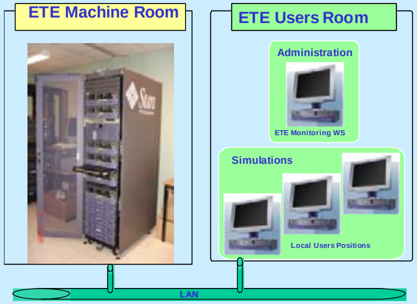
- HW Choice and Obsolescence
- HW Margin
- Versioning and intermediate delivery
- Software reuse
- Performance Analysis Tool development
- Prototype Algorithm consistency

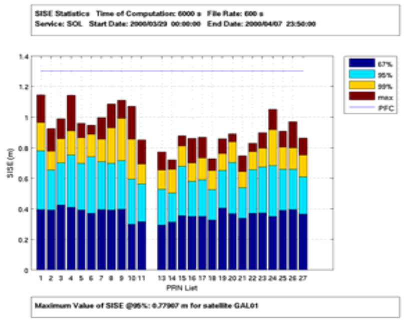
4 – ETE EVOLUTIONS

5 – CONCLUSION

6 – QUESTIONS ?







- 3- ETE LESSONS LEARNED

HARDWARE OBSOLESCENCE

Main difficulty: *It is not possible from mid-2008 to build a new identical ETE platform due to HW changes on the manufacturer catalogue*

→ New generation of Servers and Disk running only with new release of Operating System, Cluster.

Due to GMS operational life time of at least 20 years:

- *Need to procure new ETE platforms requested in FOC contract with the up-to-date HW*
- *Need of a new ETE SW Qualification with the associated up-to-date OS & SW COTS versions.*
- *Need to plan the HW upgrade/renewing of the 3 already existing ETE platforms (to not maintain/manage several ETE SW versions).*

HW Obsolescence concerns and HW renewal for evolutive project need to be tackled at the beginning of development .

HARDWARE MARGIN

<u>Main difficulty:</u> *at the beginning of the project the state of the art for GNSS algorithms was not yet fully defined (i.e. lots of unknown about memory and CPU needs, input and output files data flow not assessed)*

<u>Trade off:</u> *The ETE HW was chosen on standard HW COTS with strong capability to be upgraded and extended*

<u>Way forward</u>: *Work plan for close processing time monitoring was requested all along the development, to all the ETE elements providers as well as to ETE level.*

Partial HW Upgrade was Decided at the ETE CDR stage for the RDG and E-PAT elements (improvement CPU from Single core to Dual core and memory increase, addition of on FC Switch)

The early monitoring of HW performances needs has allowed to anticipate the processing time concerns.

The gold rule to select an HW platform with potential upgrade margin has been once again demonstrated for the ETE project.

SOFTWARE VERSIONNING

Main difficulty: *very complex exchanges between the different subcontracted ETE Element Software.*

→ all exchanges described in an ETE ICD (Interface Control Document),

→ GNSS standard format (Rinex, Sinex, SP3, XML etc …) used each time as possible,

→ in a few critical case the ETE processing time concerns have been solved by the definition of an ETE Binary Format (obs. and Integrity data),

Way Forward:

Additional Informal SW elements intermediate versions deliveries have allowed to progressively integrate and test the Elements to run together the earliest as possible (a total of 60 versions of the ETE SW have been counted over 1 year and half for the ETE V2).

An interface concern discovered at the earliest stage on a SW element, benefits often to the other interfaced Software.

Incremental integration when agreed with the SW providers allows to strongly optimise the schedule.

<u>Main difficulty:</u> ETE V2 number of lines of code was estimated to 500 000 loc. In fact this development has reached the 1 Million loc.

In order to the ETE is usable during the GMS engineering phase, its development was launched as part of the GMS anticipated developments 6 months before GMS KO.

- *At the beginning of the project, the knowledge about the complexity of the Synthetic data generation and the GNSS algorithms development was weak*
- *The ETE Loc assessment was made mainly from translation with the previous simulation Tools developed in the EGNOS project was too optimistic.*
- *During GMS design, Galileo algorithms models turned out to be much more complex and reuse less possible than estimated.*

<u>Way forward:</u> *More intermediate SW element and ETE versions have allowed to optimise the schedule as far as possible.*

If the reuse of software seems often attractive at the beginning of a project, it stays really difficult to correctly evaluate its level of suitability at the time of decision.

In any case SW reuse introduces a big risk in the project estimation.

- 3- ETE LESSONS LEARNED

ANALYSIS TOOL DEVELOPMENT

Main difficulty:

Lack of deep knowledge about the algorithms outputs (e.g. range and precisions of value expected) to be able to specify for some critical graphically analysis display.

→ Necessity for these analyses to develop prototypes tool and to perform iterative tuning, before to be able to stabilise the specifications.

***Software of little size**, not adapted to the initial GSWS life cycle used → consuming lots of effort → finally not at all compatible with GMS schedule.*

***Way forward:** decision to reinforce the testing and documentation of the Analyse prototypes tools (E-PATp) initially dedicated to the specification to submit them to a qualification process. Finally, once qualified E-PATp have been used for GMS experimentations and integrated in the ETE.*

The development of such Analysis tools requests to be developed very closely with the final users and follow an incremental life cycle (flexible and reactive).

Hence, this kind of tools should not be sub-contracted to external partner.

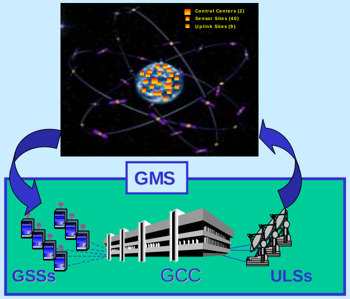
__Main difficulty:__ *One major point to achieve a representative ETE modelling of the GMS was to keep the coherency of the ETE Prototype algorithms with the Operational Algorithms.*

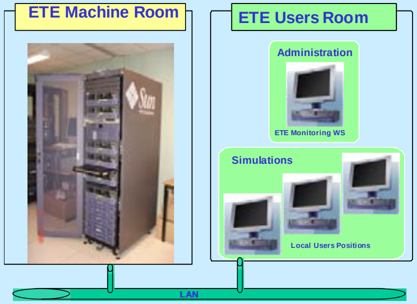
__Followed Approach:__

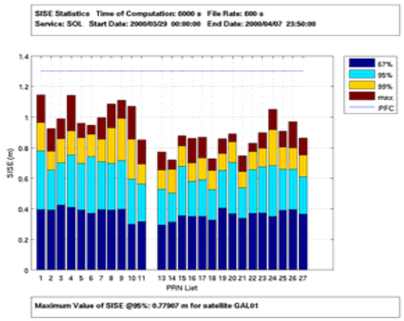
- *To start with the prototype algorithm specification, which is directly derived from the operational algorithm specification.*
- *To entrust to the same providers the Prototype algorithm in charge of the operational algorithms development (prototype and operational algorithms consistency has been requested)*
- *To verify changes done both in the ETE AIV and the GMS AIV: any anomaly detected on one side will be reported to the other side.*

Such development approach seems a strong constraint but at the end it allows to save schedule and cost for the algorithm prototypes as well as for the operational elements.

THALES

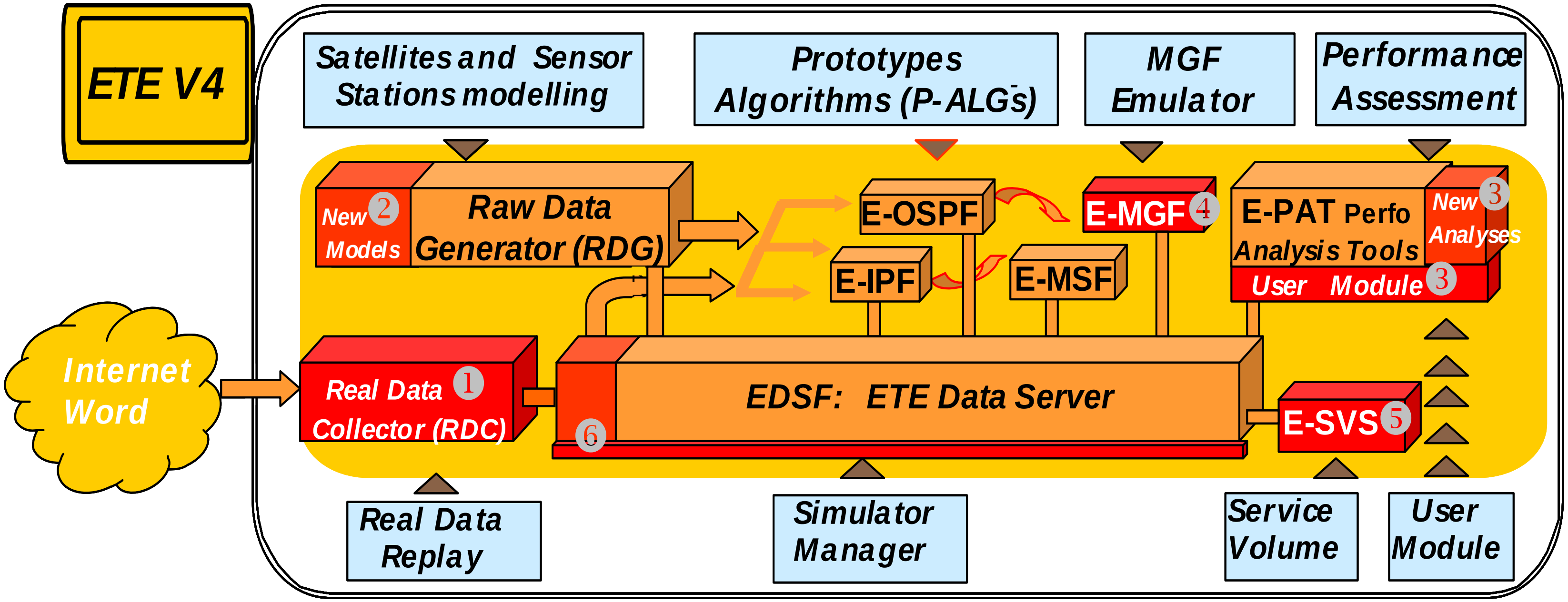

GMS
GSSs
GCC
ULSs


ETE Machine Room
ETE Users Room
Administration
ETE Monitoring WS
Simulations
Local Users Positions
LAN



- 4 - ETE EVOLUTIONS

ETE V4



❶ *RDC Element automates the collecting of Real Data from Internet servers*

❷ *RDG models link to Real Data analyse feedback and generation dynamic users measurements.*

❸ *E-PAT analyses for troubleshooting and its enlargement to host an User Module*

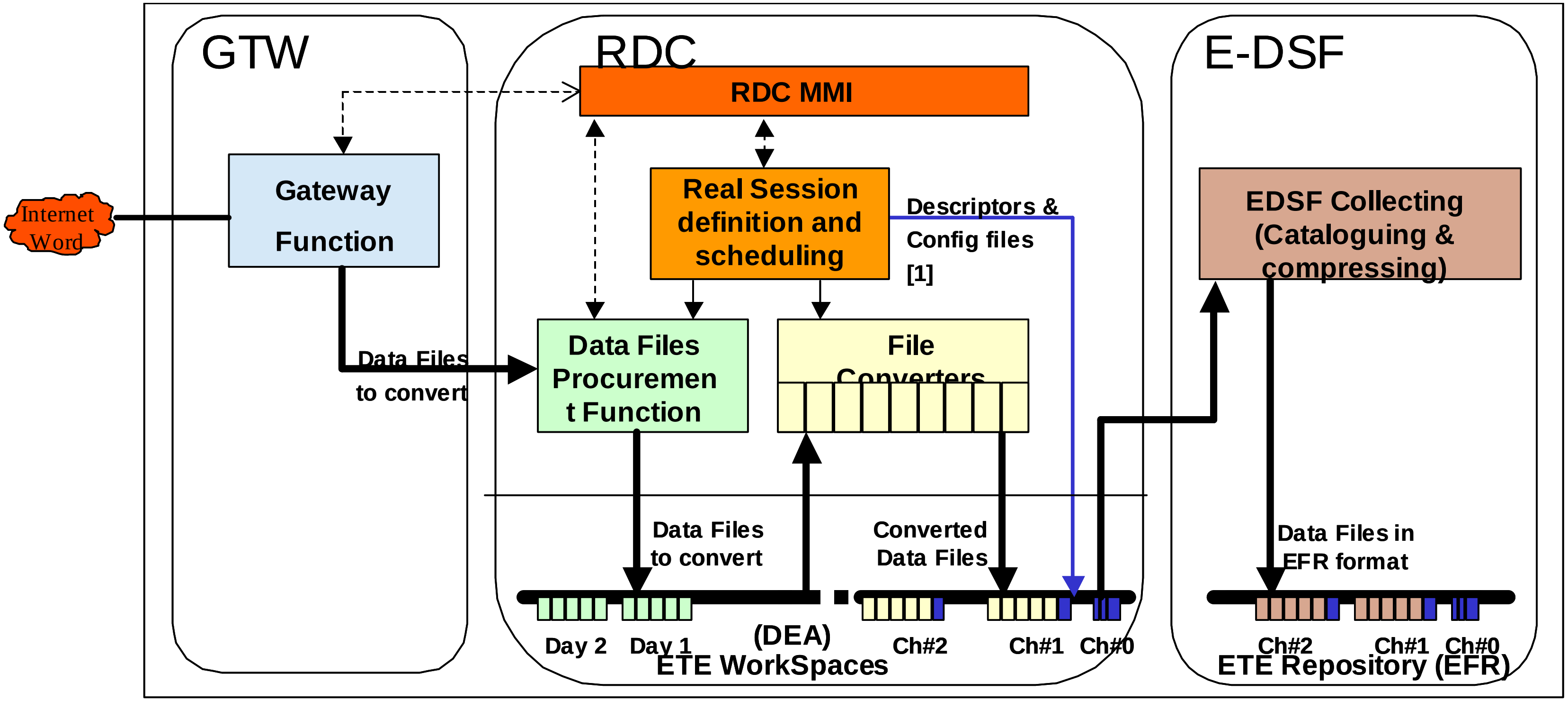
❹ *E-MGF new element to emulate the GMS MGF dissemination functionalities*

❺ *Service Volume analysis with a high level of resolution*

❻ *E-DSF improvement to manage the above evolutions*

❶ Real Data Collector (RDC)

→**RDC preparation:** Constellation and Stations configuration
→**RDC automatic Real Data collecting from Internet servers**
→**RDC automatic Real Data conversion** to the ETE format

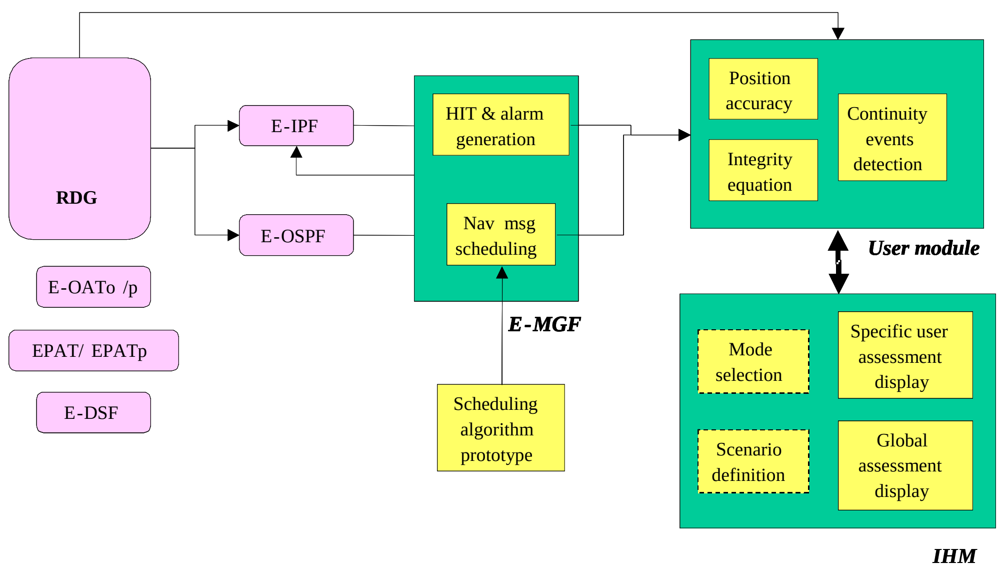


User Module & E-MGF

The ETE V2 design focuses on performance assessments for **GMS Processing chain** (Navigation and integrity determination).
The ETE V4 objective is also to address performance assessments as seen by the **Real Galileo Users**:

- assessment of GMS performances impact at User level
- evaluation of Galileo Users performance with realistic navigation/ integrity message dissemination (E-MGF) through satellite-antenna allocation tables

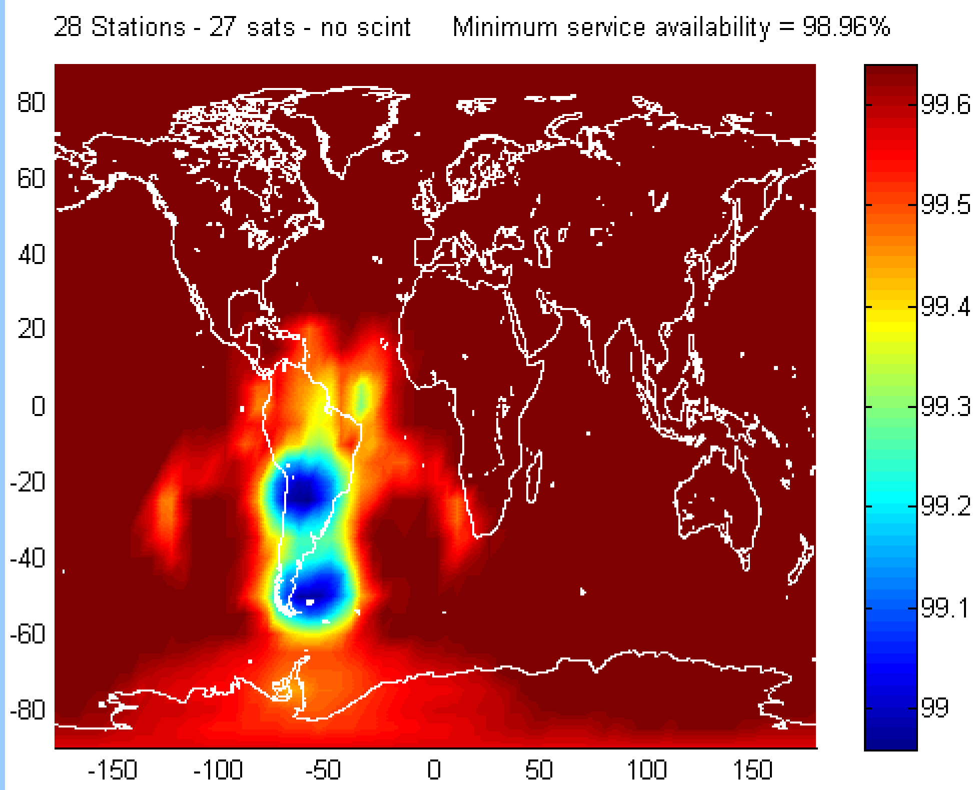
User Module architecture & interfaces including E-MGF



E-SVS Element objective:
To assess on wide area the expected performance for GNSS systems in general and more specifically for GALILEO.

Keys design:
→ **to obtain realistic simulations** relies on the capability of the E-SVS to mimic satellites based navigation system with a representative behaviour
→ **to be versatile enough for a constant use** of the tool during a GNSS project life cycle.

Performances:
Synthetic or Real data processing with the powerful ETE platform will allow **to achieve an unmatchable granularity of results**.



Others Evolutions

New RDG models: to complete or optimise current models from the Real Data analyses feedback and to generate measurements for dynamic user receiver.

New Converters: to assess and investigate the GMS Operational Element performances during the GMS deployment phase (such as OSPF/IPF and S-MSF) using real data.

New EPAT Performance Analysis : to support the GMS AIV, S&IV, FOC specification and design definition:

→ by additional GMS performances analysis

→ by complementary analysis for AIV troubleshooting.

1 – ETE INTRODUCTION

2 – ETE USAGE LOGIC & RESULTS

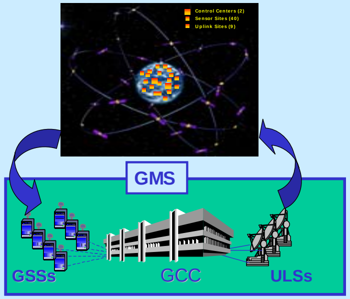
3 – ETE LESSONS LEARNED

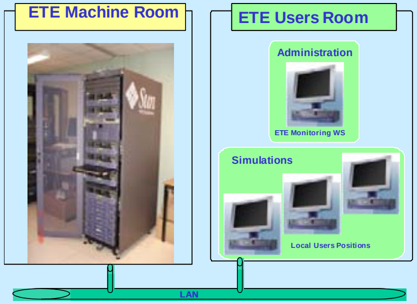
4 – ETE EVOLUTIONS

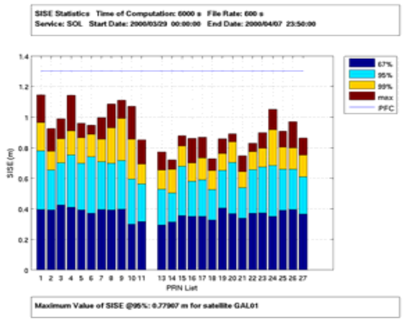
5 – CONCLUSION

- Today
- Tomorrow
- In the next future

6 – QUESTIONS ?







Today … a success

ETE V2 was a challenging simulator development ambitious and complex.

Today the ETE V2 focused on Galileo performance design mainly thanks to:

- Very high degree of modelling of the **synthetic data**
- GMS Prototype algorithm maintained in line with the operational ones
- Very powerful and fitted GMS Performance Assessment Tools
- User oriented operational concept for design engineer
- Powerful processing capability (7 time faster than real time)
- Automatic H24 functioning without any operator presence

The objective to verify the CDR GMS performance requirements have been reached, reviewed and endorsed during the **successful IOV GMS CDR**.

ETE V4 with the new proposed evolutions opens a new challenge…

Tomorrow the ETE V4 will focus on Galileo system performance troubleshooting, validation and qualification mainly thanks to:

- Automatic **Real Data Collection** from internet servers
- GMS Prototype algorithm maintained in line with the operational ones
- Very powerful GMS **and User** Performance Assessment Tools
- **Service Volume for system performances assessment**
- User oriented operational concept for **troubleshooting, validation and qualification** engineers
- Powerful processing capability (7 time faster than real time)
- Automatic H24 functioning without any operator presence

In the next future… a real future !

In the next future, capitalizing upon the assets and experience acquired during the development phase, the ETE will introduce a substantial contribution to the support of the Galileo performance Operations follow-up.

- 6 – ANY QUESTIONS ?

1 – ETE INTRODUCTION

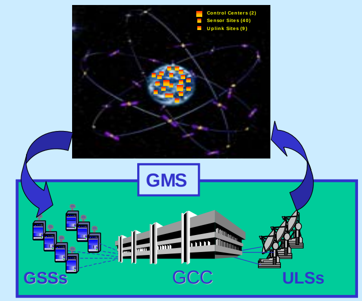
2 – ETE USAGE LOGIC & RESULTS

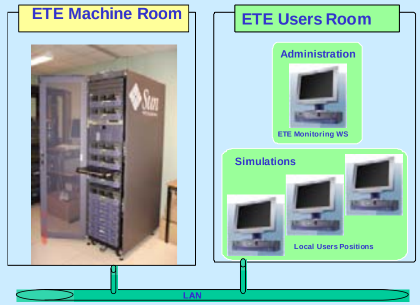
3 – ETE LESSONS LEARNED

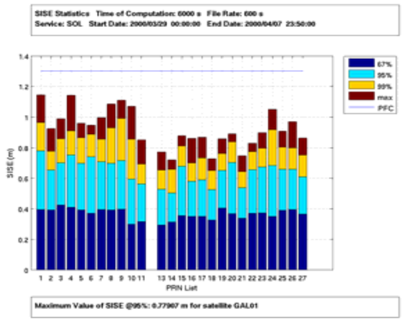
4 – ETE EVOLUTIONS

5 – CONCLUSION

6 – QUESTIONS ?





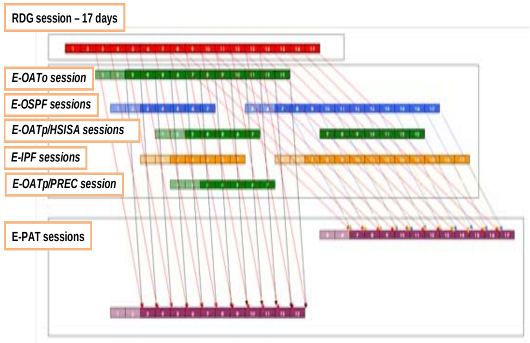


- 6 – ANY QUESTIONS ?

GMS End To End Simulator

First Usage, Lessons Learned and Perspectives

SESP 2008



alain.boyer@thalesaleniaspace.com
Bernard.amiel@thalesaleniaspace.com
Frederic.bauer@thalesaleniaspace.com
Raffaella.Franco@esa.int
Alexandre.Ballereau@esa.int