RSC Trending Tool for Archiving, Graphing, and Analysis of State of Health Telemetry

System Design and Theory

Presented at the GSAW 2005, Manhattan Beach, CA

Air Force Space and Missile Systems Center (SMC)

Vehicle Operations Directorate at the Ground Systems Research, Development, Test, and Evaluation Support Complex (RSC)

Kirtland AFB, New Mexico

Joel Castellanos – ASRC Aerospace
Rick Kapalko – ASRC Aerospace
Lt. Joseph Spagnolia – United States Air Force
Chris Worth – Lockheed Martin Mission Systems

Purpose

1. To present a ground system trending tool that is useful to the RSC and may be useful to others

   a) Either as is or,

   b) With source code that can be site customized.

2. To present a case for small group development of in-house software rather than using Commercial Off-the-Shelf (COTS) software.

3. To present a few specialized database tricks, algorithms, and design strategies.

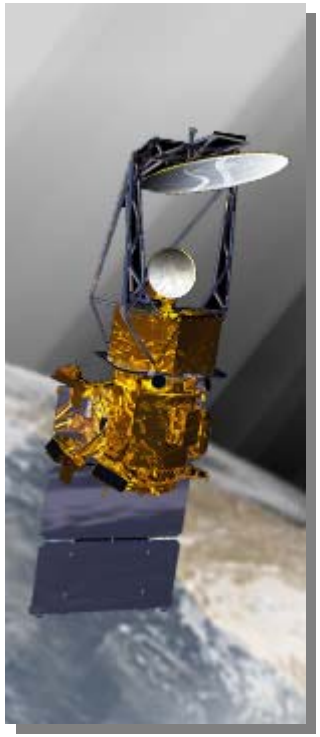
Topics

- General Description.
- User Interface.
- Data Patterns and Access Patterns that allow for specialized data management offering significant advantages over general database programs.
- Hardware Environment.
- Maintainability with Dynamic Requirements.

Input Data

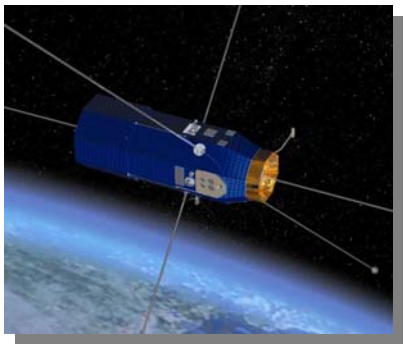
- Unique Vehicles: not constellations
- Not Real-Time
- GMT Time Series, Engineering Unit (EU) State of Health (SOH) data.
- ASCII, Comma Delimited.
- Support 3 to 7 Satellites.
- Each Satellite: 1 to 7 year Missions.
- Each Satellite: Thousands of mnemonics each sampled as much as tens of times per second (i.e. up to 1 trillion points for some vehicles).
- Not all Mnemonics Sampled at the Same Rate.
- Stored SOH (SSOH), Real-time SOH (RTSOH), etc.
- One or More Input File Per Contact.
- Time Interlaced Data on Successive Contacts.

Supported Vehicles

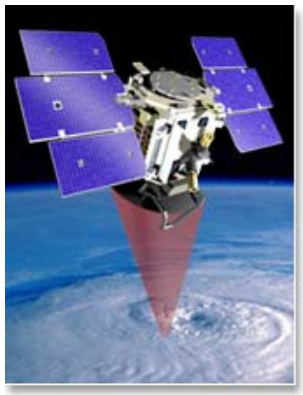


Coriolis
Operational

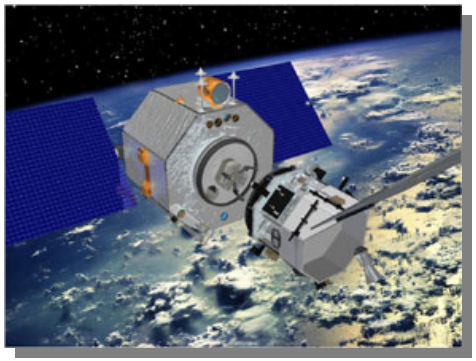
launched Jan, 2003



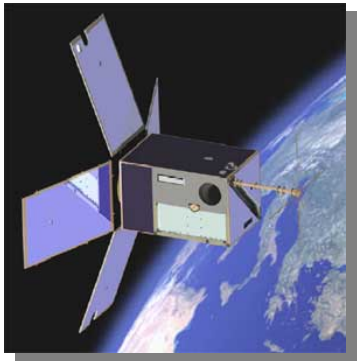
C/NOFS
Not yet Launched
FCT Data Used



CloudSat
Not yet Launched
FCT Data Used



Orbital Express
Not yet Launched
Data not yet available

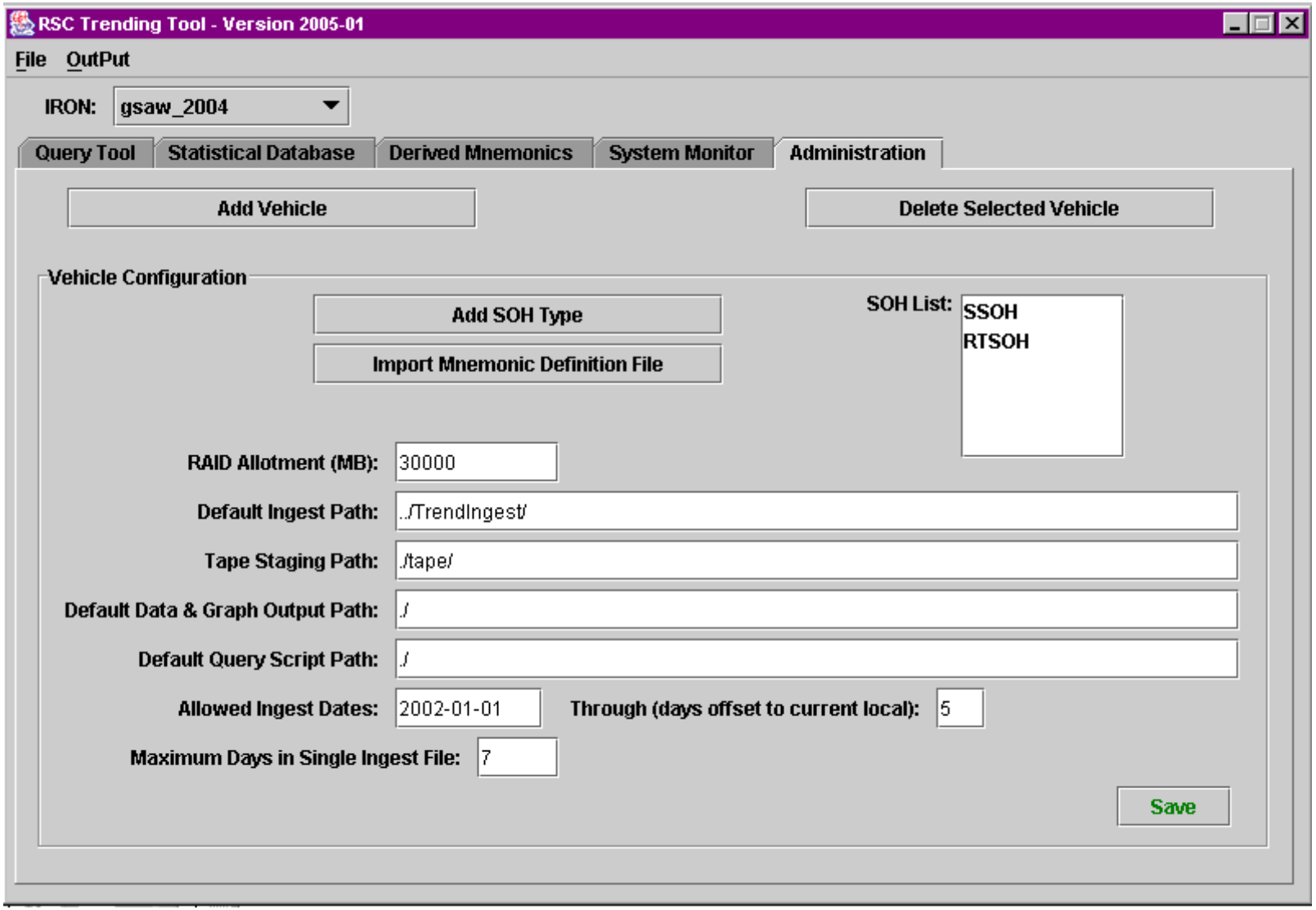


STPSat-1
Not yet Launched
Data not yet available

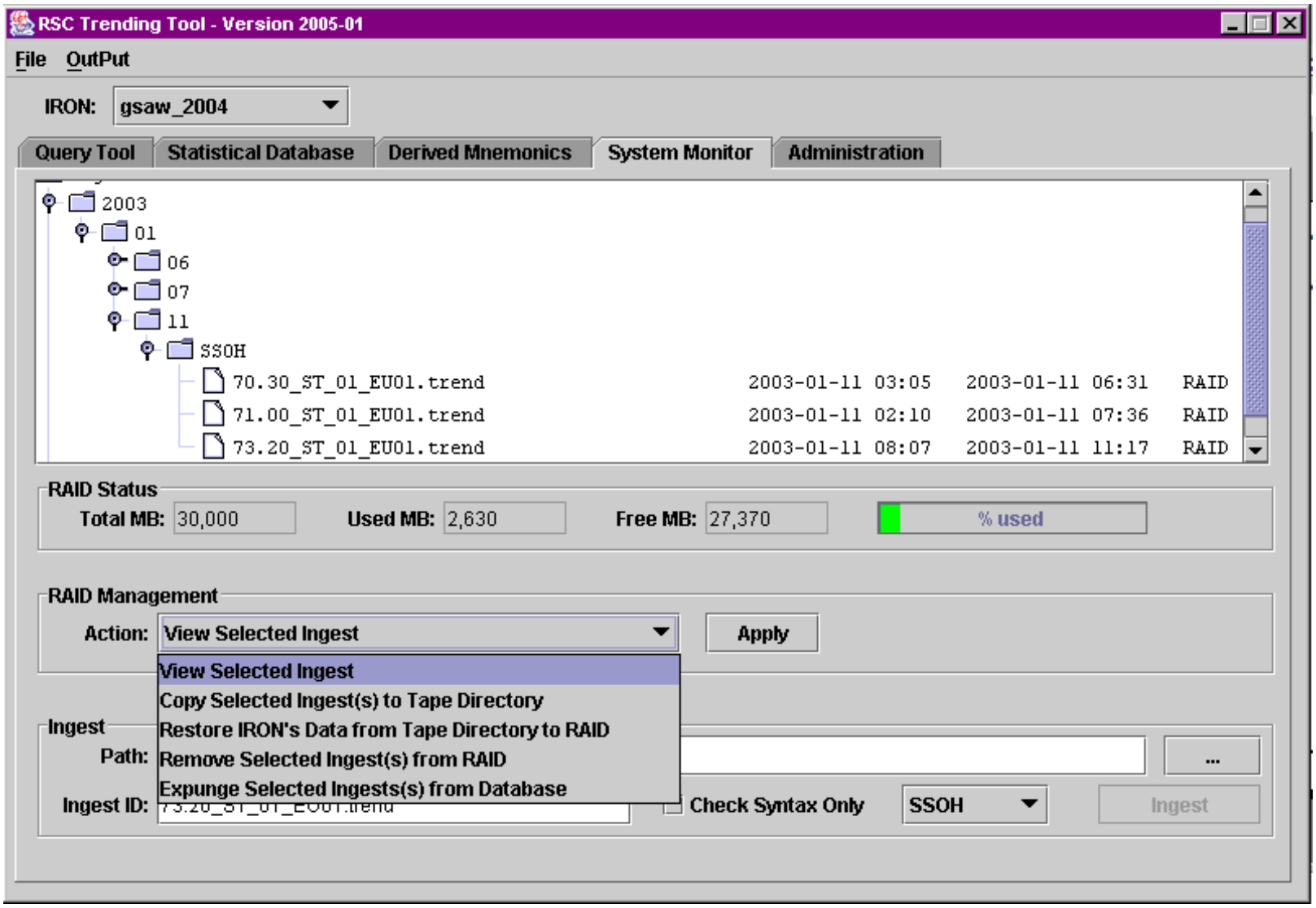
Requirements

- Short-Term Anomaly Resolution.
- Long-Term Trend Analysis.
- Reasonable Query Results in Interactive Time (seconds to minutes).
- Support Simultaneous Users.
- Simple, but Expandable Statistical Analysis.
- Query Accumulated Statistical Results.
- Interactive Graphing.
- Export results to GIF, Excel, MatLab, etc.
- Delete / Replace data by Contact and by Point.
- All GUI functions and configurations must be savable to a script that can be run automatically from a cron job on different date ranges.

Administration Tab



System Monitor Tab

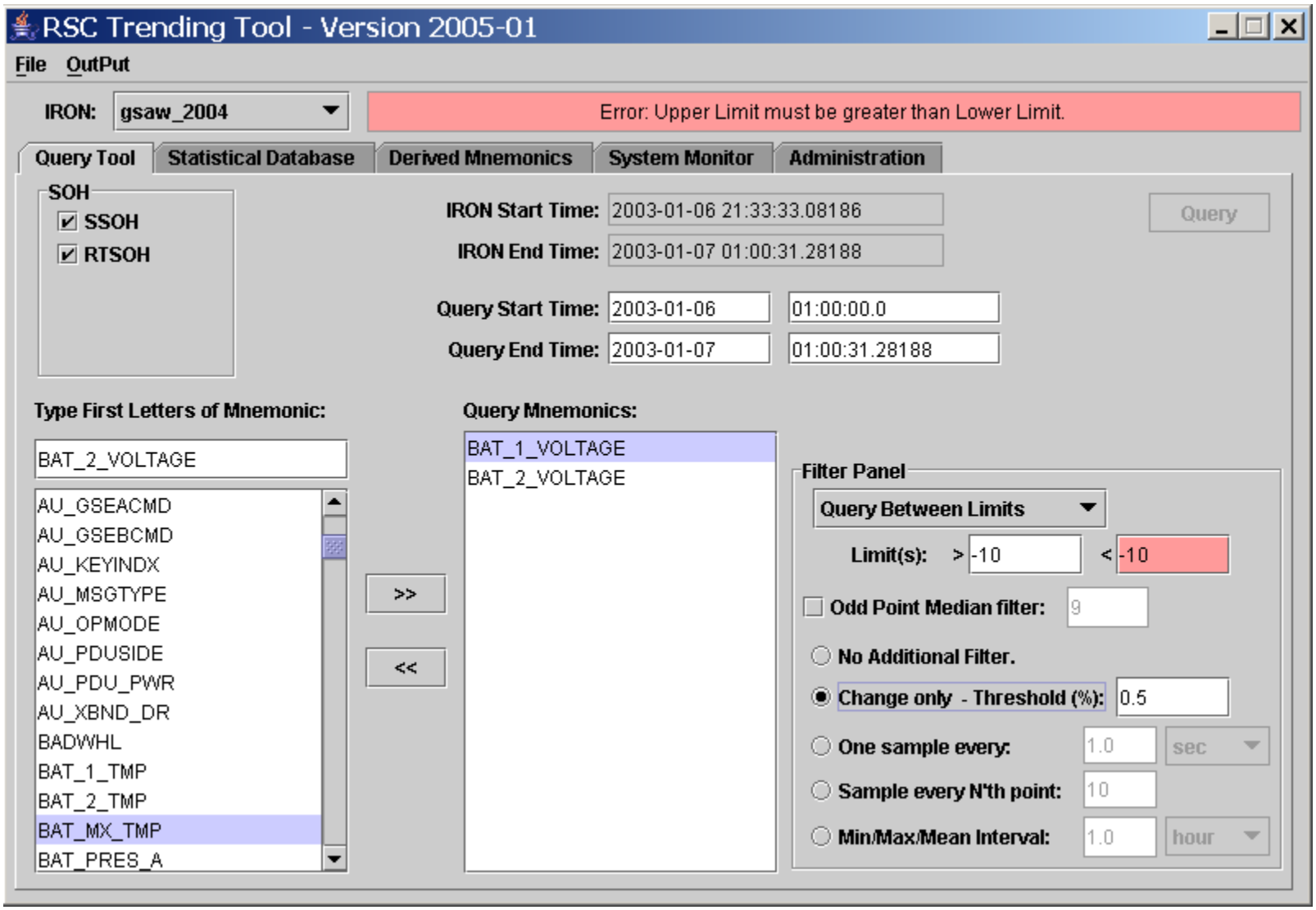


View Ingest - JTable

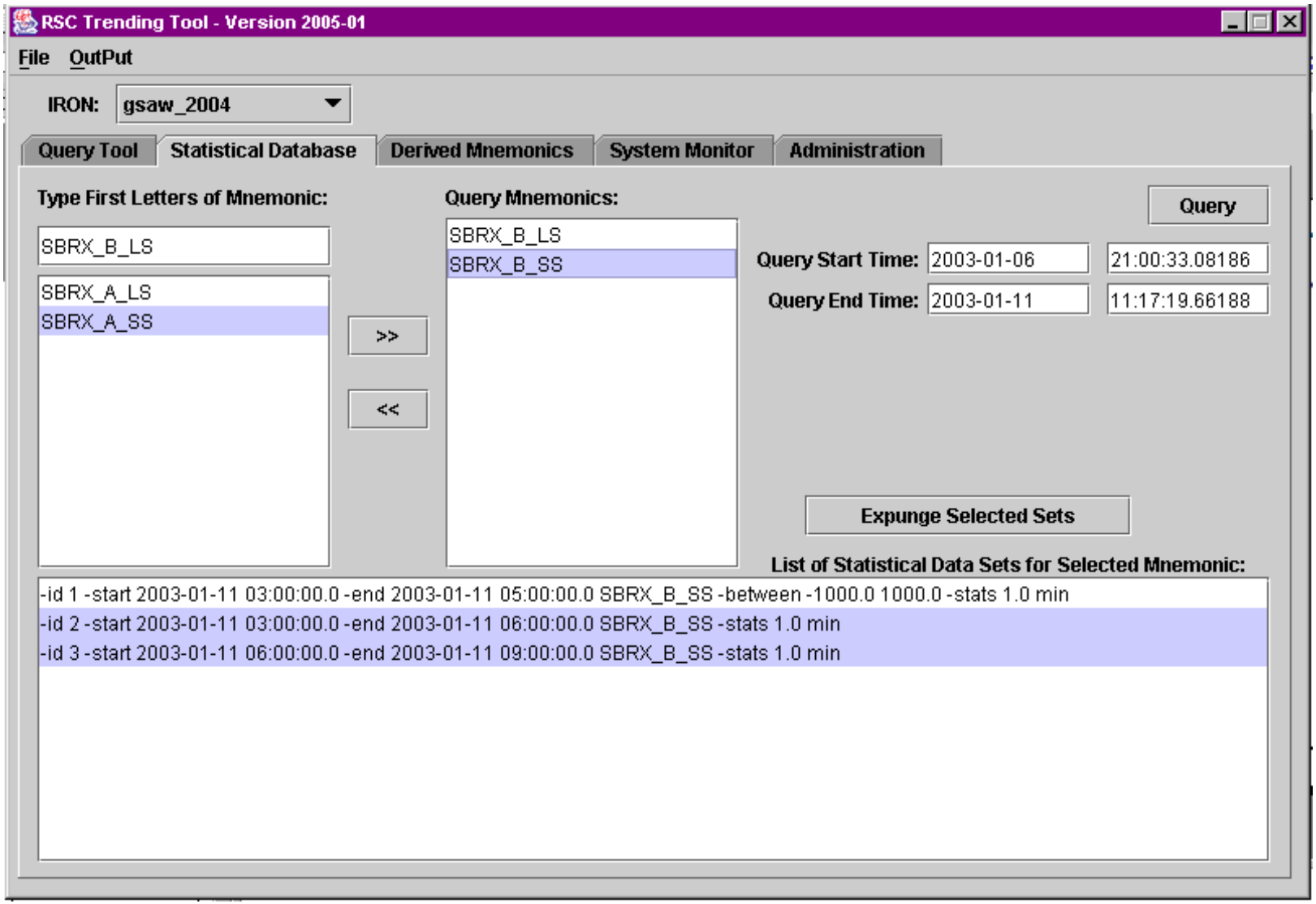
RSC Trending Tool - Version 2005-01 7.00_ST_01_EU01.trend

GMT	BAT_1_VOLTAGE	BAT_2_VOLTAGE	KGRSTCNT	KGRSTCN...	SBNDATXP...	SBRX_A_LS	SBRX_B_LS	S
2003-01-06 21:33:35.88...	1.2122511	1.212524	4145151	4320000	0	-185.73149	-13.093133	-0
2003-01-06 21:33:37.28...	1.216368	1.2167335	4145151	4320000	0	-185.73149	-13.093133	-0
2003-01-06 21:33:38.68...	1.2205015	1.2209603	4145151	4320000	0	-185.73149	-13.093133	-0
2003-01-06 21:33:40.08...	1.2246518	1.2252045	4145151	4320000	0	-185.73149	-13.093133	-0
2003-01-06 21:33:41.48...	1.2288189	1.2294663	4145151	4320000	0	-185.73149	-13.093133	-0
2003-01-06 21:33:42.88...	1.2330029	1.2337457	4145151	4320000	0	-58.17494	3.177157	-0
2003-01-06 21:33:44.28...	1.2372037	1.2380428	4145151	4320000	0	-58.17494	3.177157	-0
2003-01-06 21:33:45.68...	1.2414215	1.2423576	4145151	4320000	0	-58.17494	3.177157	-0
2003-01-06 21:33:47.08...	1.2456563	1.2466902	4145151	4320000	0	-58.17494	3.177157	-0
2003-01-06 21:33:48.48...	1.249908	1.2510405	4145151	4320000	0	-58.17494	3.177157	-0
2003-01-06 21:33:49.88...	1.2541769	1.2554086	4145151	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:51.28...	1.2584629	1.2597948	4145151	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:52.68...	1.2627661	1.264199	4145151	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:54.08...	1.2670865	1.2686212	4145151	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:55.48...	1.2714243	1.2730614	4136201	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:56.88...	1.2757794	1.2775198	4136201	4320000	0	-186.10338	46.203033	-0
2003-01-06 21:33:58.28...	1.2801517	1.2819964	4136201	4320000	0	-186.10338	46.203033	-0
2003-01-06 21:33:59.68...	1.2845417	1.2864913	4136201	4320000	0	-186.10338	46.203033	-0
2003-01-06 21:34:01.08...	1.288949	1.2910044	4136201	4320000	0	-186.10338	46.203033	-0
2003-01-06 21:34:02.48...	1.293374	1.2955359	4136201	4320000	0	-186.10338	46.203033	-0
2003-01-06 21:34:03.88...	1.2978165	1.3000859	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:05.28...	1.3022767	1.3046544	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:06.68...	1.3067545	1.3092413	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:08.08...	1.3112501	1.3138468	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:09.48...	1.3157635	1.3184711	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:10.88...	1.3202947	1.3231139	4136201	4320000	0	75.70367	88.86735	-0
2003-01-06 21:34:12.28...	1.3248438	1.3277755	4136201	4320000	0	75.70367	88.86735	-0
2003-01-06 21:34:13.68...	1.3294109	1.3324559	4136201	4320000	0	75.70367	88.86735	-0
2003-01-06 21:34:15.08...	1.3339959	1.3371552	4136201	4320000	0	75.70367	88.86735	-0
2003-01-06 21:34:16.48...	1.338599	1.3418734	4136201	4320000	0	75.70367	88.86735	-0
2003-01-06 21:34:17.88...								

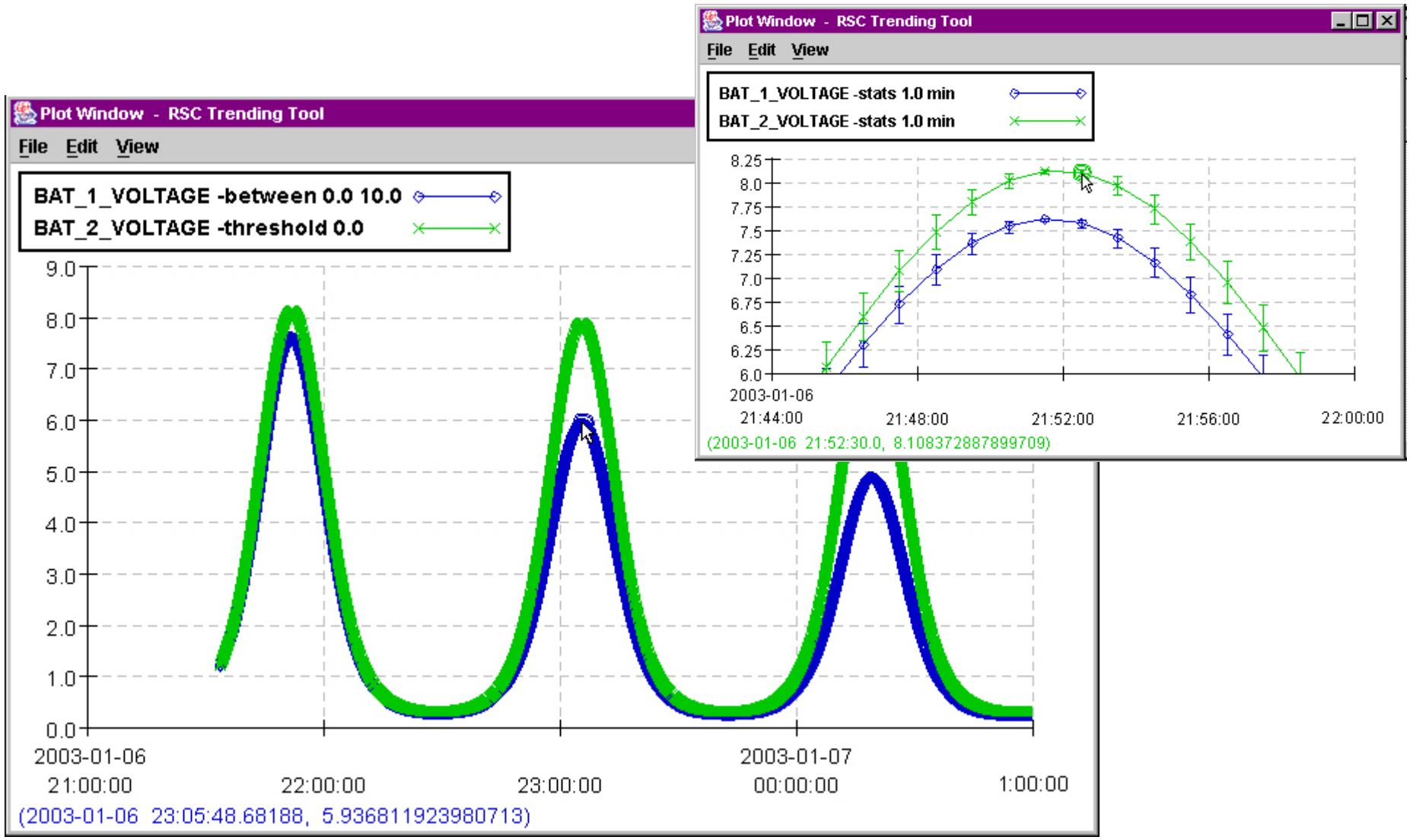
Query Tool Tab



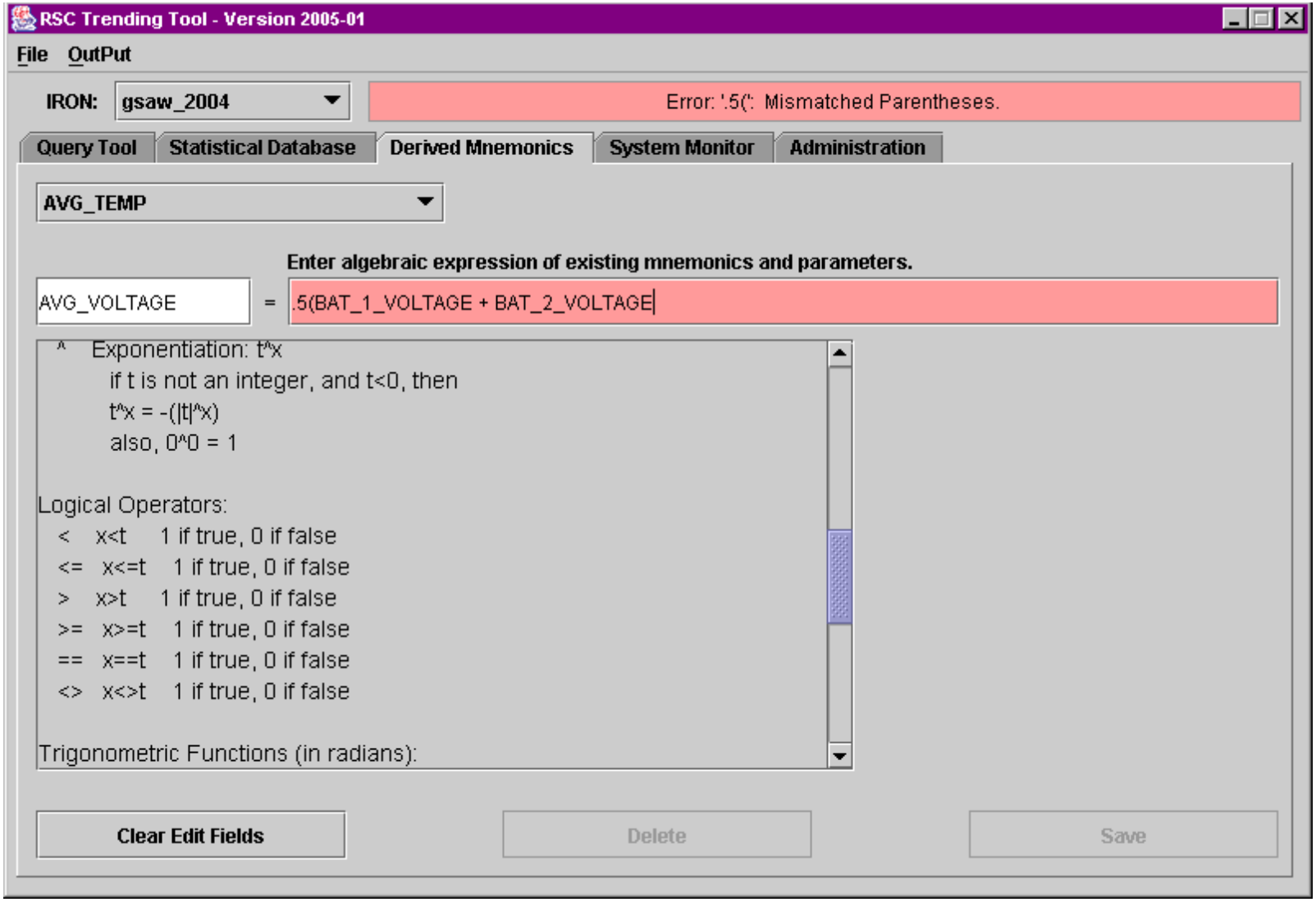
Statistics Tab



Plot Window


Plot Window - RSC Trending Tool
File Edit View
BAT_1_VOLTAGE -between 0.0 10.0
BAT_2_VOLTAGE -threshold 0.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2003-01-06
21:00:00
22:00:00
23:00:00
2003-01-07
00:00:00
1:00:00
(2003-01-06 23:05:48.68188, 5.936811923980713)
Plot Window - RSC Trending Tool
File Edit View
BAT_1_VOLTAGE -stats 1.0 min
BAT_2_VOLTAGE -stats 1.0 min
8.25
8.0
7.75
7.5
7.25
7.0
6.75
6.5
6.25
6.0
2003-01-06
21:44:00
21:48:00
21:52:00
21:56:00
22:00:00
(2003-01-06 21:52:30.0, 8.108372887899709)

Derived Mnemonics Tab



Data and Access Patterns

- No need for a Relational aspect to our database.
- Most mnemonics (both discrete and floating point) change value much less frequently than sampled.
- Using Java's ZipOutputStream() on Coriolis SOH data:
  - Same data written by Columns compresses (on average) 5 times more than when written by Rows.
- Saving disk space saves time: less disk reads, less network traffic.
- Each DB file (data from one contact) stored as a single ZIP archive composed of a logical file per mnemonic
  - Gives random access to data by mnemonic.
  - Archive file is a "good" size (One physical file per mnemonic creates too many inefficiently small files).

Data Base File Structure

- **Index file:**
  - **One file per day.**
  - **Lists all ingested files that span the given day.**
  - **Each record includes:**
    - **Ingest ID**
    - **Start and end time.**
    - **SOH type**
    - **Mnemonic set index.**
    - **Storage Location (RAID, TAPE, BOTH).**
  - **ASCII**

- **Exactly one DB file per ingest:**
  - **Isolates damage from bad data.**
  - **Directory: data\IRON\YYYY\MM\DD\SOH_TYPE**
  - **File Name: IRON.YYYY-MM-DD.SOH_TYPE.INGEST_ID.trendDB**
  - **Binary**
  - **Mixed data types (float32, float64, int8, ...)**
  - **Time saved as seconds offset from top-of-the-hour of start GMT.**
  - **ZIP Archive of mnemonic logical files.**

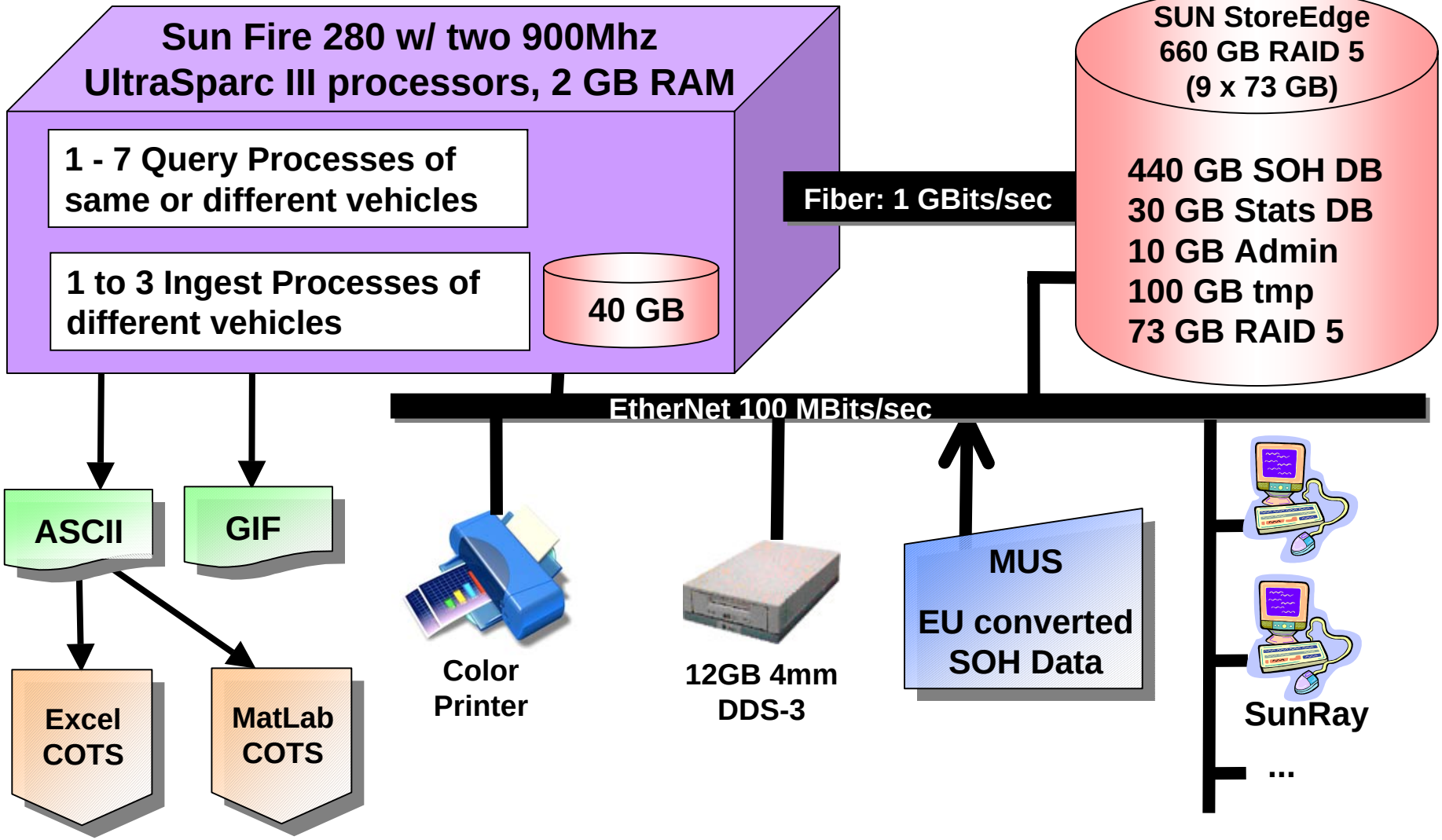
Space & Time Results - Coriolis

- **Operational for 24 months.**
- **760 mnemonics collected.**
- **SSOH: every 4 seconds.**
- **RTSOH: 10 times/sec for 6 to 8 contacts per day, each about 800 sec.**
- **Over 50 billion data points stored.**
- **13 GB of storage required.**
  - **Could be improved: Coriolis ingests each subsystem separately – making 17 copies of every Time value (low compression).**

Query and Screen Plot for 7 Days of Coriolis Data

		Points	Time
A	1 Mnemonic: no filters	608,784	3 sec
B	6 Mnemonics, all same subsystem: no filters	3,652,704	24 sec
C	6 Mnemonics, all different subsystems: no filters	3,652,704	28 sec
D	6 Mnemonics, 1 point/minute	60,480	7 sec
E	6 Mnemonics, min/max/mean over 1 minute interval	60,480	8 sec
F	6 Mnemonics, min/max/mean over 1 hour interval	1,008	4 sec

Hardware


Sun Fire 280 w/ two 900Mhz
UltraSparc III processors, 2 GB RAM
1 - 7 Query Processes of same or different vehicles
1 to 3 Ingest Processes of different vehicles
40 GB
Fiber: 1 GBits/sec
SUN StoreEdge
660 GB RAID 5
(9 x 73 GB)
440 GB SOH DB
30 GB Stats DB
10 GB Admin
100 GB tmp
73 GB RAID 5
EtherNet 100 MBits/sec
ASCII
GIF
Excel COTS
MatLab COTS
Color Printer
12GB 4mm DDS-3
MUS
EU converted SOH Data
SunRay
...

Maintainability

- All code in 100% Pure Java
- Object Oriented Design
- Full JavaDoc for all classes
- JUnit Automated tests.
- The most common extensions are expected to be to Filters and Statistical Calculations.
  - Each filter is a single method of the filter class. Some efficiency was sacrificed for this modular design.
  - All filters appear in the GUI in a separate, single column Filter Panel. GUI space is reserved for additions to the filter panel.

Effort

½ Engineer year: 3 Software Engineers working part-time on this project for two 3 month periods separated by over a year.

	Lines of Code (including comments)	Time
GUI Classes	4178	40%
Database Classes	5719	30%
Plot Classes	3821	30%

Dissemination

The RSC Trending Tool software is the property of the United States Air Force.

- Requests for a runtime package and/or source code should be submitted to:

  XXXXXXXXX

  XXXXXXXXX

  Det 12 SMC, RSC

  Kirtland AFB, MN

- Direct technical Questions to:

  Joel Castellanos: joel.castellanos@kirtland.af.mil