





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





- 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 inhouse software rather than using Commercial Off-the-Shelf (COTS) software.
- 3. To present a few specialized database tricks, algorithms, and design strategies.







- 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**



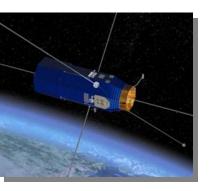
- Unique Vehicles: not constellations
- Not Real-Time
- GMT Time Series, Engineering Unit (EU) State of Health (SOH) data.
- ASCII, Comma Delimited.
- Support 3 to 7 Satellites.
- Each Satellite: 1 to 7 year Missions.
- Each Satellite: Thousands of mnemonics each sampled as much as tens of times per 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.



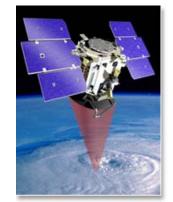
# **Supported Vehicles**



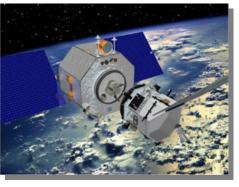




C/NOFS Not yet Launched FCT Data Used



CloudSat Not yet Launched FCT Data Used



Orbital Express Not yet Launched Data not yet available

Coriolis Operational launched Jan, 2003



STPSat-1 Not yet Launched Data not yet available

RSC Trending Tool: Design and Theory

February 1, 2005



## 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**



)N: gsa	w_2004	•				
ery Tool	Statistical Datab	ase	Derived Mnemonics	System Monitor	Administration	j
	Add Vehicl	e			Dele	te Selected Vehicle
ehicle Cor	nfiguration					
	[		Add SOH Type		SOH Lis	t: SSOH
	[	lı	nport Mnemonic Defini	tion File		RTSOH
	RAID Allotmen	t (MB):	30000			
	Default Inges	t Path:	/Trendingest/			
	Tape Stagin	g Path:	./tape/			
Default Da	ata & Graph Outpu	t Path:	J			
D	efault Query Scrip	t Path:	ſ			
	Allowed Ingest	Dates:	2002-01-01 Th	rough (days offset t	o current local):	5
Ma	aximum Days in Si	ngle Ini	gest File: 7			
						Save

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# System Monitor Tab



<u>O</u> utPut						
RON: gsa	w_2004 🔻					
uery Tool	Statistical Database	Derived Mnemonics	System Monitor	Administration		
2003						<b>^</b>
🍳 🗖 01	L					100
⁰⊏						
•						
• <b>⊏</b>	□ 11 ▶ [] SSOH					
Ÿ	- SUH 70.30_ST_01_1	FUO1 trond	20	03-01-11 03:05	2003-01-11 06:31	RAID
	- 71.00_ST_01_			03-01-11 03:03	2003-01-11 08:31	RAID
	73.20 ST 01			03-01-11 02:10	2003-01-11 07:38	RAID V
		coor.crend		05-01-11 00.07	2003-01-11 11.17	INII/
RAID Status Total Mi		ed MB: 2,630	Free MB: 27,370		% used	
		ed MB: 2,630	Free MB: 27,370		% used	
Total MI	B: 30,000 Us	ed MB: 2,630	Free MB: 27,370		% used	
Total Mi RAID Mana	B: 30,000 Us	ed MB: 2,630			% used	
Total Mi RAID Mana	B: 30,000 Us gement View Selected Ingest	ed MB: 2,630	Free MB: 27,370		% used	
Total Mi RAID Mana	B: 30,000 Us gement View Selected Ingest View Selected Ingest				% used	
Total Mi RAID Mana( Action:	B: 30,000 Us gement View Selected Ingest View Selected Ingest Copy Selected Ingest(s	) to Tape Directory	- Apr		% used	
Total Mi RAID Manae Action: Ingest	B: 30,000 Us gement View Selected Ingest View Selected Ingest Copy Selected Ingest(s Restore IRON's Data fro	) to Tape Directory om Tape Directory to RA	- Apr		% used	
Total Mi RAID Mana Action: Ingest Path:	B: 30,000 Us gement View Selected Ingest View Selected Ingest Copy Selected Ingest(s	) to Tape Directory om Tape Directory to RA st(s) from RAID	✓ App			

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## View Ingest - JTable



🌺 RSC Trending Tool - Ver	si	on 2005-01 7.00_ST_	01_EU01.trend						
GMT		BAT_1_VOLTAGE	BAT_2_VOLTAGE	KGRSTCNT	KGRSTCN	SBNDATXP	SBRX_A_LS	SBRX_B_LS	SS
2003-01-06 21:33:35.88	2000	1.2122511	1.212524	4145151	4320000	0	-185.73149	-13.093133	]-Q ▲
2003-01-06 21:33:37.28	100	1.216368	1.2167335	4145151	4320000	0	-185.73149	-13.093133	-0 🕸
2003-01-06 21:33:38.68	1000	1.2205015	1.2209603	4145151	4320000	0	-185.73149	-13.093133	-0
2003-01-06 21:33:40.08	1000	1.2246518	1.2252045	4145151	4320000	0	-185.73149	-13.093133	-C
2003-01-06 21:33:41.48	1000	1.2288189	1.2294663	4145151	4320000	0	-185.73149	-13.093133	-0
2003-01-06 21:33:42.88	1000	1.2330029	1.2337457	4145151	4320000	0	-58.17494	3.177157	-0
2003-01-06 21:33:44.28	1000	1.2372037	1.2380428	4145151	4320000	0	-58.17494	3.177157	-0
2003-01-06 21:33:45.68	1000	1.2414215	1.2423576	4145151	4320000	0	-58.17494	3.177157	-0
2003-01-06 21:33:47.08	1000	1.2456563	1.2466902	4145151	4320000	0	-58.17494	3.177157	-C
2003-01-06 21:33:48.48	1000	1.249908	1.2510405	4145151	4320000	0	-58.17494	3.177157	-0
2003-01-06 21:33:49.88	1000	1.2541769	1.2554086	4145151	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:51.28	1000	1.2584629	1.2597948	4145151	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:52.68	1000	1.2627661	1.264199	4145151	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:54.08	1000	1.2670865	1.2686212	4145151	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:55.48	1000	1.2714243	1.2730614	4136201	4320000	0	70.12539	27.763372	-0
2003-01-06 21:33:56.88	1000	1.2757794	1.2775198	4136201	4320000	0	-186.10338	46.203033	-0
2003-01-06 21:33:58.28	1000	1.2801517	1.2819964	4136201	4320000	0	-186.10338	46.203033	-C
2003-01-06 21:33:59.68	1000	1.2845417	1.2864913	4136201	4320000	0	-186.10338	46.203033	-C
2003-01-06 21:34:01.08	100	1.288949	1.2910044	4136201	4320000	0	-186.10338	46.203033	-C
2003-01-06 21:34:02.48	1000	1.293374	1.2955359	4136201	4320000	0	-186.10338	46.203033	-0
2003-01-06 21:34:03.88	1000	1.2978165	1.3000859	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:05.28	1000	1.3022767	1.3046544	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:06.68	1000	1.3067545	1.3092413	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:08.08	1000	1.3112501	1.3138468	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:09.48	1000	1.3157635	1.3184711	4136201	4320000	0	-57.80305	70.42769	-0
2003-01-06 21:34:10.88	1000	1.3202947	1.3231139	4136201	4320000	0	75.70367	88.86735	-C
2003-01-06 21:34:12.28	1000	1.3248438	1.3277755	4136201	4320000	0	75.70367	88.86735	-0
2003-01-06 21:34:13.68	1000	1.3294109	1.3324559	4136201	4320000	0	75.70367	88.86735	-0
2003-01-06 21:34:15.08	1000	1.3339959	1.3371552	4136201	4320000	0	75.70367	88.86735	-C
2003-01-06 21:34:16.48	1000	1.338599	1.3418734	4136201	4320000	0	75.70367	88.86735	-0 🗸
2003-01-06 21:34:17.88	100					3333			

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# Query Tool Tab



IRON: gsaw_2004	•	Error: Upper Limit must be greater than Lower Limit.				
Query Tool Statistical Databa	se Derived Mnemonics	System Monitor	Administration			
SOH SSOH	IRON Start Time:	2003-01-06 21:33	:33.08186 Query			
RTSOH	IRON End Time:	2003-01-07 01:00	:31.28188			
	Query Start Time:	2003-01-06	01:00:00.0			
	Query End Time:	2003-01-07	01:00:31.28188			
	BAT_1_VOLTA BAT_2_VOLTA		Filter Panel Query Between Limits			
AU_GSEACMD AU_GSEBCMD AU_KEYINDX	BAT_2_VOLTA					
AU_GSEACMD AU_GSEBCMD AU_KEYINDX AU_MSGTYPE AU_OPMODE AU_OPMODE			Query Between Limits 💌			
AU_GSEACMD AU_GSEBCMD AU_KEYINDX AU_MSGTYPE AU_OPMODE AU_PDUSIDE AU_PDU_PWR AU_XBND_DR	BAT_2_VOLTA		Query Between Limits       Limit(s):       > -10       ○ Odd Point Median filter:			
BAT_2_VOLTAGE AU_GSEACMD AU_GSEBCMD AU_KEYINDX AU_MSGTYPE AU_OPMODE AU_OPMODE AU_PDUSIDE AU_PDU_PWR AU_XBND_DR BADWHL BAT_1_TMP	BAT_2_VOLTA		Query Between Limits       ▼         Limit(s):       > -10       < -10			

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### **Statistics Tab**



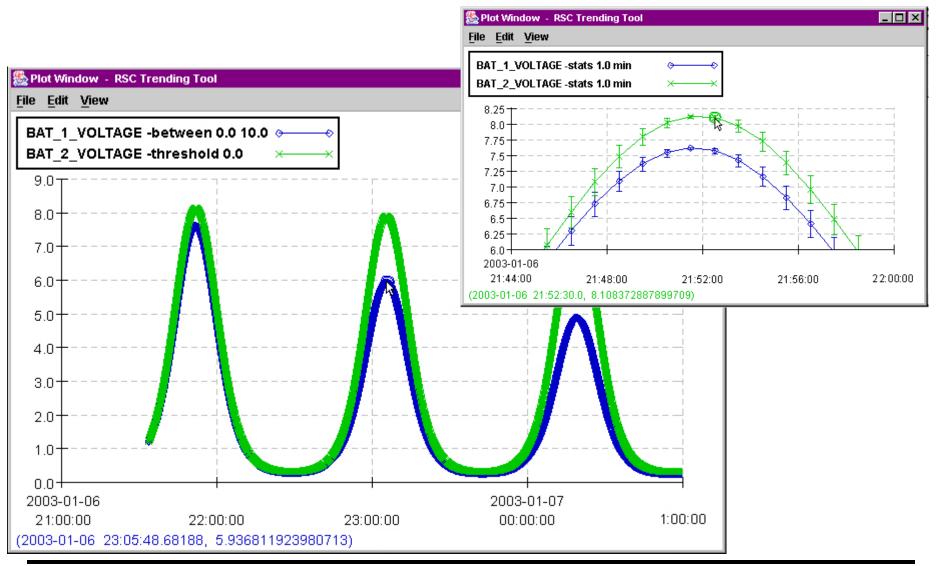
<u>O</u> utPut RON: gsaw_2004 ▼				
uery Tool Statistical Database	Derived Mnemonics	System Monitor	Administration	
pe First Letters of Mnemonic:	Query Mnemoni	:s:		Query
BRX_B_LS	SBRX_B_LS SBRX_B_SS	Q	uery Start Time: 2003-01-0	06 21:00:33.08186
BRX_A_LS	0010(_0_00		Query End Time: 2003-01-1	
BRX_A_SS	>>			
	<<			
1				
			Expunge Selected	d Sets
			List of Statistical Data Sets	for Selected Mnemonic:
d 1 -start 2003-01-11 03:00:00.0 -er				0 min
d 2 -start 2003-01-11 03:00:00.0 -er				
d 3 -start 2003-01-11 06:00:00.0 -er	id 2003-01-11 09:00:00.0	SBRX_B_SS-stats	1.0 min	

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#### **Plot Window**





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# **Derived Mnemonics Tab**



IRON: gsaw_2004   Error: '.5(': Mismatched Parentheses.				
uery Tool Statistical Databas	e Derived Mnemonics	System Monitor	Administration	
NG_TEMP	•			
Enters	algebraic expression of exi	istina mnomonics a	nd narameters	
	_1_VOLTAGE + BAT_2_VO			
if t is not an integer, an t*x = -( t *x) also, 0*0 = 1 ogical Operators: < x <t 0="" 1="" false<br="" if="" true,="">&lt;= x&lt;=t 1 if true, 0 if false &gt; x&gt;t 1 if true, 0 if false == x==t 1 if true, 0 if false</t>	9 9 9			
> x<>t 1 if true, 0 if false				
rigonometric Functions (in ra				

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- 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).





- 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.

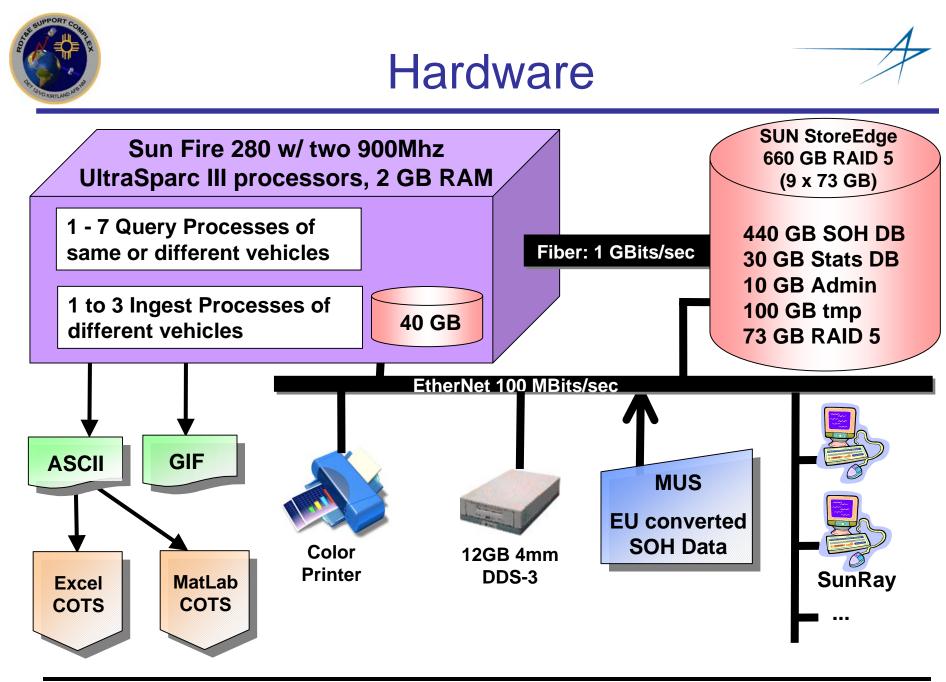


# Space & Time Results - Coriolis

- 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
А	1 Mnemonic: no filters	608,784	3 sec
В	6 Mnemonics, all same subsystem: no filters	3,652,704	24 sec
С	6 Mnemonics, all different subsystems: no filters	3,652,704	28 sec
D	6 Mnemonics, 1 point/minute	60,480	7 sec
Е	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



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- 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.







<sup>1</sup>/<sub>2</sub> 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 XXXXXXXX Det 12 SMC, RSC Kirtland AFB, MN

• Direct technical Questions to:

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