Appendix U

Model correlation of Meteosat Third Generation Platform STM

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Abstract

Meteosat Third Generation (MTG) is a series of meteorological satellites, which will take over the service provided currently by MSG. The series consist in 6 satellites: 4 Imagers (MTG-I) and 2 Sounders (MTG-S) having a common platform.
End of 2016, a Thermal Vacuum Test has been performed on a Structural Thermal Model (STM). The test's goal was on one hand to correlate the thermal model and on the other hand to qualify the structure. This presentation describes the process of model correlation from test ending until the results production. First, the thermal balance test is briefly introduced in order to set up the context and define the technical terms. The whole sequence starting with retrieving the data from the test, implementing these data into the thermal model using the ESATAN-TMS software and finally reducing the deviations between predicted and measured temperatures is presented. To illustrate the correlation process, explicit examples will be shown.

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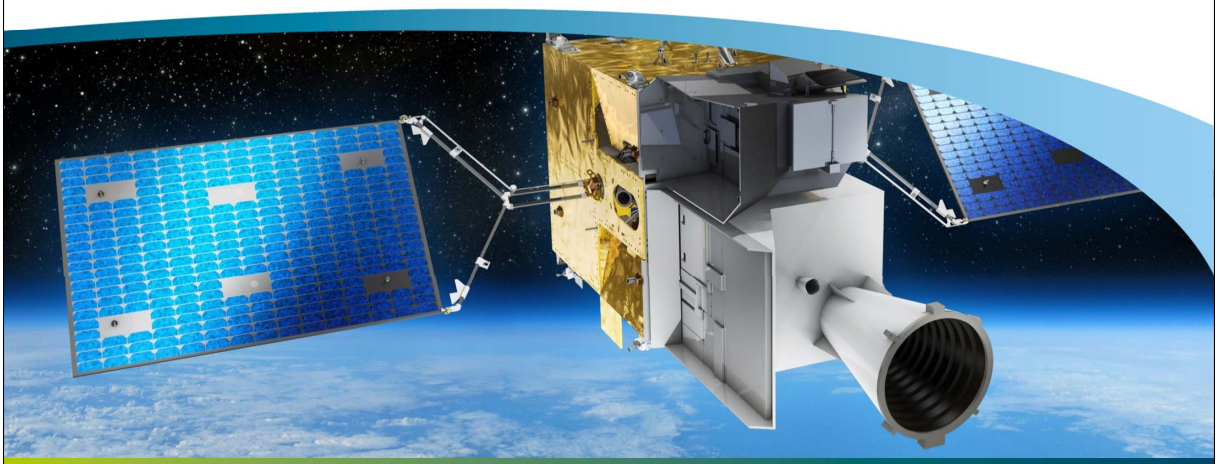
24.10.2017, ESTEC



SPACE SYSTEMS

MTG-STM Correlation

We. Create. Space.

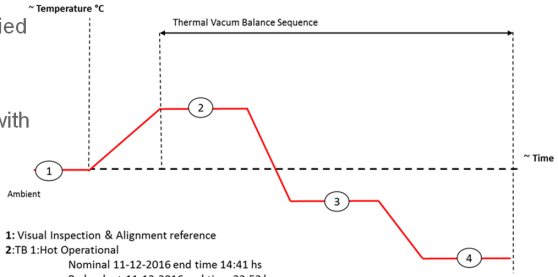
Agenda

- Context: presentation of the STM thermal balance test
- Model overview
- Correlation phase:
  - Inputs management
  - TMM configuration
  - Status before correlation
  - Process description
  - Examples
  - Final status
- Conclusion:
  - Advantages of manual correlation
  - Suggestions of ESATAN tools or functions

MTG-STM correlation

STM Thermal Balance test

- Objective: thermal model correlation and TCS verification
- 3 phases : hot balance, cold balance, safe mode balance
- STM configuration (platform only):
  - Full structure
  - Units: mechanical and thermal dummies (MTD) supplied with fixed current (EGSE)
  - 1 EM : reaction wheel
  - Heaters controlled in pulse width modulation (PWM) with EGSE
- IABG chamber
- 600 Thermocouples Type T
- Heater control thermistors NTC 15K
- Test heaters supplied with fixed current
- Use of shunt boxes on some power supplies for more accuracy



1: Visual Inspection & Alignment reference
2:TB 1:Hot Operational
Nominal 11-12-2016 end time 14:41 hs
Redundant 11-12-2016 end time 22:52 hs

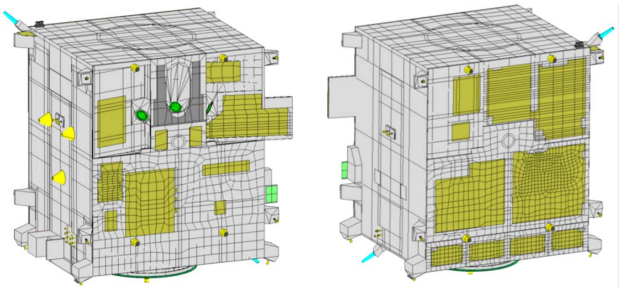
3:TB 2:Cold Operational
Nominal 13-12-2016 end time 3:30 hs
Change of Set points 13-12-2016 end time 6:05

4:TB 3:Cold Non Operational (Safe balance)
Nominal 14-12-2016 end time 10:30 hs
Change of Set points and VAE HP 14-12-2016 end time 23:59 hs

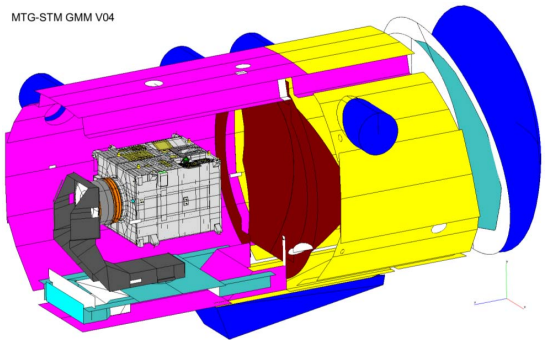
MTG-STM correlation

STM GMM overview

- Hybrid model MTG S/I
- Thermal Chamber model (provided by IABG)



STM



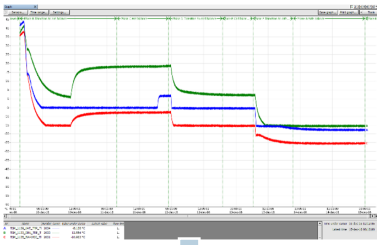
STM + chamber

MTG-STM correlation

Correlation – Inputs management

- Test data to be processed for the correlation:
  - Temperatures for all TCs and thermistors
  - Input currents of the MTD: i_{MTD}
  - Input currents of the heaters: i_{heater}
  - Flight heater duty cycles in seconds (PWM): DC_{PWM}

  To convert into power
  - Measured resistances of MTD and heater circuits: R_{MTD} and R_{heater}
- Export of data at the end of **each balance phase**: the **average of the last 30 min** is calculated for each measurement above



Measurement data results for test 'MTG ' between 12-dec-16 19:30:00 and 13-dec-

	TC_STR_1	TC_ACS_5	TC_EPS_4	TC_DHS_1	TC_EPS_3	TC_TTC_2
	#1	#2	#3	#4	#5	#6
Time	°C	°C	°C	°C	°C	°C
12.12.16 19:30	-0.75	12.89	13.38	8.93	8.99	4.72
12.12.16 19:31	-0.78	12.94	13.37	8.91	9.02	4.74
12.12.16 19:32	-0.78	12.93	13.39	8.9	9.02	4.73
12.12.16 19:33	-0.78	12.92	13.37	8.9	9.02	4.73
12.12.16 19:34	-0.82	12.98	13.37	8.83	9.06	4.74
12.12.16 19:35	-0.79	13	13.38	8.89	9.11	4.75
12.12.16 19:36	-0.87	12.89	13.44	8.85	8.97	4.89
12.12.16 19:37	-0.79	12.92	13.37	8.88	9.01	4.72
12.12.16 19:38	-0.78	12.83	13.41	8.91	8.93	4.77
12.12.16 19:39	-0.75	12.88	13.37	8.89	8.99	4.71
12.12.16 19:40	-0.79	12.84	13.42	8.89	8.94	4.8
12.12.16 19:41	-0.84	12.95	13.38	8.83	9.05	4.76
12.12.16 19:42	-0.81	12.92	13.36	8.87	8.99	4.72
12.12.16 19:43	-0.79	12.82	13.41	8.88	8.93	4.8
12.12.16 19:44	-0.82	12.83	13.44	8.87	8.9	4.8
12.12.16 19:45	-0.71	12.85	13.38	8.96	8.95	4.74
12.12.16 19:46	-0.88	12.93	13.36	8.82	9.01	4.74

Example of raw data as exported during test

MTG-STM correlation

Correlation – Inputs management

- Temperature: not a model input, but used for results comparison (see post-processing)
- Dissipation, test and flight heater power need to be calculated from the data:
  - *Dissipation of MTD:* $D_{MTD} = R_{MTD} * i_{MTD}^2$
  - *Power of test heaters:* $P_{test\_heater} = R_{heater} * i_{heater}^2$
  - *Power of flight heaters:*
    - The standard duty cycle in % is obtained by dividing the PWM duty cycle by 10 (DC_{PWM} = number of seconds where the heater is on within 10s)
    - The “installed power” of the heater is obtained with the constant current in the circuit.
  - $P_{flight\_heater} = R_{heater} * i_{heater}^2 * (DC_{PWM} / 10)$

Data implemented as arrays in the TMM (extract)

```
##################################################################
#                     |  Power Max  |  Power Max  |  Power Min
#                     | HOT BALANCE | HOT BALANCE | COLD BALANCE
#                     |   (CASE 2)  | RED(CASE 2) |   (CASE 3)
##################################################################
#
#
A_QI_MTD_WDE_05(6)   =      6.34   ,      6.34   ,      5.78   ,
A_QI_MTD_RW_5(6)     =      7.07   ,      7.07   ,      4.30   ,
#
##################################################################
# AOCS MTD HEATER LINES
A_QI_MTD_STR_01(6)   =      4.87   ,      4.87   ,      4.35   ,
A_QI_MTD_STR_02(6)   =      6.85   ,      6.85   ,      6.22   ,
A_QI_MTD_STR_03(6)   =      6.42   ,      6.42   ,      5.82   ,
A_QI_MTD_GYR(6)      =      0.50   ,      0.50   ,      2.35   ,
A_QI_MTD_GYRE(6)     =     34.91   ,     34.91   ,     23.24   ,
A_QI_MTD_WDE_01(6)   =     12.69   ,     12.69   ,      6.38   ,
A_QI_MTD_WDE_02(6)   =     12.22   ,     12.21   ,      5.96   ,
A_QI_MTD_WDE_03(6)   =     12.84   ,     12.84   ,      6.37   ,
```

```
##################################################################
#                     |    Hot      |     Hot     |    Cold     |
#                     |  Balance    |   Balance   |   Balance   |
#                     | Consum      |   Consum    |   Consum    |
#                     | (case 2)    | RED (case 2)| (case 3)    |
##################################################################
#
# AOCS HEATER
CONS_STR_01(6)   =      6.7,          6.8,          8.7,
CONS_STR_02(6)   =      6.7,          6.7,          8.6,
CONS_STR_03(6)   =      6.8,          6.8,          8.5,
CONS_STR_01_Bfle(6)=    2.9,          2.9,          2.9,
CONS_STR_02_Bfle(6)=    4.6,          4.7,          4.8,
CONS_STR_03_Bfle(6)=    3.6,          3.6,          3.8,
CONS_WDE_01(6)   =      0.0,          0.0,         11.8,
CONS_WDE_02(6)   =      0.0,          0.0,          0.0,
CONS_WDE_05(6)   =      0.0,          0.0,          5.8,
```

MTG-STM correlation

Correlation – TMM configuration

- Step 1: TMM with steady-state solver
  - Fixed dissipation and heater power for each case
  - Successive steady state runs

➕ Fast (multiple iterations possible) and easier to manipulate

➖ Local heat balance wrong as long as correlation progress is low

```
# HOT BALANCE
        ISW_OUT = 0
        CALL SET_TMTA_HOT
        CALL SET_MTD_POW(1)        } Define and place
        CALL MTD_POW_PLACEM        } MTD dissipation
        CALL TCS_HTR_PF_CONS(1)    }
        CALL TCS_HTR_PL_CONS(1)    } Define and
        CALL TCS_HTR_PF_PLACEM     } place flight
        CALL TCS_HTR_PL_PLACEM     } heater power
        CALL TEST_HTR_CONS(1)      } Define and place
        CALL TEST_HTR_PLACEM       } test heater power
      CALL SOLVFM
```

Extract of the $execution block

- Step 2: TMM with transient solver
  - Fixed dissipation for MTDs
  - Temperature set points introduced for flight and test heaters: values as-run
  - Simulation duration: 40 hours per phase

➕ Necessary to correlate the heater duty cycle

➖ Long to run

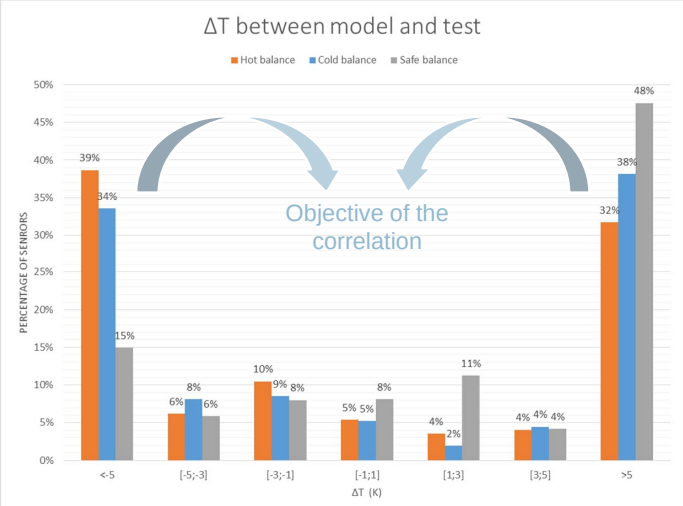
Extract of the $variables2 block

```
#====================================#
#     HOT BALANCE (CASE 2)           #
#====================================#
#
      IF(TIMEN.LT.136800.0)THEN
#
Define and place MTD dissipation
        CALL SET_MTD_POW(1)
        CALL MTD_POW_PLACEM
Define flight heater set points activate heater and place power
        CALL TCS_HTR_PF_SETP(1)
        CALL TCS_HTR_PL_SETP(1)
        CALL TCS_HTR_PF_ACTIV
        CALL TCS_HTR_PL_ACTIV
        CALL TCS_HTR_PF_PLACEM
        CALL TCS_HTR_PL_PLACEM
…same for test heaters
        CALL TEST_HTR_SETP(1)
        CALL TEST_HTR_ACTIV
        CALL TEST_HTR_PLACEM
#
      ENDIF
```


MTG-STM correlation

Correlation - Status before correlation

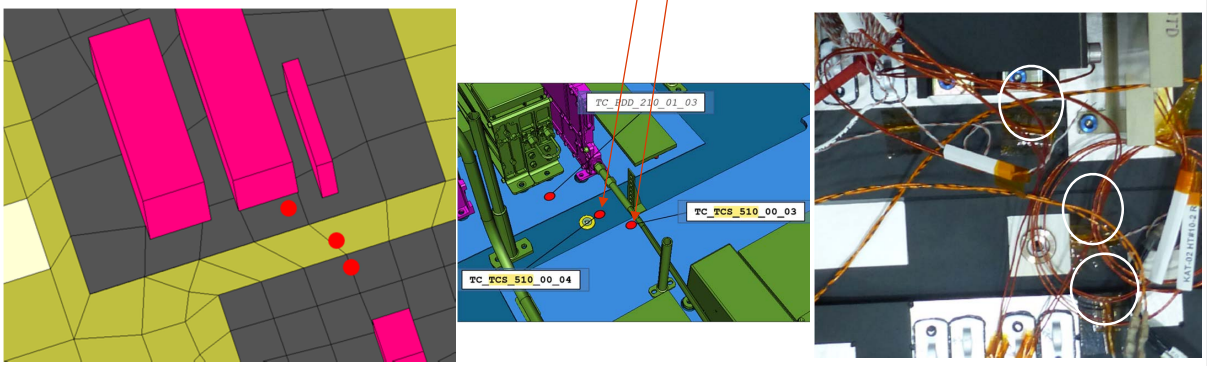
- Status before correlation on all sensors:
  - Deviation between sensor measurement and associated node temperature is calculated
  - Deviations sorted by ranges
  - ~40% of nodes within 5°C deviation
- Agreed success criteria:
- **Temperature:** 100% of TRPs ΔT to test results shall be lower than 5K.
- **Heater lines duty cycle:**
  - For each line, duty cycle deviation to test results shall be within 20%.
  - The overall power consumption deviation to test shall be within 10%.



Correlation process

- Post-processing strategy
  - Compare temperatures between test and model
  - Compare duty cycles between test and model (for transient runs)
- Correspondence Sensors (thermistors/thermocouples) and nodes: linear interpolation

	Interpolation parameters						Mod_hot_bal			
Sensor	Node1	weigh	Node2	weigh	Node3	weigh	T_1	T_2	T_3	Averag
TC_TCS_510_00_03	C_DOU_TWT:81227110	1	C_DOU_TWT:81227124	1	0	0	7.0789	6.7252	0	6.90205
TC_TCS_510_00_04	C_PF_PY_RAD:71217178	1	C_PF_PY_RAD:71217146	1	0	0	-3.7253	-3.5697	0	-3.6475
TC_TCS_510_00_05	C_PF_PY_RAD:71227004	1	C_PF_PY_RAD:71217227	0	0	0	2.3093	-1.3524	0	2.3093
TC_TCS_520_00_01	S_DOU_GYRE:83817131	2	S_DOU_GYRE:83817126	1	0	0	20.0725	26.0898	0	22.0783



Correlation process

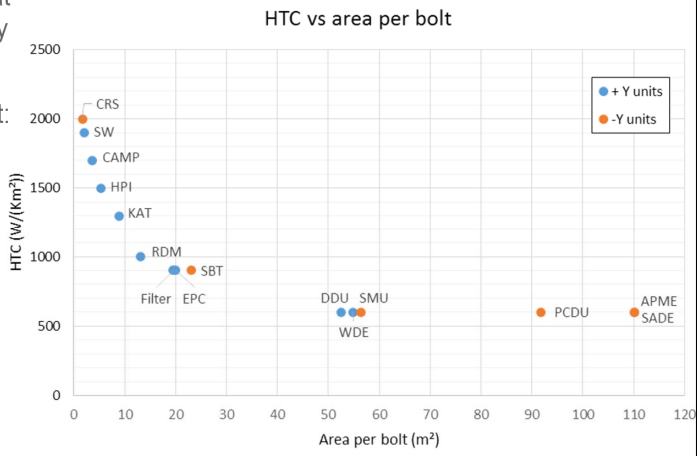
- Correlation process: **from the most global to the most local**
  - Correlate the OSR emissivity to reach a correct average T on radiators
    - Emissivity variation from 0.8 to 0.89
    - Typical correlated value around **0.83**
  - Correlate MLI performance
    - Effective emissivity defined by a temperature dependent array
    - Eff. Emissivity multiplied by a **performance factor** for each blanket
    - Correlated performance factor for external MLI: 1.25
  - Panels in plane/out of plane conductivity (aluminum and CFRP): low sensitivity of the model
  - Adjust the unit conductive I/F
  - Local correlation issues implying remodeling

MTG-STM correlation

Correlation example 1: Standard unit conductive I/F

- I/F conductance is modelled via a heat transfer coefficient (HTC) multiplied by footprint area
- First approximation at correlation start:

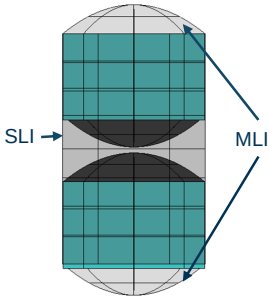
  HTC = dissipation / (ΔT * area)
- HTC adjusted to take into account distance between the sensors
- Compromise between:
  - Deviations test/model
  - Reality (hardware): area, bolts, interfiller,…

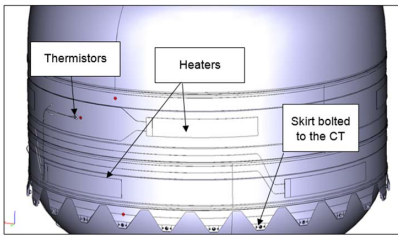


MTG-STM correlation

Correlation example 2: Propellant tanks

- Observations right after test:
- Heater power consumption higher than predicted by the model
- Impact in steady state analysis: calculated temperatures much higher than in test
- Deduction: tanks are too isolated in the model
- 2 major contributors to the coupling between tanks and platform:
- SLI on the internal side of the central tube
- I/F conductive conductors



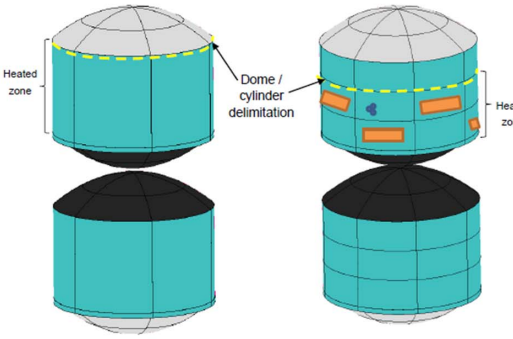


LOAD DATA		S/S	Hot balance T /°C			Cold balance T /°C			Safe balance T /°C		
			Mod_hot_bal			Mod_cold_bal			Mod_safe_bal		
Unit			Test	Mod	Delt	Test	Mod	Delt	Test	Mod	Delt
CT - Tanks				#N/A			#N/A			#N/A	
MMH bottom	UPS		20.01	29.27	9.26	14.83	25.99	11.17	9.69	23.04	13.35
MMH center	UPS		19.15	34.13	14.98	14.19	30.14	15.96	8.91	28.89	19.98
MMH tank	UPS		19.57	31.89	12.32	13.94	27.77	13.83	9.34	25.87	16.53
MMH tank bottom	UPS		20.50	29.27	8.77	15.25	25.99	10.75	10.24	23.04	12.80
MMH tank center	UPS		19.38	34.13	14.75	14.44	30.14	15.70	9.10	28.89	19.79
MMH top	UPS		20.02	31.89	11.87	14.94	27.77	12.83	9.87	25.87	15.99
MON bottom	UPS		20.52	29.58	9.06	14.91	27.95	13.04	9.53	23.77	14.24
MON center	UPS		19.55	28.88	9.33	14.09	26.01	11.92	8.17	20.22	12.04
MON tank	UPS		19.73	28.71	8.98	14.39	25.68	11.28	9.13	22.56	13.43
MON tank bottom	UPS		20.63	29.58	8.95	15.19	27.95	12.76	9.83	23.77	13.94
MON tank center	UPS		19.44	#N/A	#N/A	14.12	#N/A	#N/A	8.49	#N/A	#N/A
MON tank center	UPS		19.63	28.88	9.25	14.13	26.01	11.88	8.14	20.22	12.07
MON top	UPS		20.19	28.71	8.52	14.85	25.68	10.82	9.60	22.56	12.96

MTG-STM correlation

Correlation example 2: Propellant tanks (2)

- Necessity to remesh the tanks to have more accurate results
- I/F conductive conductance increased by a factor 5
- SLI emissivity (VDA coating) increased from 0.05 to 0.1 => **significant impact**

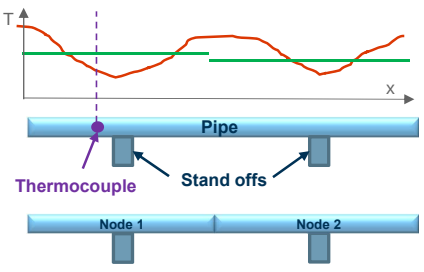


LOAD DATA		S/S	Hot balance T/C			Hot balance red T/C			Cold balance T/C			Safe balance T/C		
			Mod_hot_bal			Mod_hot_bal_r			Mod_cold_bal			Mod_safe_bal		
Unit			Tes	Mod	Delt	Tes	Mod	Delt	Tes	Mod	Delt	Tes	Mod	Delt
CT - Tanks				#N/A			#N/A			#N/A			#N/A	
MMH top	UPS		20.02	19.26	-0.76	20.01	18.34	-1.68	14.94	14.28	-0.66	9.87	9.49	-0.39
MMH tank top	UPS		19.57	19.08	-0.48	19.48	18.23	-1.25	13.94	14.57	0.64	9.34	9.40	0.06
MMH tank top	UPS		19.61	19.08	-0.52	19.54	18.23	-1.32	14.45	14.57	0.12	9.38	9.40	0.02
MMH tank top	UPS		19.46	19.59	0.14	19.42	18.84	-0.59	14.27	15.36	1.09	9.09	10.20	1.11
MMH tank top	UPS		19.93	20.07	0.14	19.89	19.01	-0.88	14.69	14.73	0.04	9.61	9.74	0.13
MMH tank top	UPS		19.70	20.07	0.37	19.69	19.01	-0.68	14.50	14.73	0.23	9.45	9.74	0.29
MMH tank top	UPS		20.62	20.98	0.36	20.54	19.87	-0.67	15.43	15.27	-0.15	10.65	10.41	-0.25
MMH center	UPS		19.15	20.15	1.00	19.16	19.37	0.21	14.19	15.61	1.41	8.91	11.09	2.18
MMH tank center	UPS		19.38	22.20	2.82	19.40	21.58	2.18	14.44	18.28	3.84	9.10	13.40	4.30
MMH tank center	UPS		18.56	19.88	1.32	18.61	19.19	0.58	13.57	15.77	2.20	8.18	10.71	2.53
MMH tank center	UPS		11.61	8.72	-2.89	11.65	8.33	-3.32	7.77	5.42	-2.36	-1.35	-5.18	-3.83
MMH tank center	UPS		21.74	22.97	1.23	21.67	21.85	0.18	16.21	17.07	0.86	12.23	12.27	0.04
MMH tank center	UPS		18.98	17.46	-1.52	19.03	16.56	-2.46	12.31	10.20	-2.11	6.19	1.50	-4.69
MMH bottom	UPS		20.01	23.52	3.51	20.03	22.64	2.61	14.43	17.64	2.81	9.69	11.81	2.12
MMH tank bottom	UPS		20.50	17.84	-2.66	20.48	17.27	-3.22	15.25	13.88	-1.37	10.24	7.86	-2.38
MMH tank bottom	UPS		19.95	17.36	-2.59	20.01	16.82	-3.20	14.75	13.63	-0.92	9.40	7.47	-1.94
MMH tank bottom	UPS		20.04	17.12	-2.91	20.04	16.57	-3.47	14.90	13.59	-1.32	9.72	7.20	-2.51
MMH tank bottom	UPS		21.05	19.11	-1.93	21.05	18.49	-2.56	15.48	14.72	-0.76	10.49	8.91	-1.57
MMH tank bottom	UPS		20.87	18.22	-2.66	20.85	17.63	-3.22	15.49	14.16	-1.34	10.55	8.13	-2.43
MMH tank bottom	UPS		20.59	18.22	-2.37	20.64	17.63	-3.01	15.31	14.16	-1.16	10.26	8.13	-2.13
MON top	UPS		20.19	17.39	-2.80	20.20	16.83	-3.37	14.85	13.63	-1.22	9.60	7.60	-1.99
MON tank top	UPS		19.73	17.06	-2.67	19.73	16.51	-3.22	14.39	13.49	-0.90	9.13	7.30	-1.83
MON tank top	UPS		19.61	17.06	-2.55	19.56	16.51	-3.05	14.33	13.49	-0.84	8.99	7.30	-1.69
MON tank top	UPS	#N/A	16.92	#N/A	#N/A	16.38	#N/A	#N/A	#N/A	13.38	#N/A	#N/A	6.92	#N/A
MON tank top	UPS	#N/A	18.22	#N/A	#N/A	17.63	#N/A	#N/A	#N/A	14.22	#N/A	#N/A	8.14	#N/A
MON tank top	UPS	20.28	18.22	-2.06	20.35	17.63	-2.72	14.80	14.22	-0.58	9.80	8.14	-1.67	
MON tank top	UPS	20.15	18.63	-1.53	20.23	18.06	-2.17	14.35	14.44	0.09	9.00	8.20	-0.81	
MON center	UPS	19.55	16.92	-2.62	19.57	16.38	-3.19	14.09	13.38	-0.71	8.17	6.92	-1.25	
MON tank center	UPS	19.63	19.24	-0.39	19.66	18.91	-0.75	14.13	16.11	1.98	8.14	7.94	-0.21	
MON tank center	UPS	19.15	17.41	-1.74	19.16	16.99	-2.17	13.58	14.06	0.48	7.46	6.18	-1.28	
MON tank center	UPS	15.83	12.34	-1.49	13.95	12.19	-1.76	6.55	4.69	-1.66	-1.43	-3.41	-1.97	
MON tank center	UPS	21.98	21.53	-0.45	21.91	21.07	-0.84	15.99	16.43	0.44	10.41	9.37	-1.04	
MON tank center	UPS	22.17	20.52	-1.65	22.20	20.21	-1.99	12.13	10.26	-1.87	5.47	2.76	-2.71	
MON bottom	UPS	20.52	23.86	3.34	20.53	23.52	2.99	14.91	17.68	2.77	9.53	10.24	0.71	
MON tank bottom	UPS	20.63	21.97	1.34	20.65	21.66	1.01	15.19	21.05	5.87	9.83	15.70	5.87	
MON tank bottom	UPS	20.23	20.67	0.44	20.23	20.40	0.17	14.79	18.67	3.88	9.09	11.96	2.86	
MON tank bottom	UPS	20.20	20.73	0.53	20.19	20.45	0.25	14.96	20.35	5.40	9.39	14.69	5.30	
MON tank bottom	UPS	21.05	20.73	-0.32	21.08	20.45	-0.63	15.67	20.35	4.68	10.27	14.69	4.42	
MON tank bottom	UPS	21.16	24.31	3.14	21.16	23.98	2.82	15.44	20.94	5.50	9.97	14.82	4.85	
MON tank bottom	UPS	21.19	22.64	1.44	21.24	22.32	1.09	15.80	21.55	5.75	10.49	16.19	5.71	

MTG-STM correlation

Correlation example 3 : Pipework

- Not sufficient correlation at the start
- Observations:
  - Higher heater consumption in test than in model (steady state temperature higher)
  - Most TCs placed close to stand-offs, while model contains large nodes which are not representative of the local temperature
  - Model not detailed enough for good correlation



Real temperature: low close to standoff, high between 2 standoffs

Calculated temperature by model: averaged value on each node

LOAD DATA	Sensor	Hot balance T/C			Cold balance T/C			Safe balance T/C		
		Mod_hot_bal			Mod_cold_bal			Mod_safe_bal		
Unit		Te	Mo	De	Te	Mo	De	Te	Mo	De
Piping			#N/A			#N/A			#N/A	
piping heaterline 1	TSM_1089_PLINES_TRP_TEMP_A1	23.59	52.38	28.79	13.56	47.41	28.85	13.51	41.13	27.62
	TC_UPS_000_01_01	47.58	46.40	-1.18	47.85	43.35	-4.50	45.88	36.04	-9.84
	TC_UPS_000_01_02	19.31	40.28	20.98	17.26	37.89	20.63	11.90	30.77	18.87
	TC_UPS_000_02_01	34.02	47.97	13.95	31.98	44.18	12.20	27.84	36.97	9.13
	TC_UPS_000_03_01	33.14	58.17	25.03	28.57	53.43	24.86	24.76	47.70	22.95
	TC_UPS_000_03_02	26.76	46.50	19.74	21.14	40.38	19.24	16.93	33.62	16.69
	TC_UPS_000_04_01	#N/A	52.83	#N/A	#N/A	47.72	#N/A	#N/A	41.26	#N/A
	TC_UPS_000_05_01	#N/A	57.05	#N/A	#N/A	52.75	#N/A	#N/A	46.88	#N/A
	TC_UPS_000_05_02	25.73	47.03	21.36	20.65	42.71	22.06	14.63	36.06	21.37
	TC_UPS_000_06_01	35.75	45.88	10.73	33.32	44.15	11.03	29.84	39.66	9.82
	TC_UPS_000_06_02	27.42	44.03	16.61	24.07	41.57	17.49	19.73	36.46	16.73
	TC_UPS_000_25_01	34.22	47.93	13.71	32.96	42.98	10.02	28.38	35.16	6.78
	TC_UPS_000_25_02	37.22	52.15	14.93	35.65	48.55	12.91	32.10	41.85	9.76
	TC_UPS_000_25_03	23.44	54.04	30.59	13.35	51.07	31.72	14.48	46.93	32.45
piping heaterline 2	TSM_1090_PLINES_TRP_TEMP_A2	21.10	52.14	31.03	16.06	48.66	32.60	10.75	50.40	39.65
	TC_UPS_000_11_01	15.40	33.70	24.30	16.63	41.05	22.43	13.37	38.73	25.36
	TC_UPS_000_12_01	28.15	49.53	23.38	25.30	47.55	22.25	24.57	49.34	24.77
	TC_UPS_000_12_02	30.65	45.07	14.41	33.11	44.78	11.67	36.50	44.96	8.46
	TC_UPS_000_13_01	21.77	44.40	22.63	16.01	40.16	24.15	10.84	38.89	28.05
	TC_UPS_000_14_01	35.41	63.16	27.75	32.14	60.23	28.09	35.19	65.82	30.63
	TC_UPS_000_15_01	28.41	50.21	21.80	26.05	47.86	21.81	25.15	43.19	24.04
	TC_UPS_000_16_01	31.51	54.56	23.05	28.81	55.26	26.45	25.79	55.67	29.88
	TC_UPS_000_16_02	31.89	55.54	23.65	27.65	51.57	23.92	26.57	53.55	26.98
	TC_UPS_000_17_01	26.21	36.18	9.97	26.20	36.38	10.18	27.03	34.85	7.82
	TC_UPS_000_17_02	11.94	30.73	13.45	8.92	30.16	21.24	3.06	29.52	26.46
	TC_UPS_000_18_01	25.75	40.44	14.70	20.86	38.62	17.76	19.88	38.19	18.31
piping heaterline 3	TSM_1091_PLINES_TRP_TEMP_A3	24.46	43.78	19.32	18.75	60.50	41.76	13.77	55.41	41.63
	TC_UPS_000_07_01	30.06	34.23	4.17	30.27	33.29	3.02	25.78	26.56	0.78
	TC_UPS_000_07_02	10.81	26.91	16.10	9.43	25.94	16.45	0.51	21.66	21.15
	TC_UPS_000_08_01	22.40	38.00	15.60	15.70	33.73	18.03	10.43	28.96	18.53
	TC_UPS_000_09_01	23.96	40.57	16.61	26.19	40.46	14.27	22.45	35.58	13.12
	TC_UPS_000_09_02	23.78	33.99	10.21	19.22	30.08	10.86	14.19	24.73	10.60
piping heaterline 4	TSM_1101_PLINES_TRP_TEMP_A5	23.01	37.20	14.19	17.79	34.82	17.03	12.73	29.77	17.04
	TC_UPS_000_19_01	30.36	45.16	14.79	27.25	47.26	20.01	25.05	45.38	20.33
	TC_UPS_000_27_01	10.70	12.46	1.76	2.22	4.78	2.56	-5.77	-4.36	1.41
	TC_UPS_000_27_02	10.61	14.98	4.37	1.99	8.06	6.07	-8.15	-0.13	8.02
piping heaterline 5	TSM_1102_PLINES_TRP_TEMP_A6	23.32	40.97	17.65	18.08	39.77	21.69	12.93	36.68	23.75
	TC_UPS_000_20_01	34.69	49.34	14.65	55.10	73.03	17.92	47.35	65.25	17.91
	TC_UPS_000_20_02	28.98	47.17	18.19	36.15	65.61	27.46	32.09	59.07	26.97
	TC_UPS_000_21_01	24.63	43.96	19.26	40.95	70.00	29.05	33.02	62.54	29.53
	TC_UPS_000_21_02	27.54	35.69	8.15	44.46	51.22	6.77	37.03	43.76	6.73
	TC_UPS_000_22_01	22.03	41.67	19.64	27.76	65.13	37.37	20.52	57.43	36.91
	TC_UPS_000_22_02	29.23	40.91	11.68	42.75	59.11	16.36	35.91	52.38	16.47
	TC_UPS_000_23_01	25.61	43.65	18.04	31.90	63.94	32.04	25.38	57.84	32.46
	TC_UPS_000_28_01	10.94	11.81	0.87	2.84	4.80	1.96	-5.77	-4.05	1.72
	TC_UPS_000_28_02	12.00	19.10	7.11	2.84	11.94	9.10	-5.71	4.42	10.13
	TC_UPS_000_23_AA	24.49	47.14	22.65	18.89	68.55	49.66	13.77	62.93	49.16
	TC_UPS_000_29_01	24.97	44.64	19.67	22.06	62.79	40.73	16.94	57.28	40.34
	TC_UPS_000_30_01	28.92	44.95	16.03	31.62	62.94	31.32	26.17	57.38	31.21
	TC_UPS_000_30_02	26.30	45.38	19.07	21.49	62.82	41.33	16.55	57.67	41.11

MTG-STM correlation

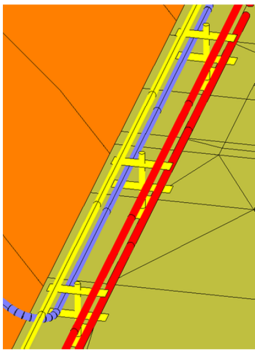
Correlation example 3 : Pipework (2)

- To decrease the general temperature level (in steady state analysis), radiative leaks have to be increased by correlating the **chofoil properties**.
- The final correlated values are:
- Radiative area increased by 50%. This is justified by integration reasons: overlapping chofoil layers, inclusion of the propulsion tubing heater, wrinkles
- Piping longitudinal conductivity increased assuming 2 layers of chofoil instead of 1 (+60%)

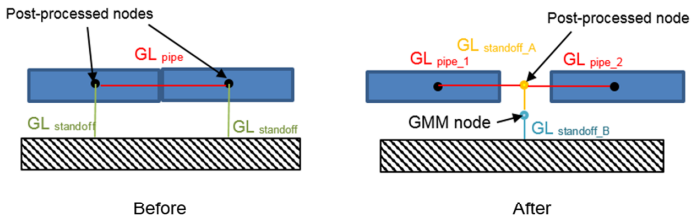
MTG-STM correlation

Correlation example 3 : Pipework (3)

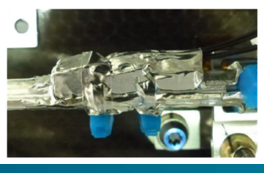
- Model improvement:
- Stand off modelling (GMM and TMM)
- Split of large nodes into 2 types of nodes: nodes close to standoff (cold spot) and nodes between 2 standoffs (hot spot)

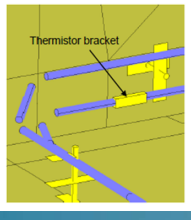


GMM of stand off



- Modelling of thermistor bracket including chofoil wrapping

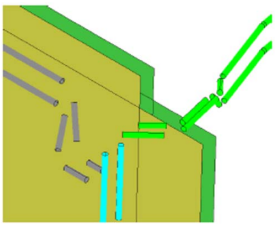


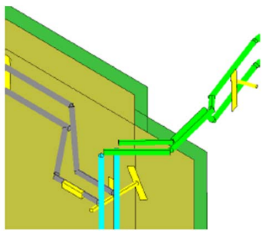


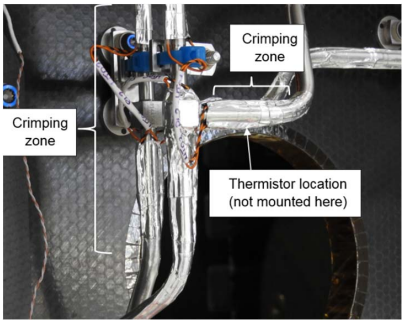
MTG-STM correlation

Correlation example 3 : Pipework (4)

- Local correlation on specific areas
- Areas close to thermistors have to be correlated carefully (impact on heater power consumption for a large bunch of pipe sections)
- Crimping zones: locally no heating (on STM only, this is reviewed for PFM as an outcome of the test)
- LAE bracket:
  - Adjustement conductive coupling
  - Consideration of chofoil wrapping





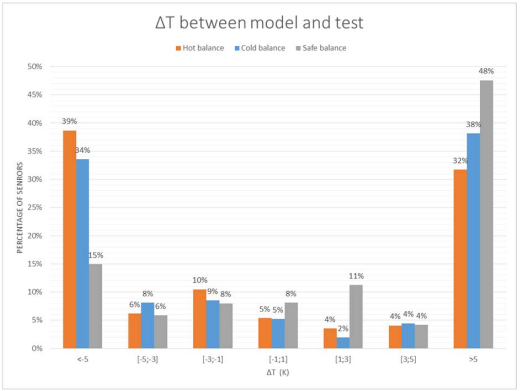


MTG-STM correlation

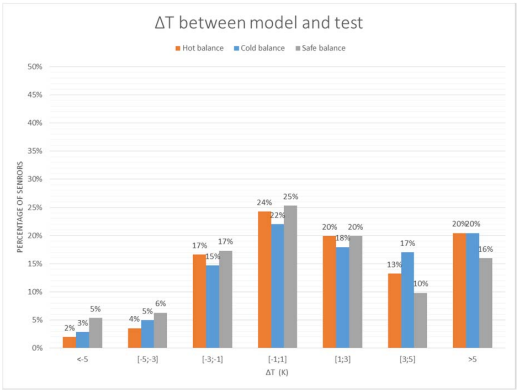
Correlation – Final status

- Status of the temperature deviations after correlation in **Steady State**:

Before correlation



After correlation



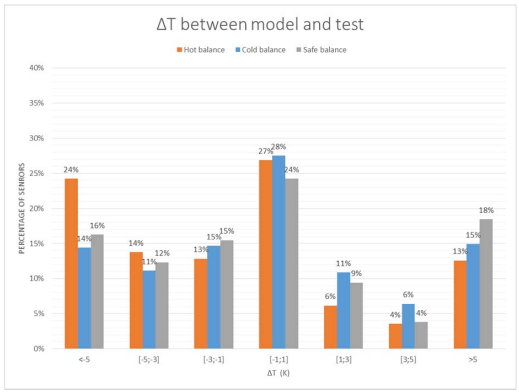
- High deviations (> 5K) are due to the fixed heater power (steady state)
- TRPs are correlated well, while graphs include the 600 TCs

MTG-STM correlation

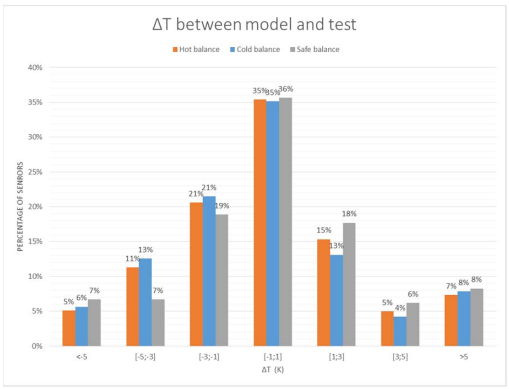
Correlation – Final status

- Status of temperature deviations after correlation in **Transient**:

Before correlation



After correlation

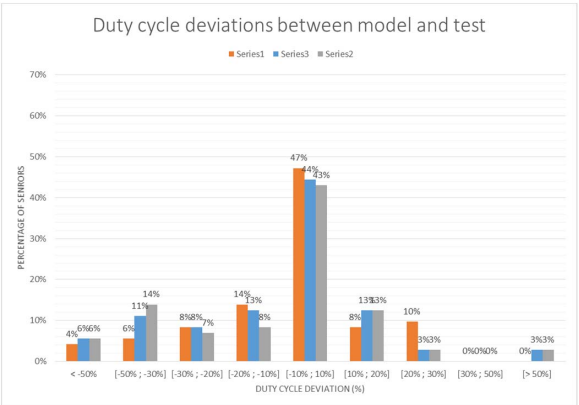


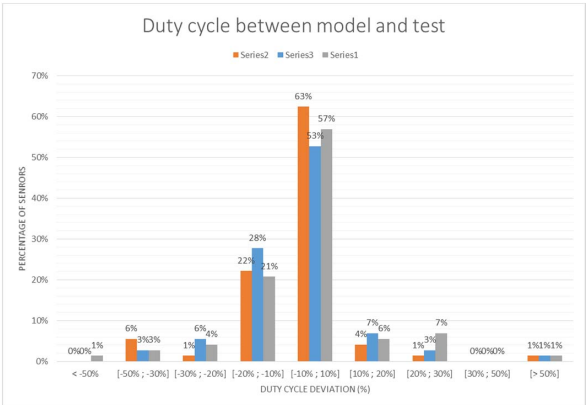
- TRPs are correlated well, while graphs include the 600 TCs

MTG-STM correlation

Correlation – Final status

- Status of duty cycles deviations after correlation in **Transient**:





Lessons learnt

- Test LL:
  - Instrumentation: piping, panels outer side, doubler I/F, panels
  - Online Data verification: deviation between shunt boxes and power supply raw data
- Correlation LL:
  - Underestimation of some parameters: Star tracker conductivity, Tanks I/F conductivity, piping model
  - Sensitivity analysis is impacted by correlation: tanks were not sensitive to platform parameter variation before correlation ; this changed after improvement of the model
- Design LL implemented on Flight Models
  - Crimping points of the propulsion tubing heater to be reviewed
  - Design changes needed for mission critical issues (tanks heaters)
  - Heat pipe start-up heaters to be implemented

Conclusion

- Manual correlation quite heavy, but “hands-on” work allows:
  - Consolidating the knowledge of sensitivity to various parameters
  - Keeping parameters within control and understanding (realistic approach of the values’ adjustment, investigation on hardware, etc.)
  - Identification of design improvements and reviewing the model in deep details
- Suggestions for ESATAN functions or improvement to help correlation:
  - Interpolation tool with sensor coordinates as an input
  - Visualization of the sensors temperatures and deltas to model predictions on the GMM (by creating a TMD from test data)