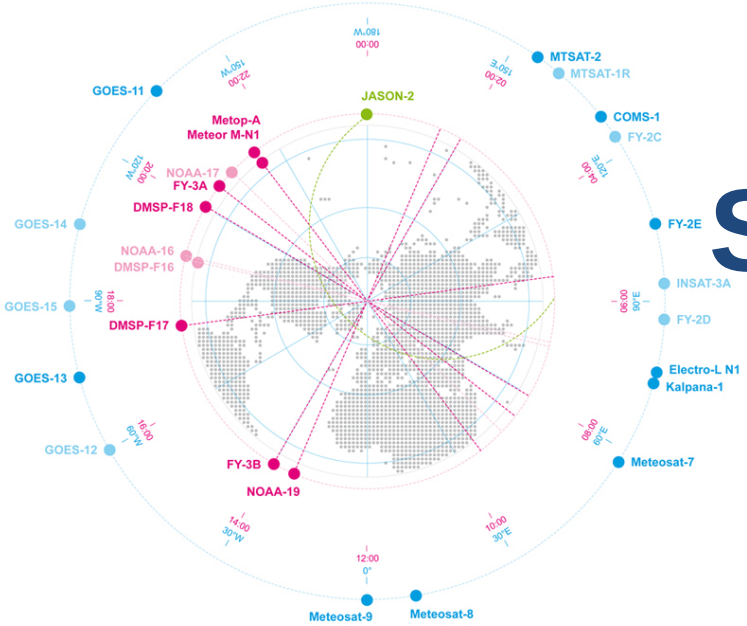

Spacecraft Anomaly Database NOAA

Presented to CGMS-43 ad-hoc meeting on space weather, agenda item [3]

William Denig
NOAA National Centers for Environmental Information (NCEI)

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Prior to 1993 the NOAA National Geophysical Data Center[1] (NGDC) managed a spacecraft anomaly database. The success of this database was the personal trust placed in the manager to safeguard technical information provided by numerous satellite operators.

Is it possible to re-establish this trust within NOAA or within another 3rd party organization?

[1]In April 2015 the NOAA data centers, including NGDC, merged to become the National Centers for Environmental Information (NCEI).

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Joe Allen
STP Chief
1981-1995

NOAA Spacecraft Anomaly Database (1984-1993)

A database of spacecraft anomalies was established within the Solar-Terrestrial Physics (STP) Division of the National Geophysical Data Center in 1984. Information included the date, time, location, and other pertinent information about incidents of spacecraft operational irregularity due to the environment. The events ranged from minor operational problems which can be easily corrected to permanent spacecraft failures. The data base included spacecraft anomalies in interplanetary space and in near-earth orbit but the main contributions were from geostationary spacecraft.

Many spacecraft were identified by aliases in order to preserve confidentiality which were prefaced with the "@" character.

The original database exists and is still available online to the user community. The data contained in the database is woefully out of date.

www.ngdc.noaa.gov/stp/satellite/anomaly/

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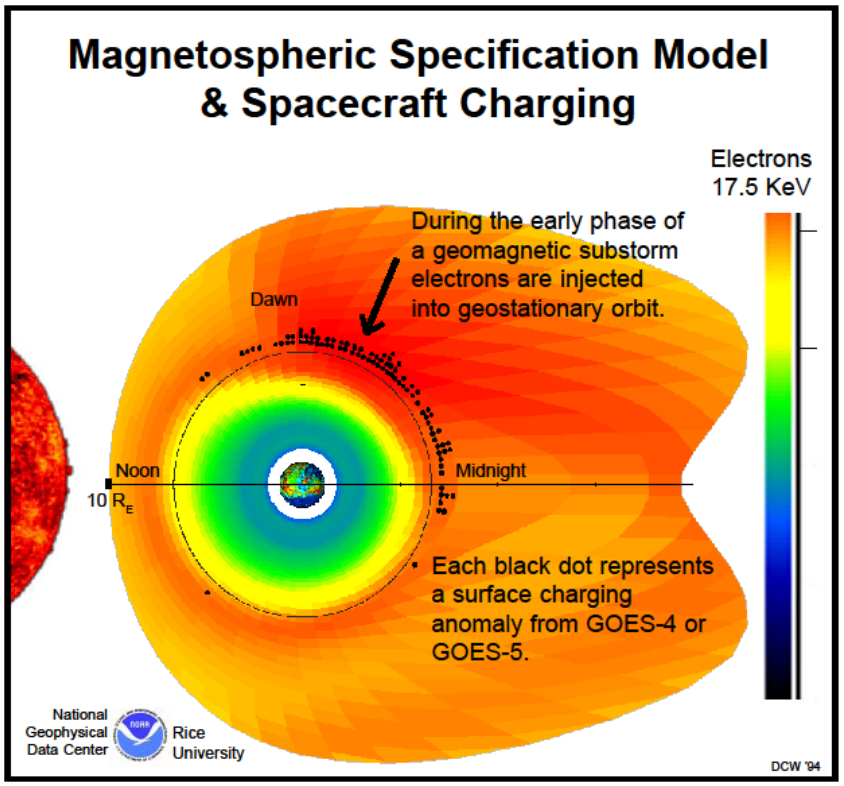
Sample of data contained in the NOAA Spacecraft Anomaly Database. This time interval includes the March 1989 great geomagnetic storm.

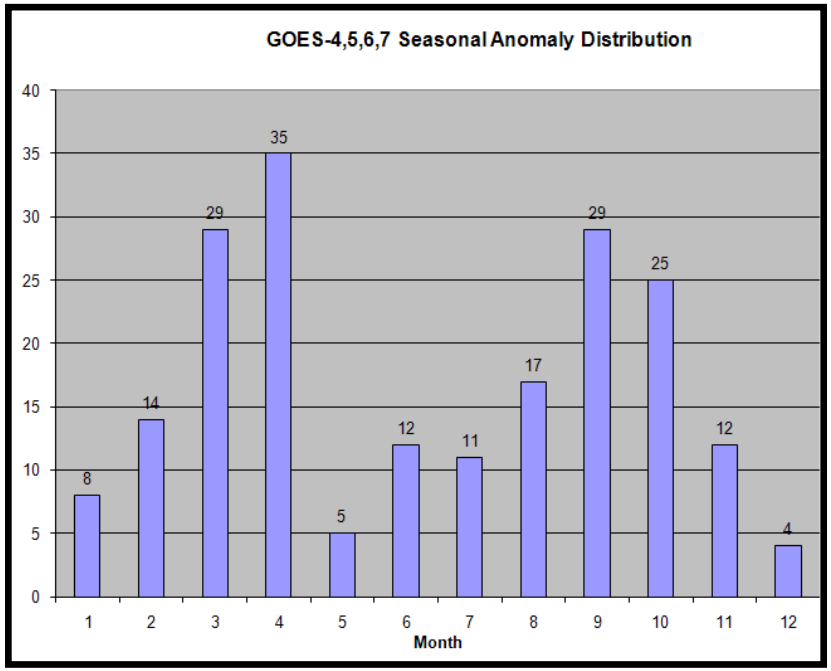
VER	BIRD	ADATE	STIMEU	STIMEL	ORBIT	ALT	ATYPE	ADIAG	ACOMMENT
5	@PN0303	11-Mar-89	1937	1145	G	35784	PC	SDC	APE 2 Switch - CMD Step to AUTO Step
5	NOAA-09	12-Mar-89	0311		P	900	UNK	UNK	No CV on first nooop cmd. VHF downlink propagation distu
5	GOES-5	12-Mar-89	0635	2323	G	35784	TE	SEU	CTU-1 Several analog words erroneous
5	METOSAT-P2	13-Mar-89	0553	0553	G	35784	TE	ESD	
5	NOAA-10	14-Mar-89	2102		P	900	UNK	UNK	Narrowband outage, pass taken under FCDA control.
5	NOAA-11	14-Mar-89	2131		P	900	UNK	UNK	Supported unscheduled L4A at socc request.
5	@PN0303	16-Mar-89	0535	2143	G	35784	PC	SDC	APE 2 Switch - CTR 1 to CTR 2
5	NOAA-11	16-Mar-89	1252		P	900	UNK	UNK	No CV on first nooop cmd, conflict with stored table.
5	IRON 9363	16-Mar-89	1800	0120	G	35784	UNK	UNK	SFC(104) Earth sensor reference problem.
5	IRON 9365	16-Mar-89	1953	1841	G	35784	UNK	UNK	SFC(104) Earth sensor reference problem.
5	METOSAT-P2	17-Mar-89	0749	0749	G	35784	TE	ESD	
5	GOES-7	17-Mar-89	0842	0130	G	35784	PC	ESD	Ch.5 Gain Step change 3 to 4
5	MARECS-A	17-Mar-89	1026	2218	G	35784	TE	ESD	
5	MARECS-A	17-Mar-89	1058	2250	G	35784	TE	ESD	
5	MARECS-A	17-Mar-89	1327	0119	G	35784	TE	ESD	
5	MARECS-A	17-Mar-89	1428	0220	G	35784	TE	ESD	
5	MARECS-A	17-Mar-89	1508	0300	G	35784	TE	ESD	
5	MARECS-A	17-Mar-89	1606	0358	G	35784	TE	ESD	
5	MARECS-A	17-Mar-89	1855	0647	G	35784	TE	ESD	
5	TDRS-4	18-Mar-89	0734	1858	G	35784	SE	UNK	SFC(108) Bit flip.
5	@GG0510	18-Mar-89	1821		G	35784	PC	UNK	
5	METOSAT-P2	18-Mar-89	2135	2135	G	35784	TE	ESD	
5	@GG0501	20-Mar-89	0040	1228	G	35784	PC	UNK	
5	GOES-7	21-Mar-89	1041	0329	G	35784	PC	ESD	Ch.5 Gain Step change 3 to 4
5	METOSAT-P2	22-Mar-89	0153	0153	G	35784	TE	ESD	
5	METOSAT-P2	22-Mar-89	0707	0707	G	35784	TE	ESD	
4	AUSSAT-A2	24-Mar-89	1913	0537	G	35784	PC	ESD	subcom lost count

Applications for a Spacecraft Anomaly Database "GOES Example"

Spatial distribution of GOES 4/5 anomalies at fixed local times



Seasonal distribution of GOES 4-7 spacecraft anomalies



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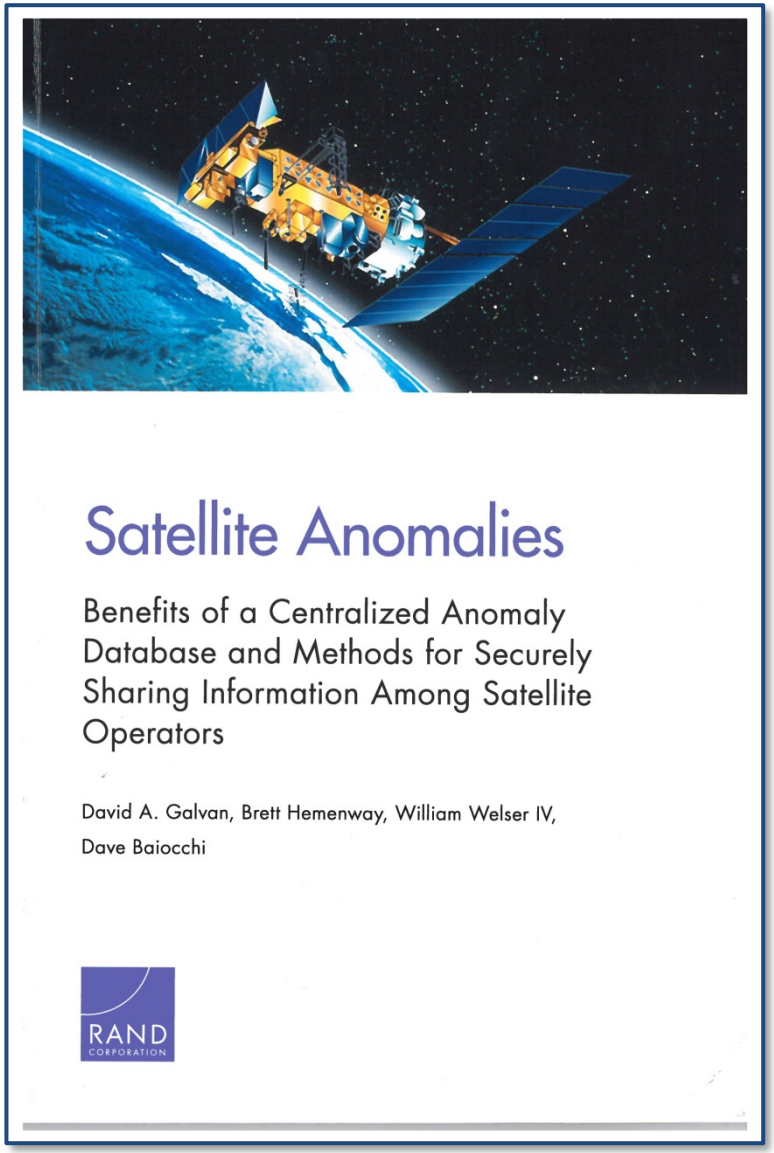

Satellite Anomalies – Benefits of a Centralized Database and Methods for Securely Sharing Information Among Satellite Operators (2014)

Book Review by W. Denig, R. Redmon, J. Rodriguez and J. Allen

"The authors point out that while satellite operators generally acknowledge the benefits of a centralized anomaly database, many are reluctant to readily contribute information to a shared database due to concerns about the inadvertent release of sensitive details regarding the performance and integrity of their respective satellite systems. The main conclusion of the volume is that a secure anomaly database that safeguards the identity of the contributor by taking advantage of modern cryptographic approaches could potentially alleviate proprietary concerns and lead to overall improved satellite operations."

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Book: http://www.rand.org/pubs/research_reports/RR560.html
Review: http://onlinelibrary.wiley.com/doi/10.1002/2014SW001100/abstract

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In the table to the right (after O'Brien et al [2011]), the authors list critical information that would be required in an anomaly database. They also provide an assessment as to whether the individual items in the contents of the database could be used, in principle, to reveal the identity of an anonymous source.

The authors offer potential solutions to the reluctance of satellite operations reporting anomalies by either relying on the integrity of a "trusted third party" to safeguard sensitive information or by taking advantage of modern crypto--graphic technologies which shield providers and users from unwarranted information "leakage."

Reference: O'Brien, Paul, Joseph E. Mazur and Timothy B. Guild, Recommendations for Contents of Anomaly Database for Correlation with Space Weather Phenomena, El Segundo, Calif.: Aerospace Corporation, TOR-2011(3903)-5, November 10, 2011.

Recommended information to be included in a modern anomaly database, including information that potentially can divulge the source.

Description*	"Required"*	Reveals Identity (alone)	Reveals Identity (combined)
1. Date and Universal Time of anomaly	x	No	Yes
2. Fully specified spacecraft location during anomaly	x	Yes	Yes
3. Velocity or orbital elements at time of the anomaly	x	Yes	Yes
4. L-shell at time of anomaly		No	Depends
5. Magnetic Local Time of vehicle during anomaly		No	Depends
6. Eclipse state of the vehicle (full, penumbra, partial, none)		No	Depends
7. Vector to sun in spacecraft coordinates		No	Depends
8. Velocity vector of spacecraft in spacecraft coordinates		No	No
9. Initial guess at type of anomaly (SEU, discharge, TID)		No	No
10. Estimated confidence of that guess		No	No
11. Anomaly category (e.g., affected subsystem or type of disruption)		No	Depends
12. Vehicle identity (possibly anonymized)		Yes	Yes
13. Notes on recent operational states or changes (e.g., recent commands, attitude schemes)		Depends	Depends

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CGMS has taken the first step

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TEMPLATE FOR SPACE WEATHER RELATED SPACECRAFT ANOMALIES (Items in bold are required)

Source: Recommendations for Contents of Anomaly Database for Correlation with Space Weather Phenomena, P. O'Brien, J.E. Mazur, T. Guild, November 2011, AEROSPACE Report No.TOR-2011(3903)-5.

1. Date and Universal Time of the anomaly	**2. Fully specified location of the anomaly** (spacecraft location)	**3. Velocity or orbital elements at time of the anomaly**	4. Eclipse state of the vehicle (full, penumbra, partial, none)	5. Vector to Sun in spacecraft coordinates	6. Velocity vector of spacecraft in spacecraft coordinates	7. Initial guess at type of anomaly (See taxonomy below)	8. Estimated confidence of that guess	9. Anomaly category (e.g., affected system or kind of disruption)	10. Vehicle identity	11. Notes (e.g. unusual operational states or recent changes to operations (recent commands, attitude scheme, etc.)

Taxonomy of Satellite Anomalies Caused by In Situ Charged Particle Environment (to be used for column 7):

1. Electrostatic discharge (charging)
    - 1.1 Surface charging
        - 1.1.1 Plasma sheet (subauroral)
        - 1.1.2 Auroral
    - 1.2 Internal charging
        - 1.2.1 Subsurface charging (e.g., beneath blanket)
        - 1.2.2 Deep charging (e.g., inside a box)
2. Single-Event Effects
    - 2.1 Protons
        - 2.1.1 Solar proton event
        - 2.1.2 Geomagnetically trapped protons
    - 2.2 Heavy ions
        - 2.2.1 Galactic Cosmic Rays
        - 2.2.2 Solar energetic particles
        - 2.2.3 Geomagnetically trapped heavy ions
3. Total Dose
    - 3.1 Long-term dose accumulation (multiple causes combined)
    - 3.2 Short-term (days or less) dose accumulation
        - 3.2.1 Solar protons
        - 3.2.2 Geomagnetically trapped protons
        - 3.2.3 Geomagnetically trapped electrons

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v2, 14 March 2014

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White Paper

NCEI Spacecraft Anomaly Mitigation Program

NOAA will enhance its spacecraft anomaly mitigation program starting in FY15 by improving the identification and classification of space weather induced spacecraft anomalies in accordance with the recommendations of the CGMS and the guidelines proposed by COPUOS.

Program Goals[1]:

FY15 – Review and seek to improve the state of anomaly reporting procedures in accordance with the recommendations and proposed guidelines of the CGMS and COPUS.

FY16 – Develop the Satellite Anomaly Information System (SAIS) web portal.

FY17 – Transition, as appropriate, SAIS into an operational real-time support product.

Evolving - Develop a satellite anomaly database to assemble information regarding the occurrence of satellite anomalies and their impact on operations.

[1]*Pending availability of funds.*

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Concluding Thoughts:

- Satellite manufacturers/operators have expressed keen interest in re-establishing a spacecraft anomaly database (reference)
- Community members must be willing to share information with assurances that proprietary information is safeguarded (reference)
- A "trusted agent" approach is the most straightforward approach and has precedence (reference)

Recommended Actions:

- CGMS can play a key role by encouraging members to contribute to an initial spacecraft anomaly database hosted by a member organization or third-party
- CGMS should establish a working group to solicit the participation of commercial satellite operators such as the Space Data Association
- NOAA should pursue its enhanced Spacecraft Anomaly Mitigation Program