Numerical Scenario Evaluation

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Numerical Scenario Evaluation

- Task Objective: Verify the software architecture (the top-level software design) will meet all of the software performance requirements, e.g.
  - CPU loading
  - Bus loading
  - Message throughput
  - Uplink and downlink throughput
  - Storage
  - Timing
  - Command processing
- Approach: Generate realistic quantitative scenarios
  - Scenarios generated with events and physical models of internal processes
  - Calculation of resource usage/performance

Numerical Scenario Evaluation

- Motivated by desire to address performance-related requirements
  - Many IV&V methods do not handle performance requirements very well, which typically involve meeting performance goals. i.e. actual vs. budgeted performance

- Directly triggered by requirement to perform MAVEN architecture assessment task
  - Evaluation of architecture assessment led to focus on performance requirements, which led to this approach

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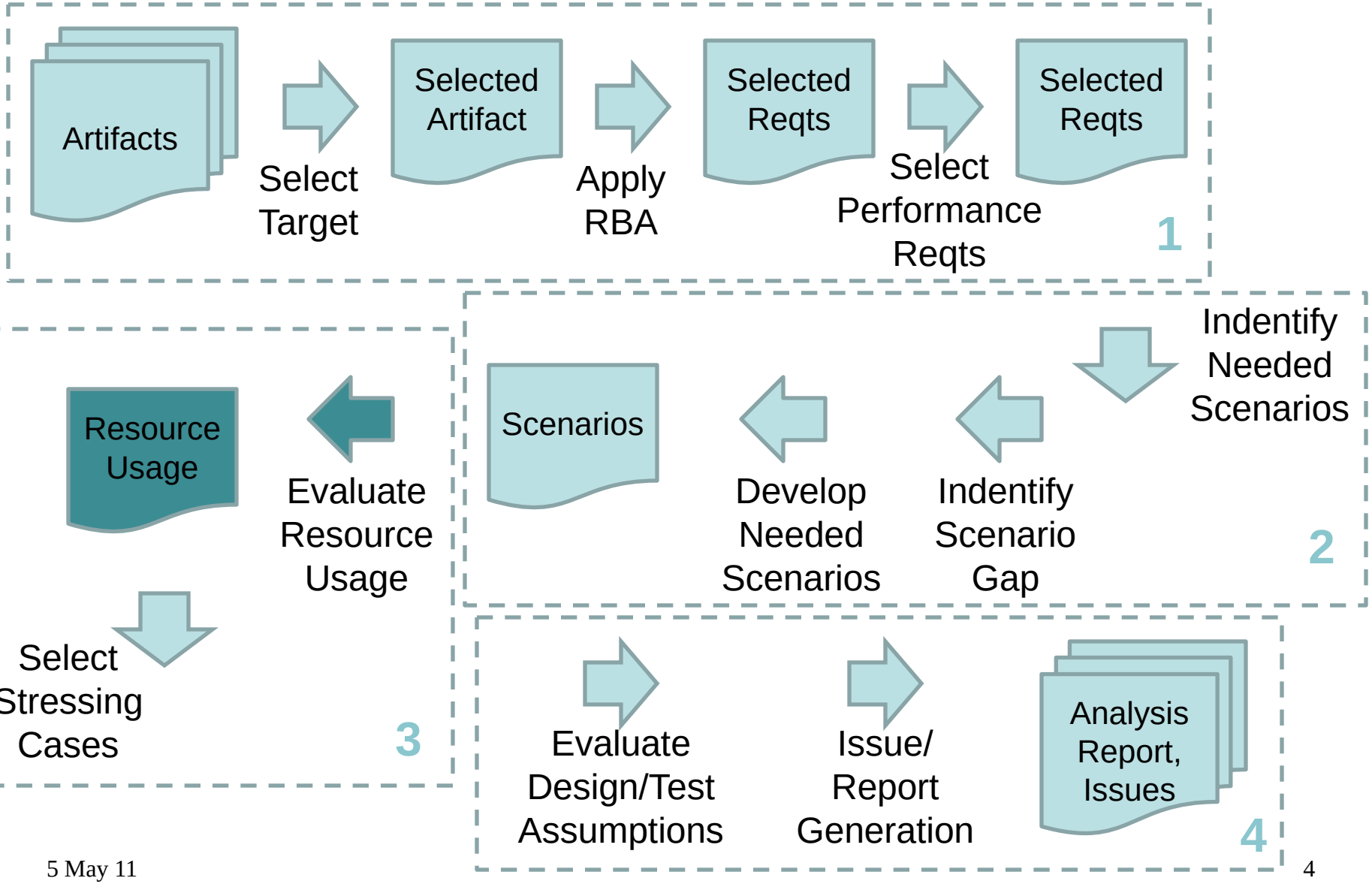
Analysis Process Flow



Evaluating Resource Usage

- This is the step for which the tool is used (the darker blocks on flow diagram)
- Approach is to capture, numerically vs. time, all resource requirements
- Total all requirements to come up with a plot vs. time of the total resource consumption
- Approach depends on detailed data of resource utilization by every consumer of the resource

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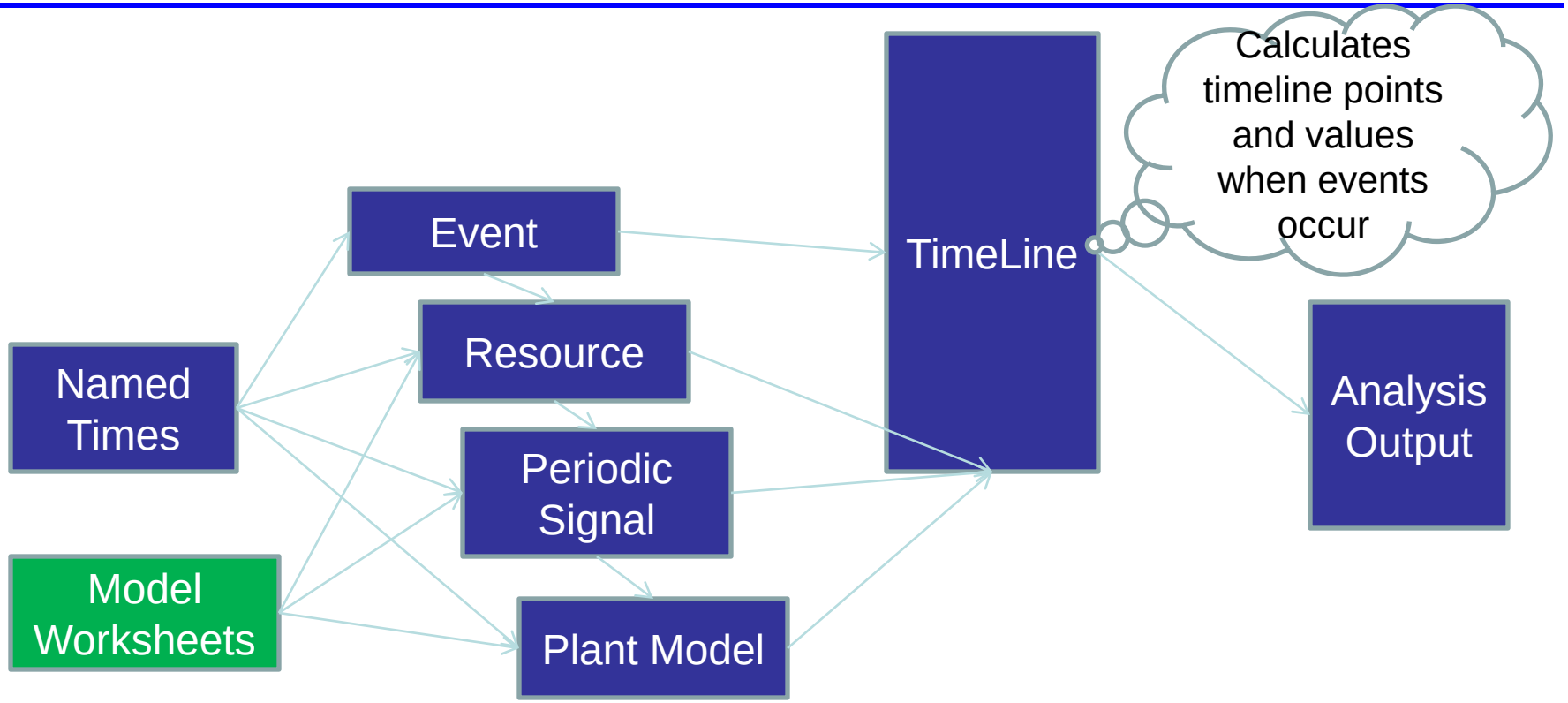
Scenario Components and Build-Up: How it Works



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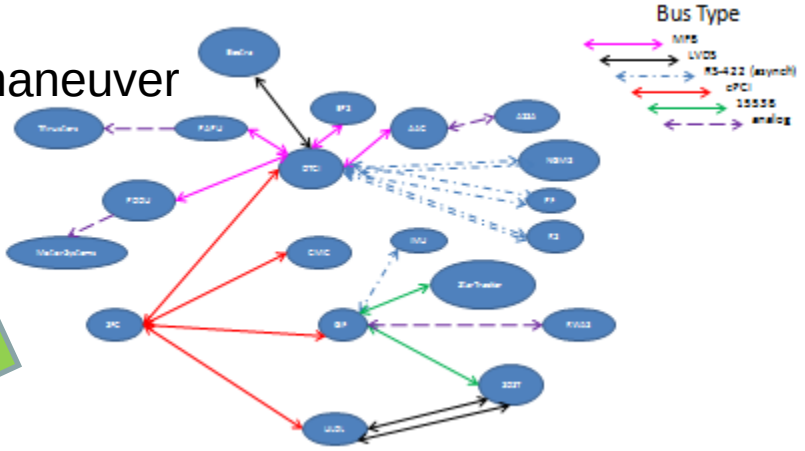
Resource Usage in Critical Maneuver: Building the Model Identify Resources

Objective: Evaluate bus traffic during a critical maneuver



	A	B	C	D
1	ResourceName	Capacity	Limit	CapUnits
2	LVDS	33		Mbps
3	MFB	6	10%	Mbps
4	MIL-STD-1553	1	30	Mbps
5	RS-422_IMU	4	50%	Mbps
6	RS-422__a_PF_data	4	50%	Mbps
7	RS-422_a_PF_cmd	57	50%	Kbps
8	RS-422_a_RS_data	4	50%	Mbps
9	RS-422_a_RS_cmd	57	50%	Kbps
10	RS-422_a_NGIMS_data	2	50%	Mbps
11	RS-422_a_NGIMS_cmd	57	50%	Kbps
12	LVDS_s_EUT_up	10	50%	Mbps
13	LVDS_s_EUT_dwn	12	50%	Mbps
14	LVDS_s_SDST_up	33	50%	Mbps
15	LVDS_s_SDST_dwn	33	50%	Mbps
16	cPCI bus	33	50%	Mbps
17	*END*			
18				
19				
20				
21				
22				

2			0	6	
3			0	7	
4			0	8	
5			0	9	
6			0	10	
7			0	11	
8			0	12	
9			0	13	Ref: high s
10			0	14	
11			0	15	
12					ULDL uses
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					

Author:
MAVEN CDR F2 pg 34
SDST synchronous downlink

hor:
EN CDR F2 Pg 34
T synchronous uplink

Author:
MAVEN CDR C2 21
Asynch fast for data

F2 pg 21

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Resource Usage in Critical Maneuver: Building the Scenario Identify Driving Events

Mission Description Documents

	A	B	C	D	E	F	G	H	I
1	Network loadings								
2	Node1	Node2	Data words per	Rate (Hz)	Resource	Protocol	Words/se	MBPS	When
3	SSA/AAC	DTCI	768	1	MFB	Synch/Serial	960	0.03072	SSA powered
4	DTCI	SSA/AAC	1	1	MFB	Synch/Serial	1.25	0.00004	SSA powered
5	EPS	DTCI	12	1	MFB	Synch/Serial	15	0.00048	always
6	DTCI	EPS	2	1	MFB	Synch/Serial	2.5	0.00008	always
7	DTCI	USM	2	1	MFB	Synch/Serial	2.5	0.00008	always
8	DTCI	PAPU	16	10	MFB	Synch/Serial	200	0.0064	RCS events
9	DTCI	PAPU	16	5	MFB	Synch/Serial	100	0.0032	articulation eve
10	GIF	SDST	4	1	MIL-STD-1553	CMD/2DATA words	5	0.00016	changing SDST r
11	ST	GIF	16	10	MIL-STD-1553	1553 RT/BC	200	0.0064	when ST is on (a
12	SDST_UPL	ULDL	32	1	LVDS_SDST_UP	Synch/Serial	40	0.00128	during data pas
13	ULDL	SDST_DWN	8	10000	LVDC_SDST_DWN	Synch/Serial	100000	3.2	during data pas
14	IMU	GIF	64	200	RS-422_IMU	Synch/Serial	16000	0.512	IMU powered
15									
16									
17									

Author: Cannot be less than 4 32 bit words. In addition, commanding, housekeeping data and

Author: The GNC ST data is read from the instrument at 10 Hz, but read from the GIF card at 5 Hz. Half the samples are discarded.

	A					
1	EventDescription (optional)					
2	BCM					
3	SASM TM					
4	USM TM					
5	SDST setup					
6	SDST done					
7	SDST setup	6	t0	MIL-STD-1553	0.00016	Relative
8	SDST done	7	t0	MIL-STD-1553	-0.00016	Relative
9	SSA on	8	t0	MFB	0.03072	Relative
10	SSA TM	12	t0	MFB	0.00004	Relative
11	desat IMU	-24	desat	RS-422_IMU	0.512	Relative
12	desat	-20	desat	MFB	0.0064	Relative
13	desat end	40	desat	MFB	-0.0064	Relative
14	gofast	-5	gofast	MFB	0	Relative
15	gofast end	5	gofast	MFB	0	Relative
16	LGA40	-5	LGA40	MIL-STD-1553	0.00016	Relative
17	LGA40 end	5	LGA40	MIL-STD-1553	-0.00016	Relative
18	MOI_start	0	MOI_burn	MFB	0.0064	Relative
19	MOI_end	0	MOI_burn_DV	MFB	-0.0064	Relative
20	MOI IMU off	500	MOI_burn_DV	RS-422_IMU	-0.512	Relative
21	*END*					
22						

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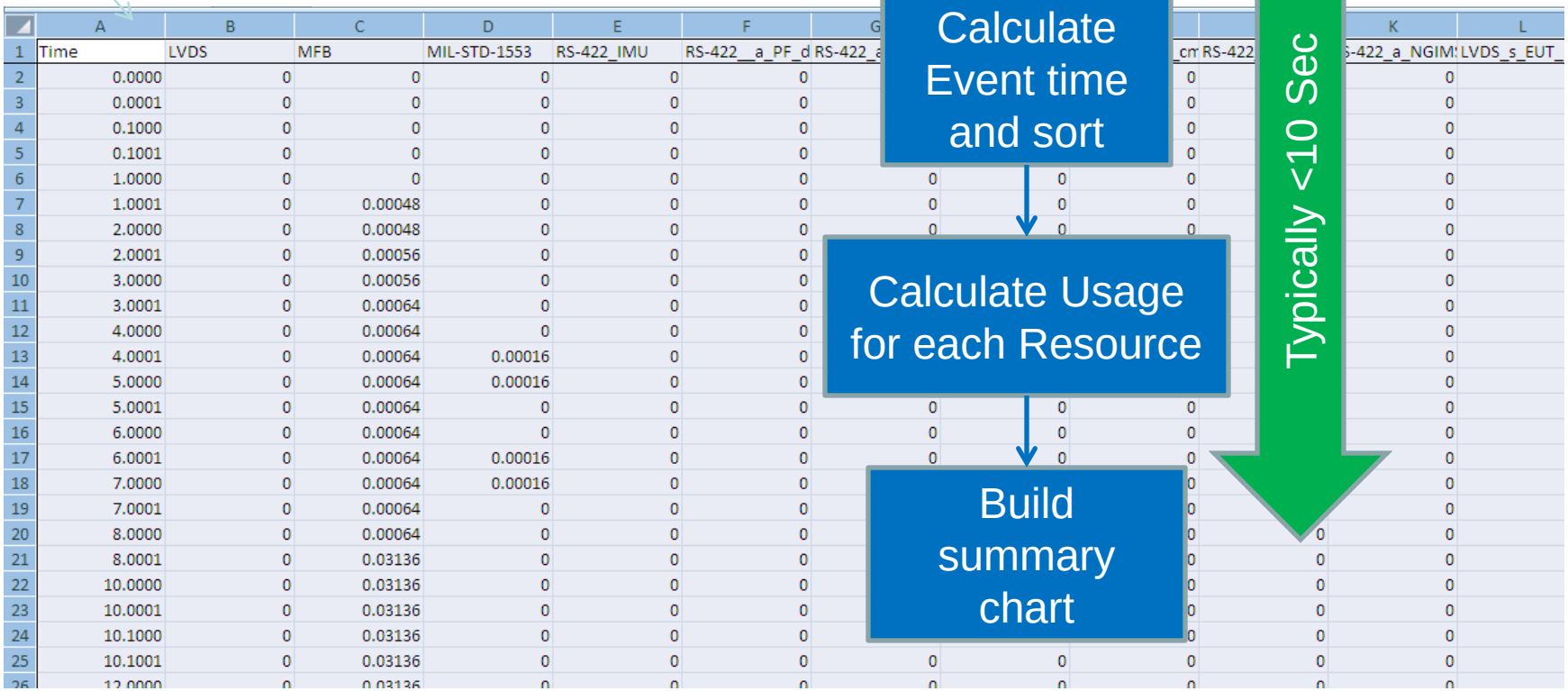
Resource Usage in Critical Maneuver: Building the Timeline

Time

Resources



	A	B	C	D	E	F	G	K	L
1	Time	LVDS	MFB	MIL-STD-1553	RS-422_IMU	RS-422__a_PF_d	RS-422_a	-422_a_NGIM	LVDS_s_EUT_
2	0.0000	0	0	0	0	0		0	
3	0.0001	0	0	0	0	0		0	
4	0.1000	0	0	0	0	0		0	
5	0.1001	0	0	0	0	0		0	
6	1.0000	0	0	0	0	0	0	0	
7	1.0001	0	0.00048	0	0	0	0	0	
8	2.0000	0	0.00048	0	0	0	0	0	
9	2.0001	0	0.00056	0	0	0		0	
10	3.0000	0	0.00056	0	0	0		0	
11	3.0001	0	0.00064	0	0	0		0	
12	4.0000	0	0.00064	0	0	0		0	
13	4.0001	0	0.00064	0.00016	0	0		0	
14	5.0000	0	0.00064	0.00016	0	0		0	
15	5.0001	0	0.00064	0	0	0	0	0	
16	6.0000	0	0.00064	0	0	0	0	0	
17	6.0001	0	0.00064	0.00016	0	0	0	0	
18	7.0000	0	0.00064	0.00016	0	0		0	
19	7.0001	0	0.00064	0	0	0		0	
20	8.0000	0	0.00064	0	0	0		0	0
21	8.0001	0	0.03136	0	0	0		0	0
22	10.0000	0	0.03136	0	0	0		0	0
23	10.0001	0	0.03136	0	0	0		0	0
24	10.1000	0	0.03136	0	0	0		0	0
25	10.1001	0	0.03136	0	0	0	0	0	0
26	12.0000	0	0.03136	0	0	0	0	0	0

{Performed in VBA }

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Resource Usage in Critical Maneuver: Evaluation

MFB usage during MOI

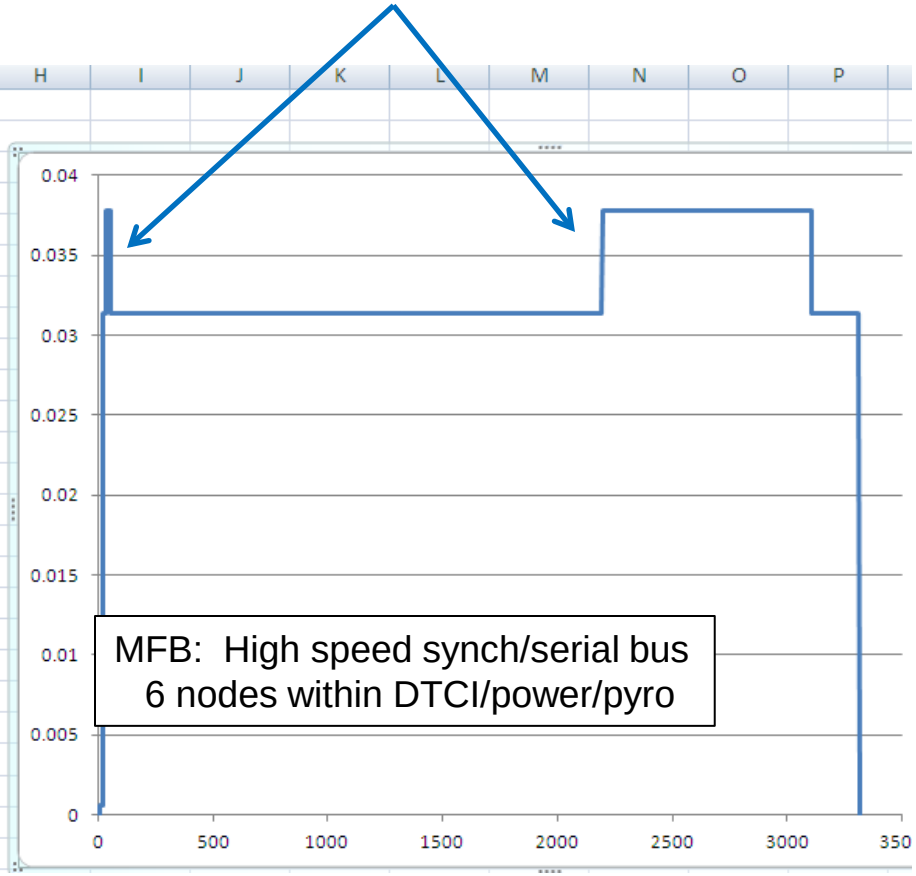
Refresh List

Selected Resource	MFB
Show Capacity Line	No
Show Limit Line	No

Update Chart

Time	MFB	MFB_Cap	MFB_Lim
0	0	6	0.6
0.0001	0	6	0.6
0.1	0	6	0.6
0.1001	0	6	0.6
1	0	6	0.6
1.0001	0.00048	6	0.6
2	0.00048	6	0.6
2.0001	0.00056	6	0.6
3	0.00056	6	0.6
3.0001	0.00064	6	0.6
4	0.00064	6	0.6
4.0001	0.00064	6	0.6
5	0.00064	6	0.6
5.0001	0.00064	6	0.6
6	0.00064	6	0.6
6.0001	0.00064	6	0.6
7	0.00064	6	0.6

PAPU Traffic during thruster events



Bus traffic far below hardware or software resource limitations

Complex Resource Usage: Model Development for Buffer Sizing

Science Orbit Scenario

- Data buffer sizing with missed DSN passes
- Multiple instruments with varying duty cycles
- Track orbit phases and activities
- Asynchronous periodic events

Plant: The portion of a model which represents internal state of a system

Timer
And
Or
Xor
First_order
Summer
Integrator
Buffer

Plant Model

Periodic Signals

	A	B	C	D	E	F	G	H	I
1	SignalName	StartEvent	EndEvent	Period	Duration	DrivenResource	EventType	ZeroRe	Value
2	Apoapsis	t0		16140	1	OrbitCount	Relative	TRUE	1
3	DataPass	D1		43200	18000	Telem	Relative	TRUE	0.55
4	*END*								

Complex Resource Usage: Building a Plant Model

Plant model consists of 41 elements
- 8 ors
- 4 ands
- 13 timers
- 9 first order
- 5 summers
- 1 buffer
- 1 integrator

Orbit phase construction

Orbit type construction

Instrument state construction

PlantName	PlantType	Input	Initial Value	Parameter1	Parameter2	Parameter3	Parameter4	Notes	Columr
PostApoapsis	timer	Apoapsis		0	0	2712	0	from ap to begin slew	Timers use para
Slew1	timer	Apoapsis			2712	600	0		Param2 = on del
Inbound	timer	Apoapsis			3312	3480			Param3 = off de
Slew2	timer	Apoapsis			6792	600			Param4 = retrigg
Preperiapsis	timer	Apoapsis			7392	666			
Periapsis	timer	Apoapsis			8058	1			
Postperiapsis	timer	Apoapsis			8059	689			
Desat	timer	Apoapsis			8748	300			
Slew3	timer	Apoapsis			9048	600			
Outbound	timer	Apoapsis			9648	3180			
Slew4	timer	Apoapsis							
PreApoapsis	timer	Apoapsis							
op_Periapsis	or	Preperiapsis							
op_Apoapsis	or	PreApoapsis							
op_DataPass	and	DataPass							
IsScience	and	-op_DataPass							
DeepDip	timer	Preperiapsis							
IUVS	first_order	op_Apoapsis							
op_NGIMS	and	-DeepDip							
NGIMS	first_order	op_NGIMS							
op_STATIC	and	IsScience							
op_SWEA	or	Inbound							
op_SWIA	or	IsScience							
op_SEP	or	op_Apoapsis							
op_LPW	or	Inbound							

Mission Description Document

	Node2	Data words per	Rate (Hz)	Resource	Protocol	Words/se	MBPS	When	Comments		On-usage rate
H	Buffer	2000	1	MFB	Synch/Serial	2000	0.002	Always	2419.2	All rough estimates	0.002
MS	Buffer	281	1	MFB	Synch/Serial	281	0.000281	Periapsis	339.8976		0.003345
IUVS	Buffer	628	1	MFB	Synch/Serial	628	0.000628	Apoapsis (preferred)	759.6288		0.000628
PF	Buffer	5200	1	MFB	Synch/Serial	5200	0.0052		6289.92		
>static	PF				internal		0.001	Always			
>swea	PF				internal		0.001	Sun Pointed	Sides		
>SWIA	PF				internal		0.001	Always			
>SEP	PF				internal		0.002	not Sun Pointed			
>LPW	PF				internal		0.001	Sun Pointed	Sides		
>EUVM	PF				internal		0.002	not Sun Pointed			
>MAG	PF				internal		0.001	Always			
Buffer	Telem	250000	1	MFB		250000	0.25	Datapasses 2 per week	302400		
					0.003344646						

Periodic signals	sec	duration
Apoapsis	16140	1
Data Pass	43200	43200

Science Pass Type		
1		
2		Average bps
3	630	1041.667

Events | Resources | **Plant Models** | PeriodicSignals | Named Times | Timeline | Chart Data | System description | Network Log

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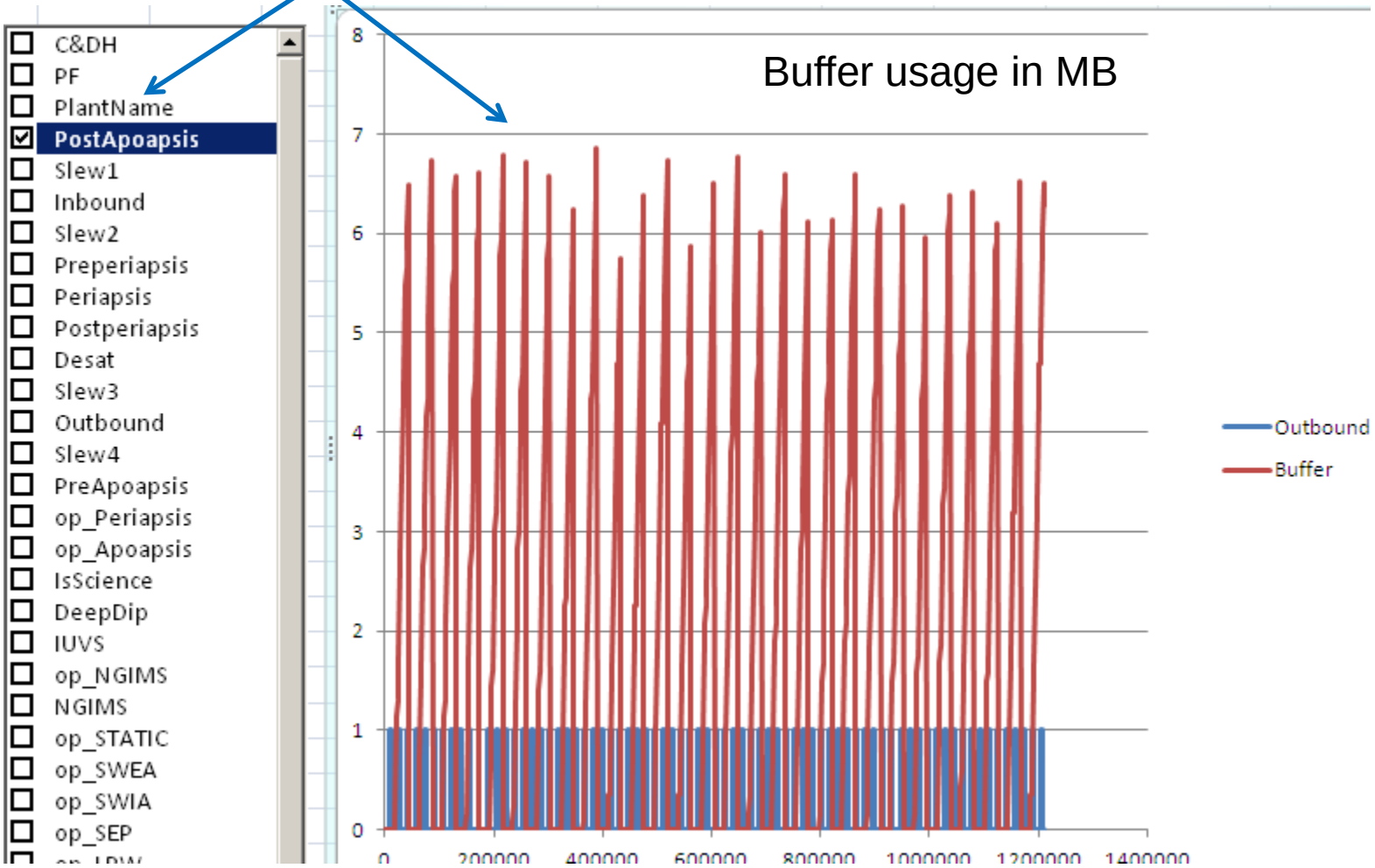
Complex Resource Usage: Evaluating Results (lots of code later)

Option for multi-plots



Data buffer size has adequate margin

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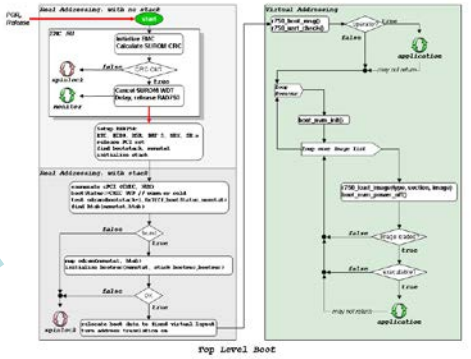
Complex Scenario: Building a large-scale model

Objective: Evaluate MOI reboot timeline
(time-limited sideswap/reboot/initialization during critical flight phase)

Approach: Step by Step boot/initialization model with multiple path and semaphores including such variations as memory bank failures and variable instrument warm-up times.

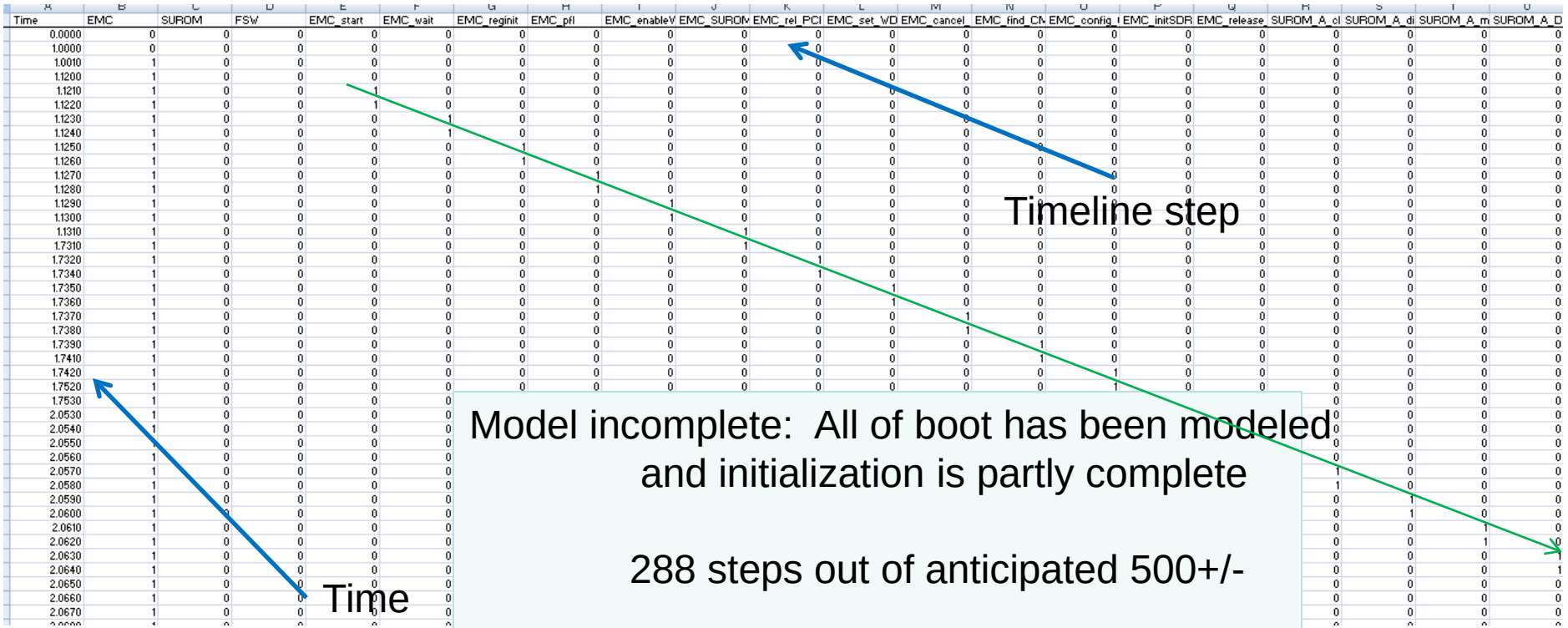


A	B	C	D	E	F	G
HW Activity	RAD750 Activi	EMC Activity	line	Implementation	Function	Addr. Mode
POR				hw	na	na
EEPROM Segment Select				hw	na	na
EMC SUROM init>		SUROM Init		EMC		
		wait (MRO heritage)		emc_main.emc	START	EMC
		EMC register initialization				
		increase cache p	122			
		enable EMC vec	130			
		SUROM CRC che	138			
		Release PCI rese	247			
		Set HW WDT		EMC		
		cancel EMC wdt	263			
		Find CMIC on PC	268			
		configure CMIC	327			
		Initialize CPU lo	394			
		Release RAD750	432	EMC		
		Enter monitor mode				
	release reset			R750_asm_main.s	START	real, no stack
	clear time base registers		71			
	disable external interrupts		77			
	turn on machine check enable		82			
	disable sequential instruction		88			
	disable ins/data in MMU		94			
	clear/initialize the BAT registe		100			

A	B	C					
PlantName	PlantType						
EMC_start	timer						0.001
EMC_wait	timer						0.001
EMC_reginit	timer						0.001
EMC_pfl	timer						0.001
EMC_enableVI	timer						0.001
EMC_SUROM_CRC	timer						0.6
EMC_rel_PCI	timer						0.002
EMC_set_WDT	timer						0.001
EMC_cancel_EMCwdt	timer					0	0.001
EMC_find_CMIC	timer					0	0.002
EMC_config_CMIC	timer					0	0.01
EMC_initSDRAM	timer					0	0.3
EMC_release_R750	timer					0	0.001
SUROM_A_clear_timebasereg	timer	EMC_release_R750			0	0.001	0.001
SUROM_A_disable_int_int	timer	SUROM_A_clear_timebasereg			0	0	0.001
SUROM_A_m_chk_ena	timer	SUROM_A_disable_int_int			0	0	0.001
SUROM_A_DSI	timer	SUROM_A_m_chk_ena			0	0	0.001
SUROM_A_ids_IDMMU	timer	SUROM_A_DSI			0	0	0.001
SUROM_A_initBATs	timer	SUROM_A_ids_IDMMU			0	0	0.001
SUROM_A_TLB	timer	SUROM_A_initBATs			0	0	0.003
SUROM_A_SetDBATs	timer	SUROM_A_TLB			0	0	0.004
SUROM_A_init_seg_reg	timer	SUROM_A_SetDBATs			0	0	0.004
SUROM_A_setupFP	timer	SUROM_A_init_seg_reg			0	0	0.002
SUROM_A_memtest	timer	SUROM_A_setupFP			0	0	30
SUROM_A_setupCstack	timer	SUROM_A_memtest			0	0	0.002

Complex Scenario: Evaluating a Big Model

Anticipated a big model and amply rewarded.



Time	EMC	SUROM	FSW	EMC_start	EMC_wait	EMC_reginit	EMC_pfl	EMC_enableW	EMC_SUROM	EMC_rel_PCI	EMC_set_WD	EMC_cancel_	EMC_find_CM	EMC_config_t	EMC_initSDR	EMC_release_	SUROM_A_cl	SUROM_A_di	SUROM_A_m	SUROM_A_D
0.0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0010	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1200	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1210	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1220	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1230	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1240	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1250	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1260	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1270	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1280	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1290	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1.1300	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1.1310	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1.7310	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1.7320	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1.7340	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1.7350	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1.7360	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1.7370	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1.7380	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1.7390	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1.7410	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1.7420	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1.7520	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1.7530	1	0	0	0	0												0	0	0	0
2.0530	1	0	0	0	0												0	0	0	0
2.0540	1	0	0	0	0												0	0	0	0
2.0550	1	0	0	0	0												0	0	0	0
2.0560	1	0	0	0	0												0	0	0	0
2.0570	1	0	0	0	0												1	0	0	0
2.0580	1	0	0	0	0												1	0	0	0
2.0590	1	0	0	0	0												0	1	0	0
2.0600	1	0	0	0	0												0	1	0	0
2.0610	1	0	0	0	0												0	0	1	0
2.0620	1	0	0	0	0												0	0	1	0
2.0630	1	0	0	0	0												0	0	0	1
2.0640	1	0	0	0	0												0	0	0	1
2.0650	1	0	0	0	0												0	0	0	0
2.0660	1	0	0	0	0												0	0	0	0
2.0670	1	0	0	0	0												0	0	0	0

Model incomplete: All of boot has been modeled and initialization is partly complete

288 steps out of anticipated 500+/-

5 minutes out of 13 minutes modeled

Requires non-timeline post-run analysis

Notes on Architecture: Good, bad, and not so pretty

Did it work?
- Yes!
- Accurate results depend upon careful modeling

Why Excel/VBA?
- Tables as framework for input parameters
- Use of scratchpad worksheets
- VBA is clearly adequate for the purpose
- Self-documenting via comments
- Rich and flexible post-processing including statistical analysis

Limitations?
- Model size (at an absurd 16,384 elements)
- Slightly annoying VBA /Excel integration
- NOT a simulation – feedback cannot be modeled

***On** the Horizon*

- Monte Carlo
  - This is the key remaining future capability, and in my mind the capability that enables broader usage and highly meaningful results
  - Necessary due to syncing (i.e. fine alignment/overlap of utilizations)
- Time Series Simulation and Feedback
  - Requires model evaluation sorting
  - Logic regarding state propagation and time sampling/integration periods.

Conclusions

- Numerical Scenario Analysis supported and validated design features for MAVEN
  - Bus utilization and C&DH data flow
  - Science data buffer sizing
  - Partial view of boot timeline

- Developed a general and flexible scenario evaluation tool
  - Numerical performance analysis
  - Integrated graphical and data analysis
  - Integrated scenario setup using Excel capabilities.