ESA/ESOC REAL TIME DATA PROCESSING

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10 May 2006

Outline

1. The ESA/ESOC RT tracking network
2. The ESOC Real Time processing strategy
3. Sequential filter prototype for RT estimation of clock biases and ZTD
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5. Conclusions
6. Future ESOC RT infrastructure: RETINA

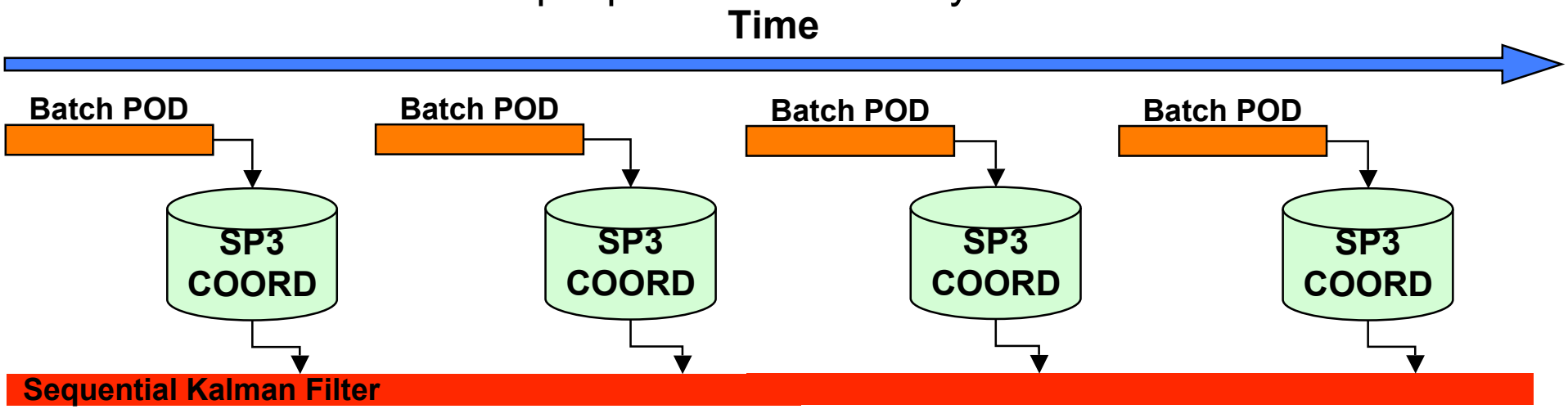
1/2 ESA/ESOC RT Tracking Network

- ESA/ESOC RT tracking network status
  - ESOC has been supporting the IGS RT working group since 2004. There are currently 9 sites submitting 1Hz GPS data streams in Real Time. Eventually the whole network will be operating in RT.
  - The migration from the previous RT data management application (RTGlocal & RTGremote) to the new standard RT IGS software (Ashtechreader & UDPrelay) has been accomplished.
  - The RT data streams cannot be directly routed from the remote sites but need to be transmitted to the control facilities at Darmstadt before the streams can be made publicly available.
  - Recovering of data through ftp retrieval of batch data files

2/2 ESA/ESOC RT GPS Tracking Network

1/2 ESOC Real Time processing strategy

- The ESA/ESOC RT solution is based on a combined batch/sequential filtering approach.
  - The orbits (predictions) and the precise geodetic coordinates are estimated by batch POD processes. The frequency of these batch runs is higher than the IGU (normally one run every hour).
  - Those orbits and coordinates will be used as inputs by the sequential clock bias estimator. Apart from the clock biases, the filter estimates tropospheric zenith delays for all the stations.



2/2 ESOC Real Time processing strategy

- Advantages of the combined batch/sequential filtering
  - Simplicity
  - Reduced computation time
  - Very low latency of the navigation solution
  - Accuracy improvements in the GNSS products (i.e. the s/c clock biases) for RT users
  - RT monitoring of the GNSS SIS as a result of the implementation of sequential GNSS data processing

Sequential filter for RT estimation

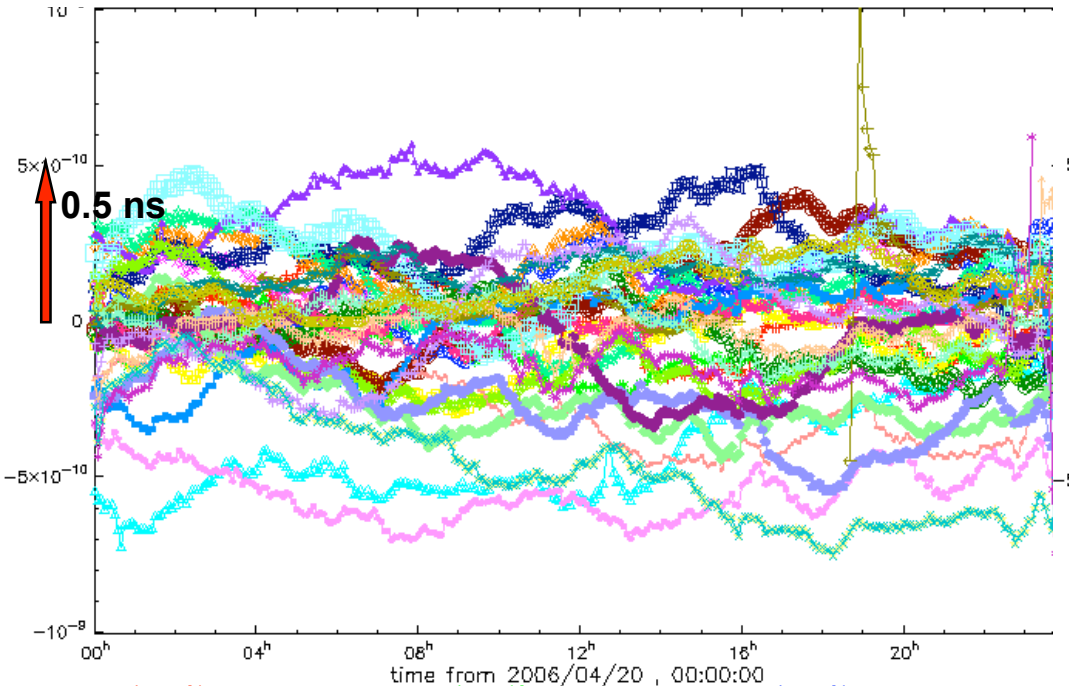
- Main features
  - Sequential data processing through the implementation of a Kalman filter
  - Processing of iono free combinations of code and phase GNSS observables
  - Estimated parameters:
    - » clock bias estimates for all spacecrafts and stations in the system
    - » An intersystem bias value for every combined GPS/GLONASS receiver
    - » a ZTD value for each site and
    - » initial ambiguities for all the phase observations.
  - Built-in algorithms for the detection of cycle slips and outliers in the data.
  - Improved performance through the use of highly efficient code for doing the low level algebra computations (ATLAS package)

1/2 Test case 1

- Assessment of the maximum accuracy achievable by the current prototype
- Only the RT filter prototype is tested
- Test period: GPS week 1371 dow 4 (20/04/2006)
- Clock estimates are computed based on:
  - A globally distributed network of 52 IGS sites
  - ESA final orbits and coordinates
- Scenario settings:
  - The sampling of the measurements processing is 30 seconds
  - Elevation mask set to 10º

2/2 Test case 1 - Results

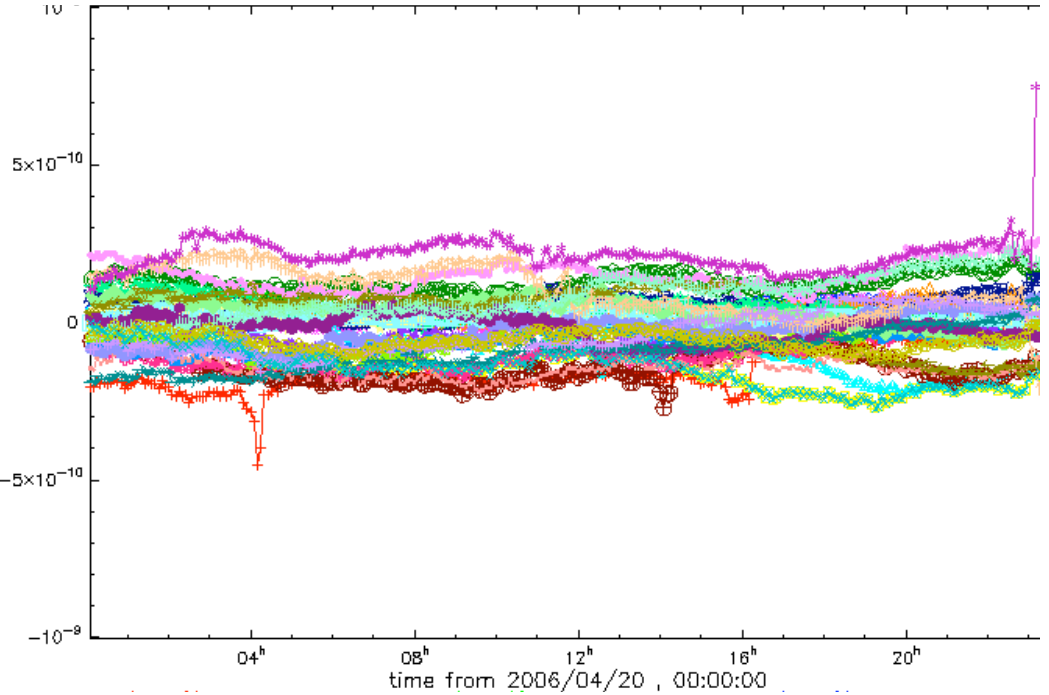
Filter vs. IGR s/c clock bias comparison 1371_4



Overall RMS: 0.240 ns

Best Clock RMS: 0.048 ns

ESA final vs. IGR s/c clock bias comparison 1371_4



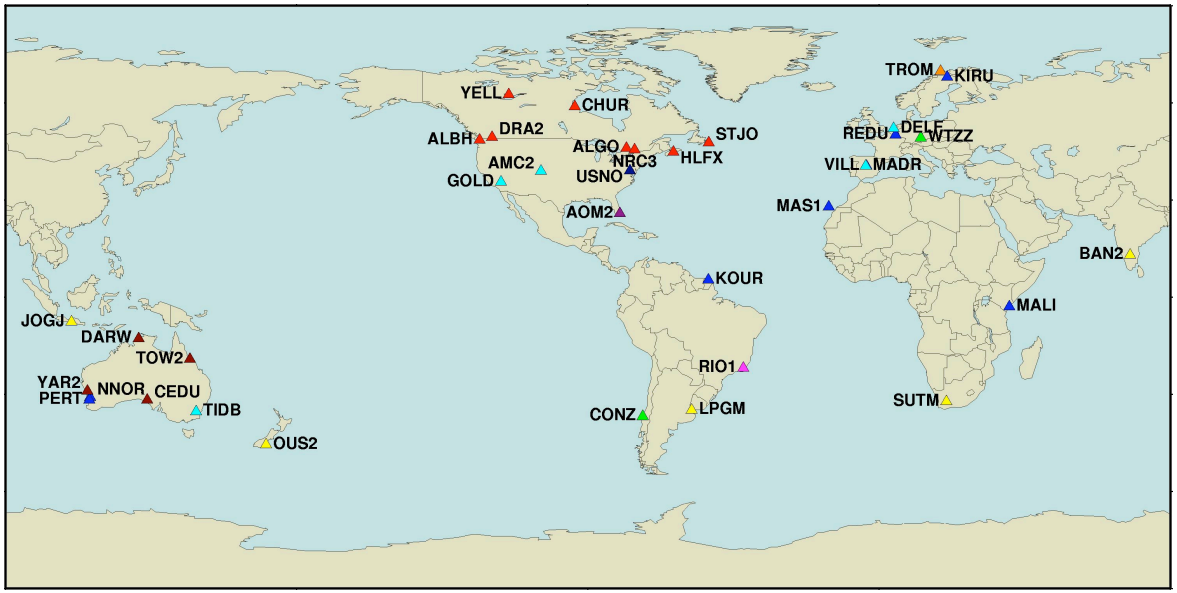
Overall RMS: 0.106 ns

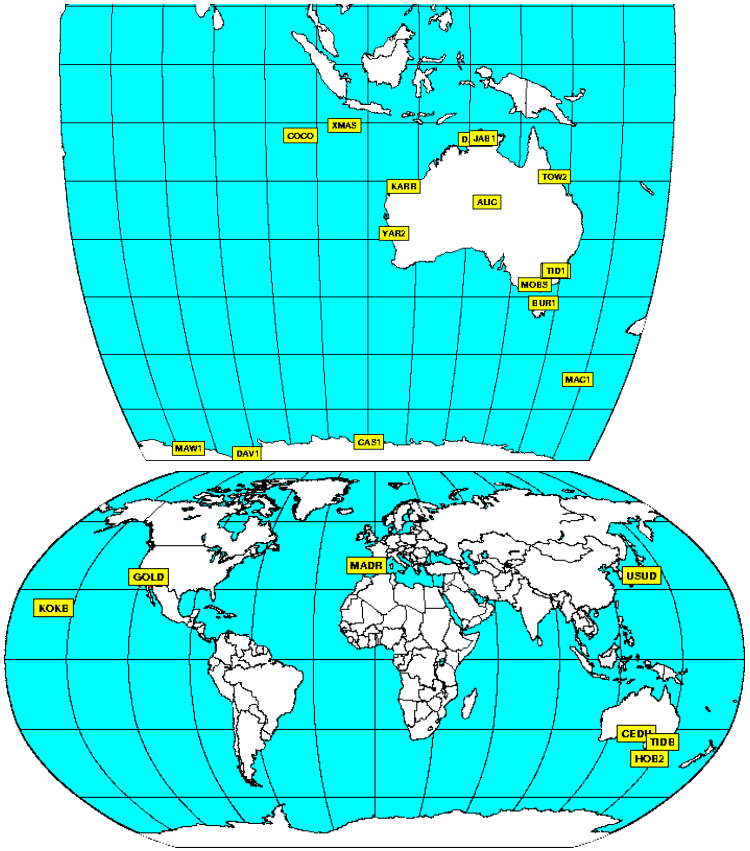
Best Clock RMS: 0.025 ns

1/4 Test case 2

- RT emulation. The whole system runs in the same way as in the planed operational environment
- Meant to show the achievable performance in RT using current resources available (Tracking network & software)
- Test period: GPS week 1367 dow 5 (24/03/2006)
- Clock estimates are computed based on:
  - A tracking network of 32 IGS LEO sites.
  - Frequent batch updates (orbits and coordinates are computed every hour)
- Scenario settings:
  - The sampling of the measurements processing is 1 second
  - Elevation mask set to 5º (due to poor coverage in certain areas)

2/4 Test case 2 – Stations availability





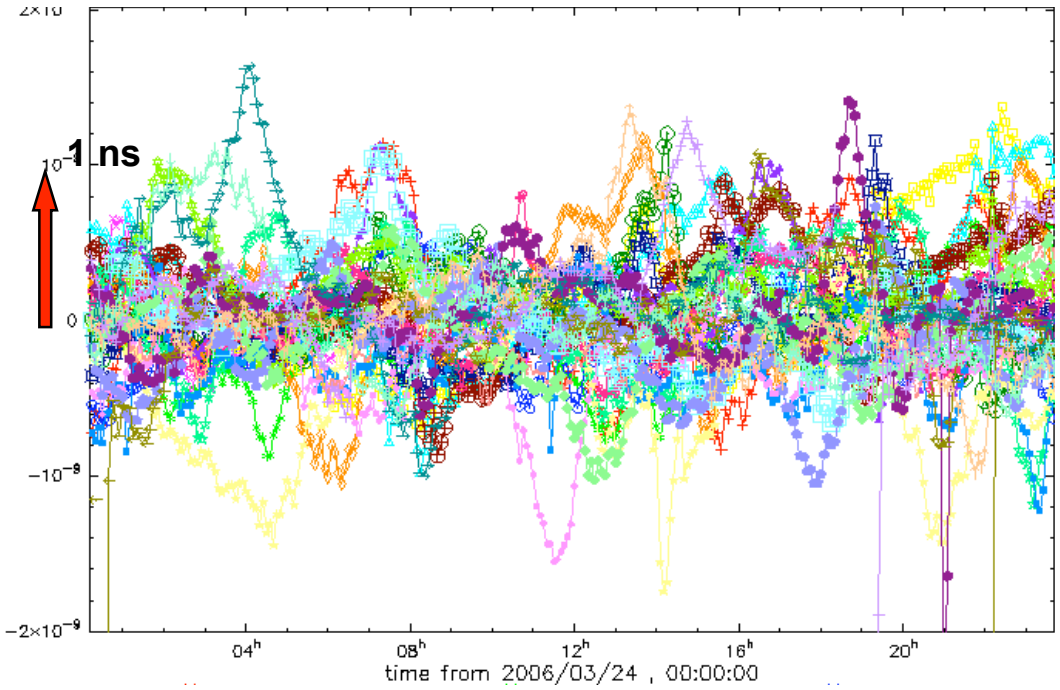
IGS RT prototype network. Current and committed stations

(Source: igsdr.geod.nrcan.gc.ca)

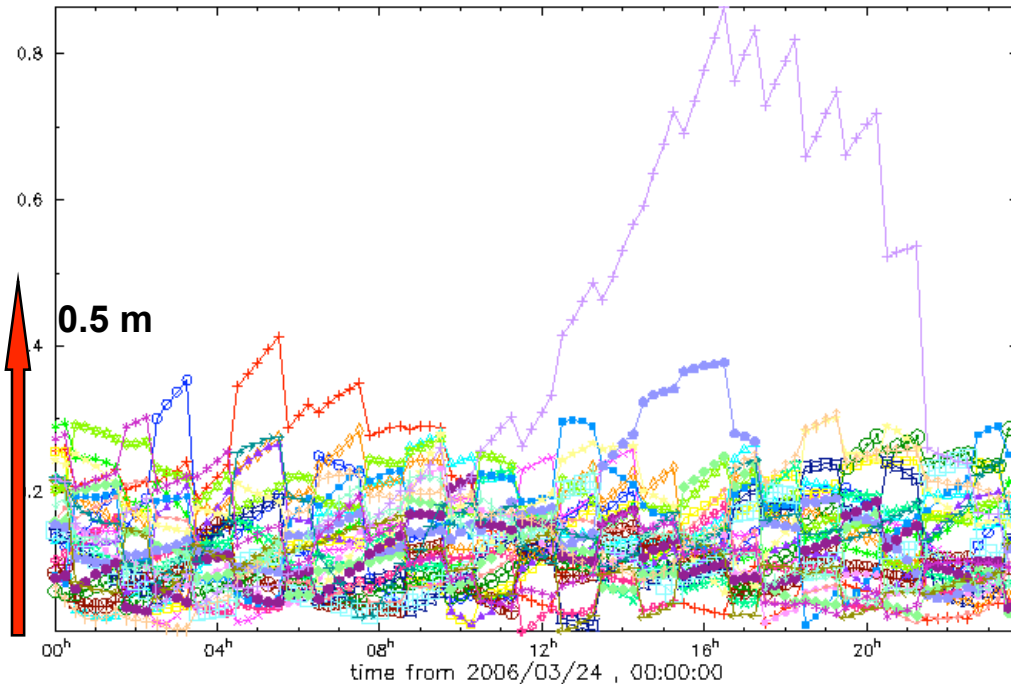
3/4 Test case 2 – Selected network

2/2 Test case 2 - Results

RT vs. IGF s/c clock bias comparison 1367_5



Batch prop. orbits vs. IGF orbits total error 1367_5



Overall RMS:	0.424 ns
Best Clock RMS:	0.199 ns

Overall typ RMS:	9.7 cm
Best s/c typ RMS:	5.4 cm

PPP results

- Further assessment on the RT products quality based on static PPP
- Precise coordinates for site WTZR (Germany) have been computed with NAPEOS using the previous products
- Those results have been compared with the coordinates computed using the ESA Final products
- Test Case 1 (Estimated orbits)
  - Residuals in local system (mm): 6.0 N -20.9 E -31.7 U
- Test Case 2 (RT emulation)
  - Residuals in local system (mm): -7.70 N -35.8 E 72.7 U

Conclusions

- ESA/ESOC is actively contributing with the IGSRT WG
- ESA/ESOC RT processing software is at a prototype stage
  - It was developed for evaluating the combined batch/sequential filter approach
  - The implementation of the physical models needs an in depth review

  However
- The tests carried out so far show that the products generated by the system are good enough for obtaining decimetre level positioning accuracies

1/5 ESOC Future RT Infrastructure: RETINA

- RETINA (System for REal TIme NAvigation)
  - Software system being developed for ESOC by Symban
  - Suite of algorithmic, visualisation and infrastructure elements to enable the processing, distribution and archiving of both Real Time and Near Real Time (Batch) GNSS data and results.
  - Borrows heavily from concepts used in Satellite Control systems
    - » GNSS data and results are treated as Telemetry Streams
    - » Application messages and alarms monitored from a single console

2/5 ESOC Future RT Infrastructure: RETINA

- RETINA subsystems:
  - Infrastructure
    - » written in C++
    - » History Filing and Event Logging middleware, Job Scheduling
    - » Java, C++ and FORTRAN interfaces
  - Algorithmic
    - » written in Fortran 90 and including heritage code in Fortran 77
    - » Real Time and Batch Data Processing and Estimation, Product Generation and Comparison Statistics
  - Visualisation
    - » written in Java
    - » Real Time graphical and alphanumeric displays, GUI software

3/5 RETINA Software Main Elements

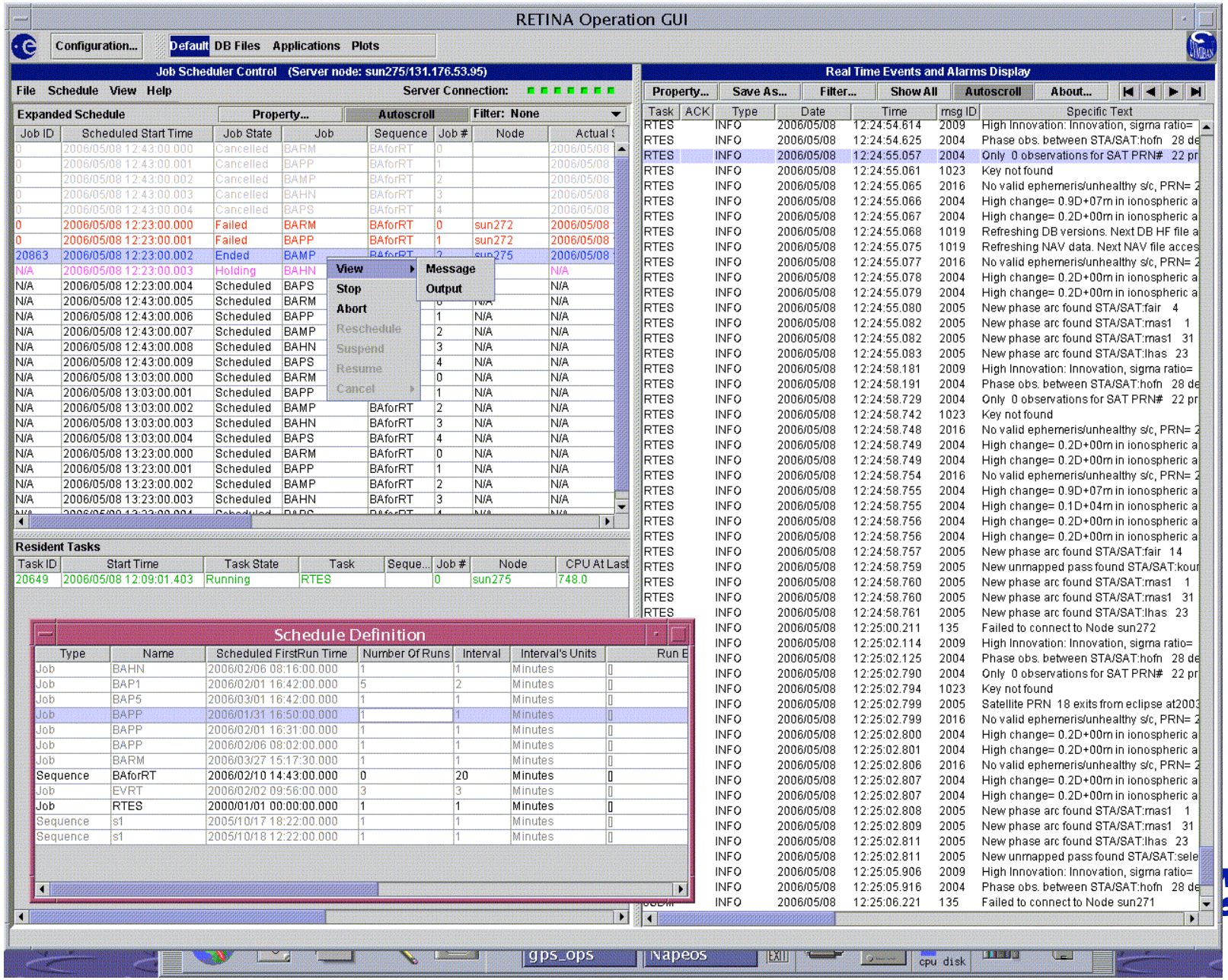
- Filing and Archiving
  - Main tool for streaming and archiving of Real Time data using “circular” files
  - Middleware layer with API calls for:
    - » Filing data to (time) key indexed History Files
    - » Update of existing HF records
    - » Retrieving ‘live’ (recent) data
    - » Retrieving archived (old) data (backward and forward directions)
    - » Derived retrieval by parameter name e.g. phase bias between s/c x and receiver y
  - History File Open and Access Servers relay data to external users via TCP
- Event Logging
  - Server for filing messages to a Log History File
  - API calls for issuing error, warning and information messages.
  - Events and Alarms Display application (with Real Time updates) for displaying logged messages and allowing the operator to acknowledge alarms

4/5 RETINA Software Main Elements

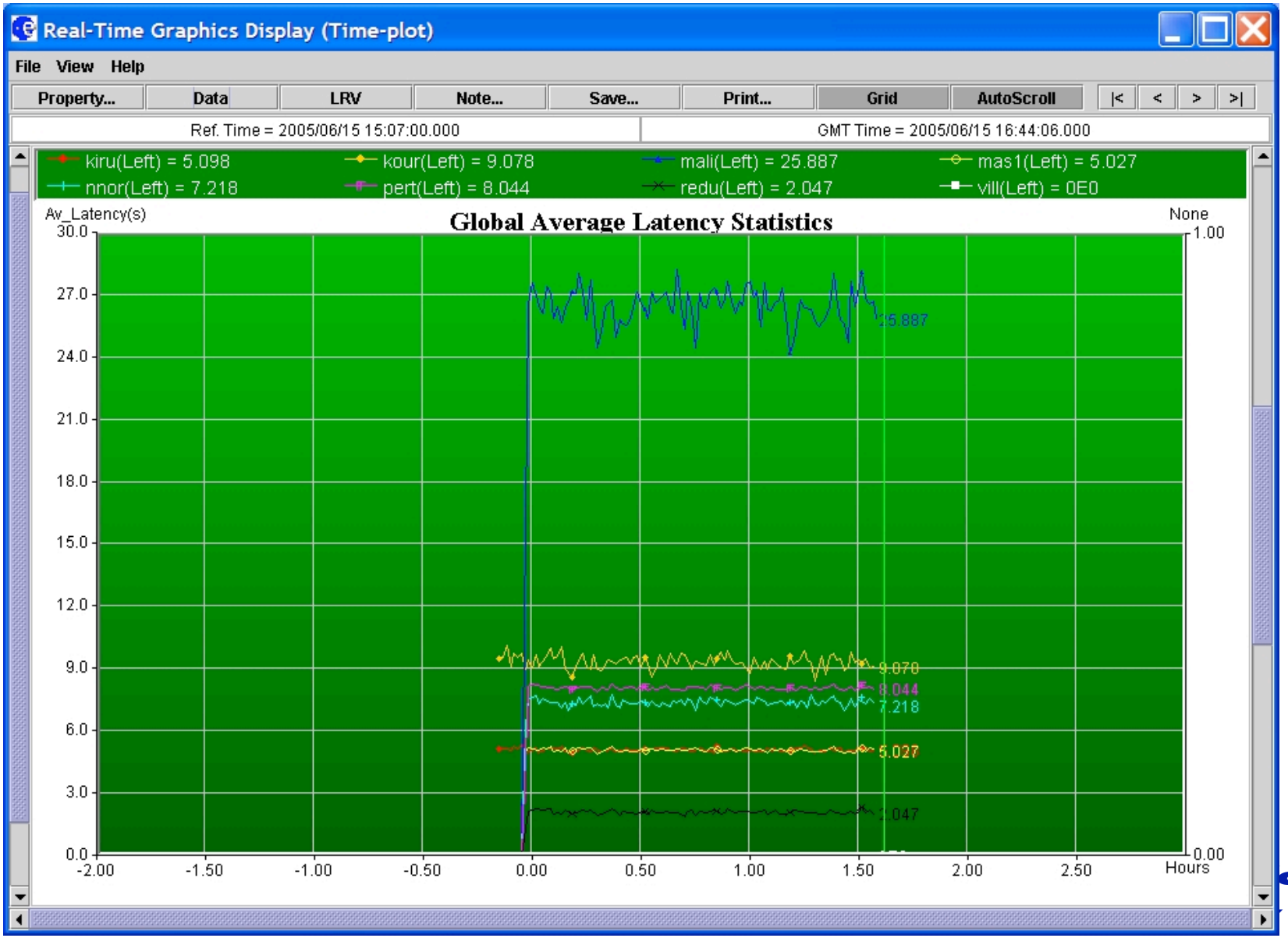
- Real Time Estimation
  - Operates either in Real Time or in Retrieval mode
  - Uses the History File API to read the streamed raw measurements (filed by a data collection task) and predicted orbit data from Batch Estimation
  - Writes out Real Time results obtained using a Kalman Filter to History Files
    - » S/c and receiver clock biases and ZTD
    - » Phase biases and processed measurements
  - Allows configuration changes without interruption (addition/removal of satellites or receivers)
- RETINA Job Scheduler
  - Scheduling of individual batch jobs or job sequences
  - Monitoring and automated restart of Resident Tasks
  - Jobs are submitted on any machine on the network and are monitored centrally via an Expanded Job Scheduling Display
  - User can intervene to cancel, abort, suspend or reschedule selected jobs

5/5 RETINA Software Main Elements

- Batch Software
  - Scheduled to run every 1-2 hours
  - Batch Run Management prepares the data and configures the software
  - Orbit Determination computes precise orbits and clocks
  - Batch Products and Statistics generates standard products, updates the Orbit History File and generates comparison statistics between batch and Real Time results and between RETINA and IGS results.
    - » Summary Results are filed to History File and product files are compressed and archived
- Real Time Graphics
  - Graphical and alphanumeric display application with Real Time update
  - Plots data from History Files and/or from ASCII files
  - Autoscrolling and auto-scaling features for hands-free operation
  - Display / export of alphanumeric data



RETINA Integrated GUI



Real Time Graphics