



Ground Data System Analysis Tools To Track Flight System State Parameters for the Mars Science Laboratory (MSL) and Beyond

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Overview

- Background
- About Parameters and Tracking Them
- Tracking Tool Implementation
- Issues
- Conclusions



Parameter Tracking Background

- In 2006, Mars Global Surveyor (MGS) was lost due to spacecraft commanding against an invalid fault mode parameter configuration¹
 - Situation led to non-Earth orientation of HGA as well as rapid, fatal power drain
 - Clearly parameter state must be tracked or risk invalid flight system behavior
- Mars Exploration Rovers (MER) parameter experience led to design and implementation of an MSL Parameter Management Tool (PMT)
- So... What are parameters?
 - Configurable system values residing in volatile and persistent memory
 - E.g. Thermal and power targets, fault monitor behavior...
 - Specified in dictionaries of one sort or another
- Why parameters vs. configuration tables?
 - More fine tuned control, can potentially modify down to a single parameter at time
 - However, they are significantly more complex to track
- What questions do we ask?
 - “What is the current state of parameters as of time X” (Snapshot Query)
 - “What parameter changes have occurred between time X and Y” (History Query)



Dictionary Example

Battery Control Board (BCB) Module Parameters

MON Parameter Group

Parameters specifying fault monitor configuration

Group Copies:

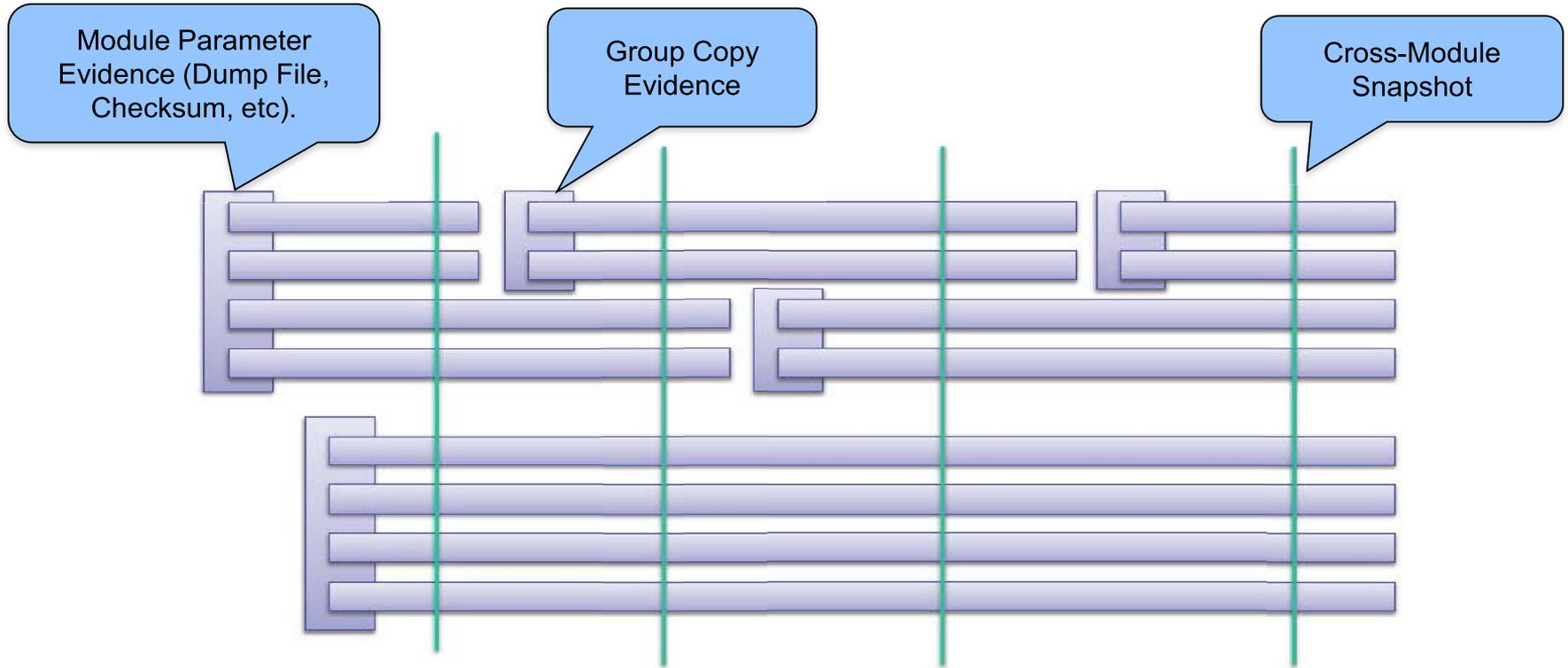
batt_offline_at_boot_bcb1, batt_offline_at_boot_bcb2, batt_offline_imminent_bcb1, batt_offline_imminent_bcb2, fail_to_communicate_with_both_bcbs

Parameter	Type	Default	Units	Range	Description
detection_enabled	Bool (in gbl/gbl_pub.h)	TRUE	none	FALSE : TRUE	<i>Whether or not detection is enabled for this monitor</i>
response_enabled	Bool (in gbl/gbl_pub.h)	TRUE	none	FALSE : TRUE	<i>Whether or not response is enabled for this monitor</i>
error_persistence	U32	1	none	1 : 0xFFFFFFFF	<i>Error count at which monitor becomes YELLOW</i>
fault_persistence	U32	1	none	1 : 0xFFFFFFFF	<i>Error count at which monitor becomes RED</i>

Parameter identifier generated from module, group copy (if present) and parameter



Enabling a Snapshot Query



Spacecraft Event Time



Snapshot times

A parameter value over time

MSL parameter evidence is downlinked as per module or for a specific group copy. But evidence specification in telemetry is not consistent across missions.



Implementation

- Designed a parameter tracking web service with a back-end database
 - Start of coding green lighted 3 months prior to MSL launch
 - Flight software (FSW) had been in development for over 5 years by this time
 - Three half time developers, all supporting other critical software development
 - MSL data management, relay planning systems..
 - Implemented on top of MSL Mission Processing and Control Systems (MPCS) software
- Technologies and Standards
 - Coded in Java and Python
 - ReST for server interactions
 - ReSTlet Java web server
 - Hibernate for information persistence
 - HTML and Velocity templates for data visualization
- Deliveries
 - Early cruise version
 - Multiple surface ops versions
 - Including recent ops version to deal with design issues found along the way



Visualization

Parameter Management Toolkit

[Parameter History Report - CBM Report&History](#)

Multiple data views configurable via Velocity templates

Snapshot Report	
SCET	<input type="text" value="now"/>
Venue	<input type="text" value="Surface"/>
RCE	<input type="radio"/> A <input checked="" type="radio"/> B
Persistence	<input checked="" type="radio"/> Memory <input type="radio"/> Saved
Template	<input type="text" value="snapshot.html"/>
Filter	Category <input type="text" value=""/>
	- Or - FSW Module <input type="text" value="bcb"/> Group <input type="text" value=""/> Group Copy <input type="text" value=""/> Parameter <input type="text" value=""/>
<input type="button" value="Get Snapshot Report"/> <input type="button" value="Reset"/>	

[Home](#) - [Venues](#) - [Parameter Dictionaries](#) - [Report Templates](#) - [Parameter Categories](#)

Parameter Snapshot Report

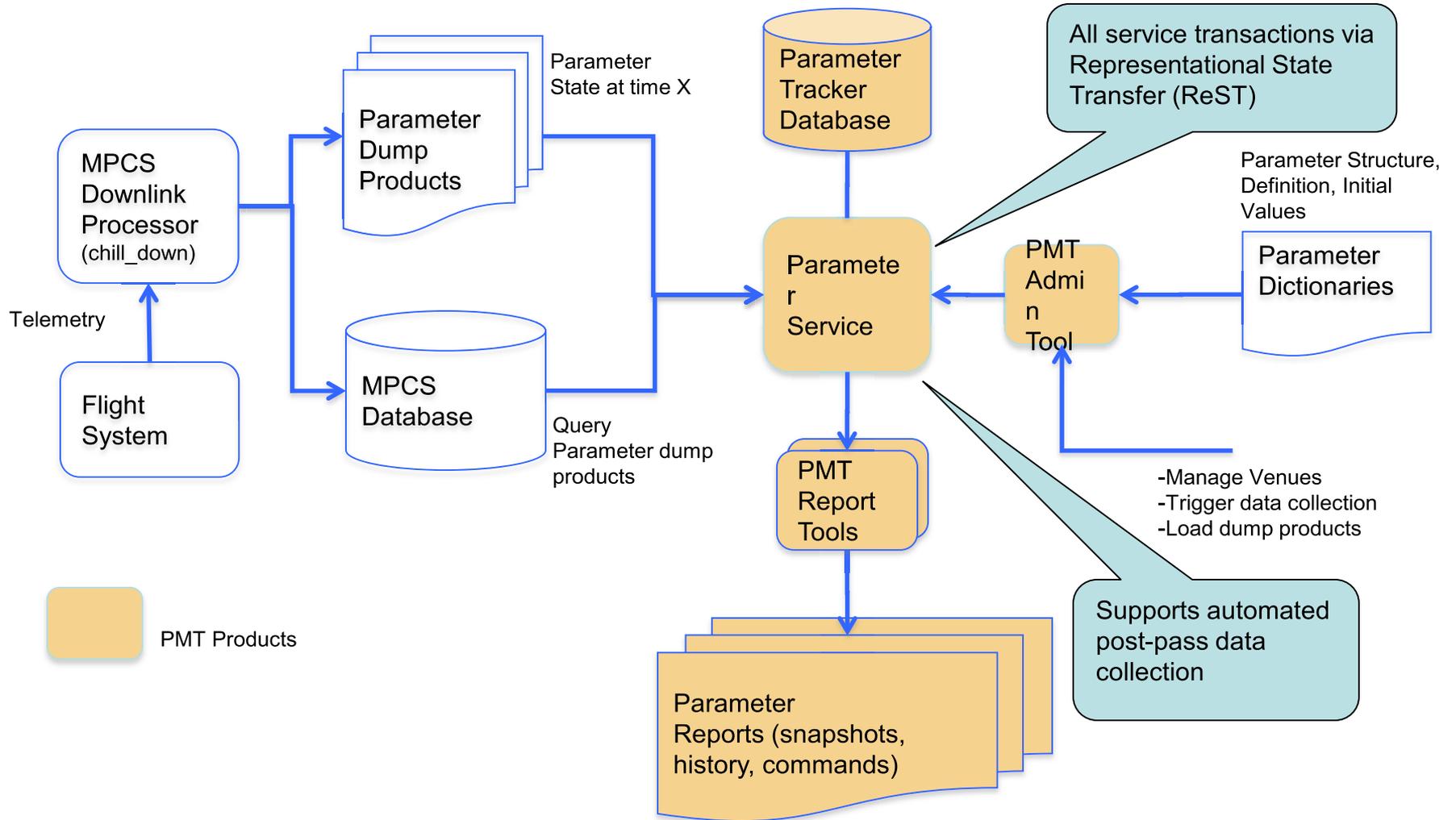
Venue: Surface
RCE: B
Module: bcb
SCET: 2014-105T19:12:16 UTC
Report Time: 2014-105T19:12:16 UTC

Module	Group	Group Copy	Parameter	Value	Units	Last Update	From Evidence	Evidence
bcb	mon	batt_offline_imminent_bcb1	detection_enabled	True		2014-091T03:48:04.435	2 weeks earlier	BcbParms_0449595466-30997-1.dat
bcb	mon	batt_offline_imminent_bcb1	response_enabled	True		2014-091T03:48:04.435	2 weeks earlier	BcbParms_0449595466-30997-1.dat
bcb	mon	batt_offline_imminent_bcb1	error_persistence	1		2014-091T03:48:04.435	2 weeks earlier	BcbParms_0449595466-30997-1.dat
bcb	mon	batt_offline_imminent_bcb1	fault_persistence	1		2014-091T03:48:04.435	2 weeks earlier	BcbParms_0449595466-30997-1.dat
bcb	mon	batt_offline_imminent_bcb2	detection_enabled	True		2014-091T03:48:04.435	2 weeks earlier	BcbParms_0449595466-30997-1.dat
bcb	mon	batt_offline_imminent_bcb2	response_enabled	True		2014-091T03:48:04.435	2 weeks earlier	BcbParms_0449595466-30997-1.dat
bcb	mon	batt_offline_imminent_bcb2	error_persistence	1		2014-091T03:48:04.435	2 weeks earlier	BcbParms_0449595466-30997-1.dat
bcb	mon	batt_offline_imminent_bcb2	fault_persistence	1		2014-091T03:48:04.435	2 weeks earlier	BcbParms_0449595466-30997-1.dat

Simple HTML web interface



Parameter Management Toolkit Architecture

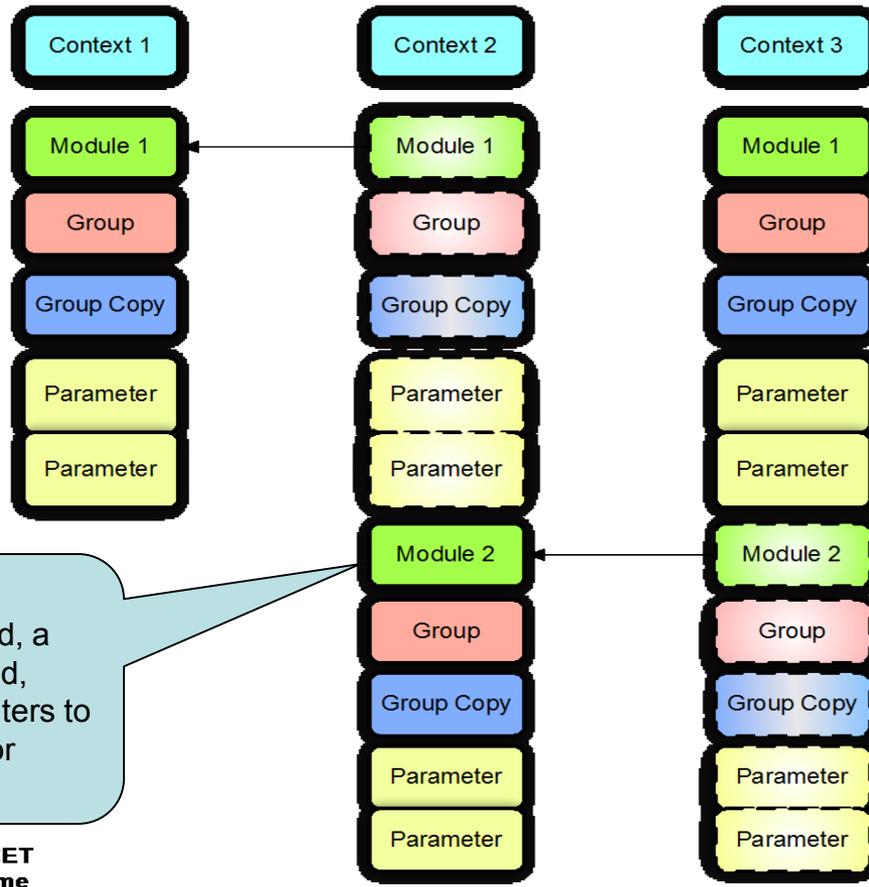




Challenges and Issues

- Challenges
 - Flight software developed for years ahead of PMT implementation, and fully locked down by the time it started
 - Any design issues were the problem of the PMT implementation
 - Always lower priority to MSL's data management systems
 - Iterative design updates well up through Surface
- Primary Design Issues
 - Lack of standards across dictionaries and downlink data leading to issues in parameter identification/mapping of parameter data out of telemetry
 - Revision management approach in the face of out-of-order data receipt

Parameter Revision Management



At each point in time where parameter evidence is found, a *context revision* is generated, including that data and pointers to the most recent evidence for every other parameter

A snapshot at any time is merely a query for 'most recent prior context', with pointer references auto-resolved via Hibernate. Made for a very fast query.

SCET
Time



Actual Revision

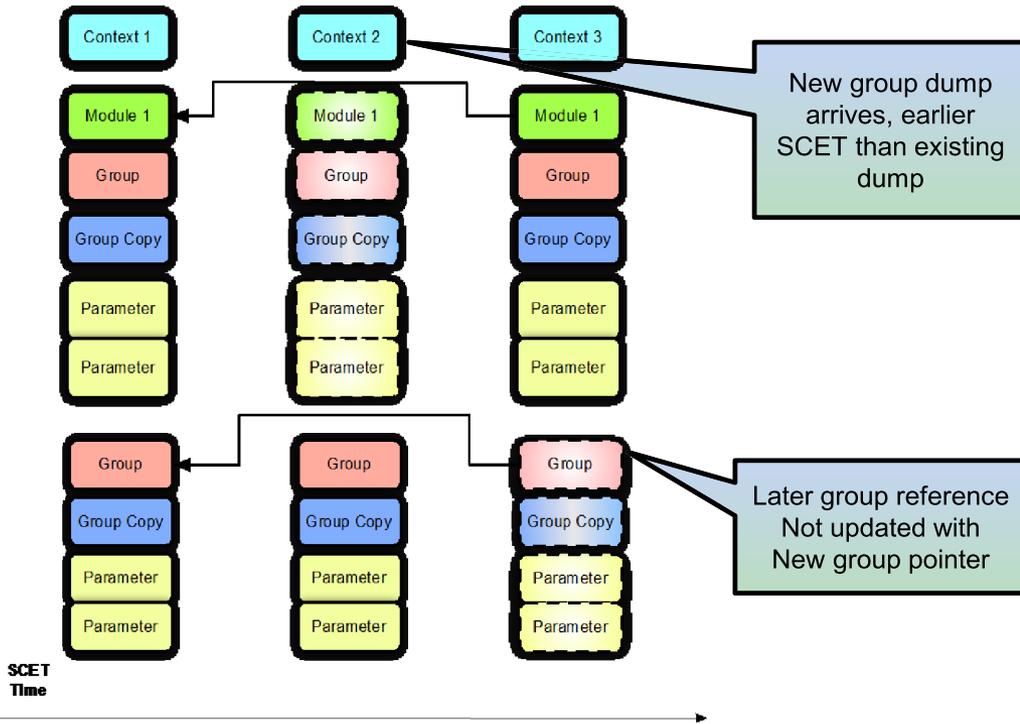


Revision Pointer to past evidence



Some Design Issues

Out of Order Data Handling



Actual Revision Revision Pointer to past evidence

Required substantial additional meta-data management to solve

Identification Mismatches

Even though there is a 1-1 mapping between parameters in dictionary and telemetry, the identifiers are not consistent between the two, requiring error-prone substring matching to put back together. dictionary ID may be A_B_C_D, telemetry may be B_C_D_E. Varies from one FSW module to another.

A 1-1 unique identifier between dictionary and telemetry evidence would make this aspect of the problem trivial.



Conclusions

Lessons Learned

- While we did eventually implement a working version of the tool, the late start and resulting inability to affect interfaces or otherwise address integration issues at the design level resulted in overall higher than expected costs. Design and integration of these and similar functions must be addressed much earlier in the mission development lifecycle.

Continued Work

- Version recently implemented and released for Soil Moisture Active-Passive (SMAP)
- MSL updates to improve revision management and to track evidence of parameter “truth” using memory checksums and command set counters



References

¹ “Mars Global Surveyor (MGS) Loss of Contact” NASA lesson learned, URL: <http://lis.nasa.gov/lesson/1805>, 13 April 2007.

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