

Simposio de Tecnología Aeroespacial y Nuclear

Organizado por X-Plan S.R.L. y Siemens Digital Industries Software



SATELLOGIC THERMAL DESIGN FLOW, IN ORBIT VERIFICATION AND VALIDATION STRATEGY USING SPACE SYSTEMS THERMAL AND TMG CORRELATION TOOL

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Satellogic, Buenos Aires, Argentina



Agenda

1. Corporate Presentation
2. Satellogic Thermal Design Flow based on the use of Space Systems Thermal
3. In Orbit Verification & Validation Strategy
4. Space Systems Thermal CAD, FEM and SIM files flow
5. Thermal Model Correlation using Maya TMG Correlation Tool

| Corporate Presentation

PROVEN LEADERSHIP

Emiliano Kargjeman



CEO & Founder

25+ years developing technology and tech companies, including Core Security Technologies, Garage Lab, and Aconcagua Ventures as well as consulting for corporations and government agencies.

Gerardo Richarte

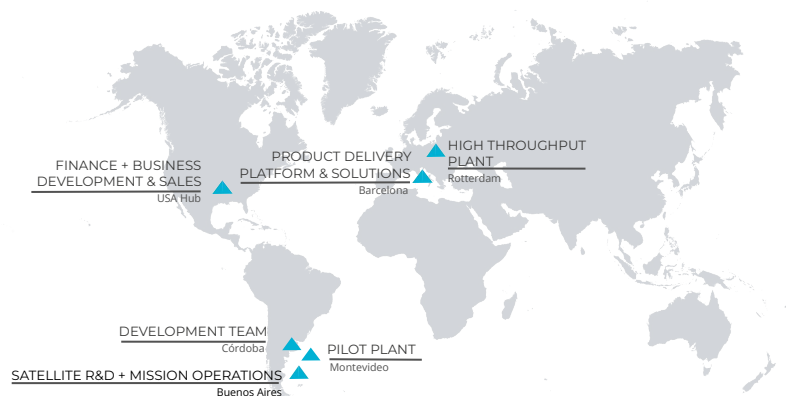


CTO

25+ years leading technology labs and research teams, co-founding tech firms as well as consulting for enterprise tech and governments agencies

GLOBAL FOOTPRINT

- Founded in 2010**
- 400+ member distributed team across 10+ countries**



CONSTELLATION DEPLOYMENT

34

Satellites Launched
(3 early prototypes +
31 NewSats)

26

Operational
satellites in orbit

4

Satellites under
integration process

INTELLECTUAL PROPERTY

23

Granted
patents

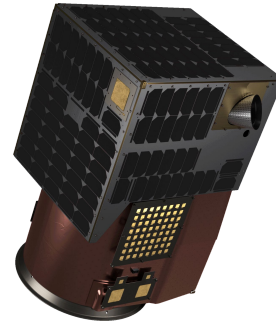
46

Pending
applications

20+

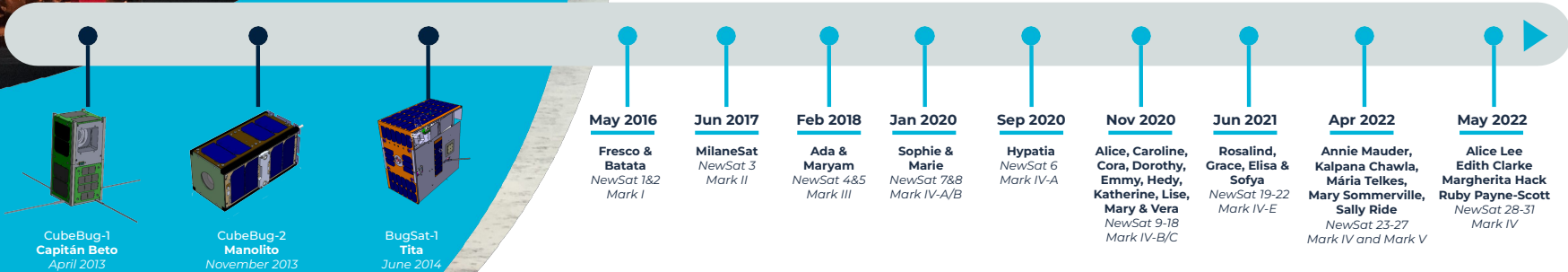
Inventions in
pipeline





- ▶ 34 **satellites** launched
26 **operational satellites** in orbit
- ▶ 100% **satellite deployment**
success rate

A history of success and technological evolution



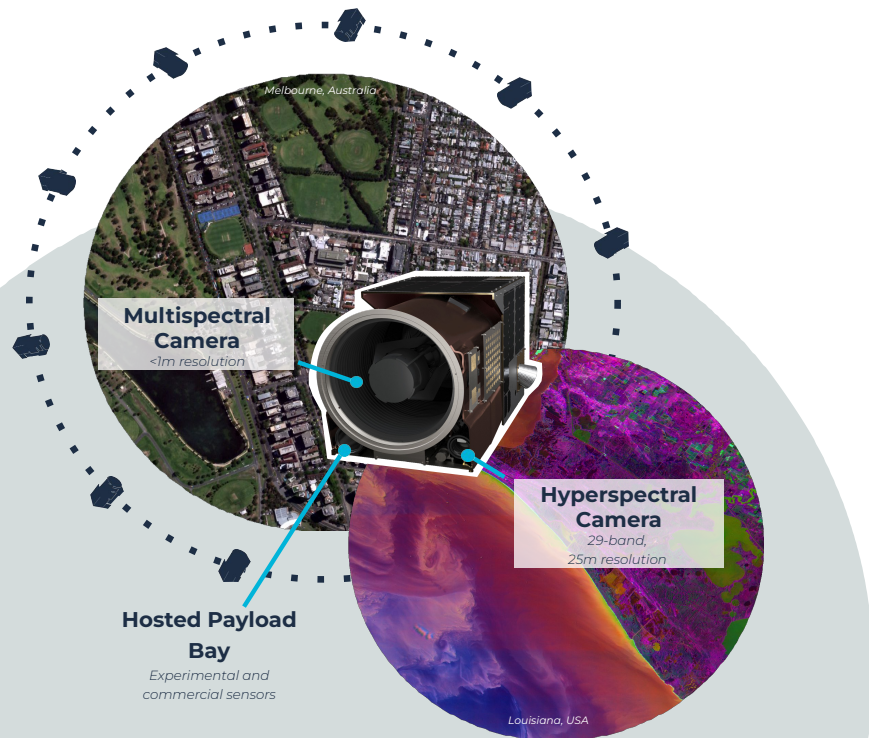
3 prototypes launched and tested successfully



OUR
PILOT
PLANT



- ▶ Located in Zonamerica, the first Free Trade Zone in **Uruguay**
- ▶ **833 sq mt** manufacturing plant **Class**
- ▶ **100,000 / ISO 8** cleanroom **Lean**
- ▶ **Manufacturing** Methodology



NewSat Design: MASS: ~40 kg | LEO SSO: ~475 km | LIFETIME: 3-4 YEARS

We reinvented the satellite from the ground up to create a smaller, lighter, and more cost-effective system that can be produced at scale without compromising image quality. Our constellation delivers diverse, rich geospatial data at unmatched frequency, resolution, and cost.

- ▶ **Multispectral** and **Hyperspectral** cameras
- ▶ **Full-Motion Video** capability
- ▶ **Off-nadir** capturing with +/-25° angles
- ▶ **100x more cost-efficient** than traditional satellites

CAPTURE MODES





IMAGERY

High-resolution
global captures



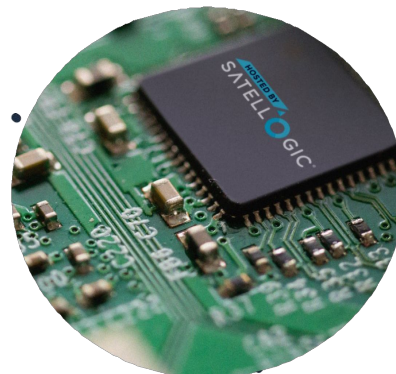
AI LAYERS

Planetary-scale
insights



**DEDICATED
SATELLITE
CONSTELLATIONS**

Satellite-as-a-service



**HOSTED
PAYLOAD**

Third-party sensor and
hardware testing



We plan to leverage our cost advantage for continuous capacity growth beyond weekly remaps

	2021	2022	2023	2024	2025+
SATELLITES IN ORBIT	17	34	63	139	202
SATELLITE CHARACTERISTICS (GSD RESOLUTION)	0.99m at 470 km	0.70m at 470 km	0.40m at 440 km		0.30m at 330 km
DAILY REVISITS OF POINTS OF INTEREST	4	7	13	28	40
PRODUCT LAUNCHES	DSC	Data Platform	Weekly World Remaps		Daily World Remaps

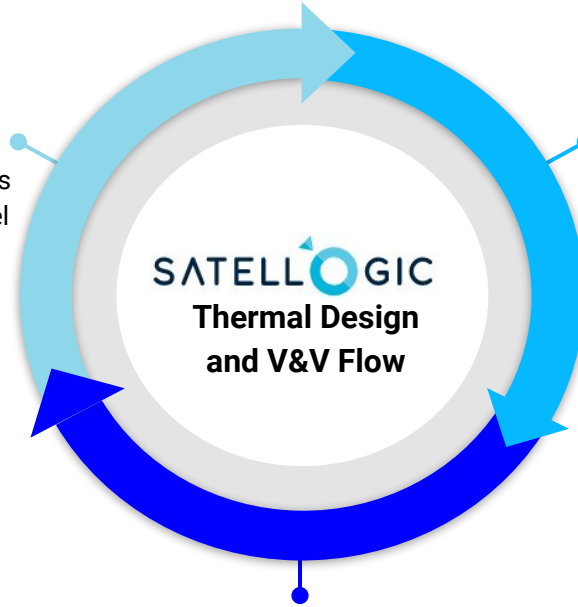


Thermal Design Flow based on the use of a Space System Thermal

Thermal Design Flow

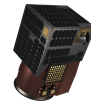
REQUIREMENTS

Thermal Requirements
Analysis Cases Requirements
Thermal Mathematical Model
Requirements



ANALYSIS VERIFICATION

Simcenter 3D



IN ORBIT VALIDATION

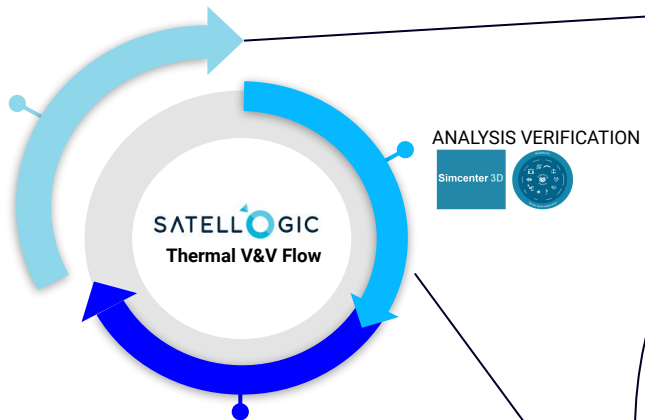
We **replace** the concept of **Thermal Model (TM)** by the **Flight Thermal Model Concept (FTM)**
Constant Telemetry Feedback

Thermal Requirements

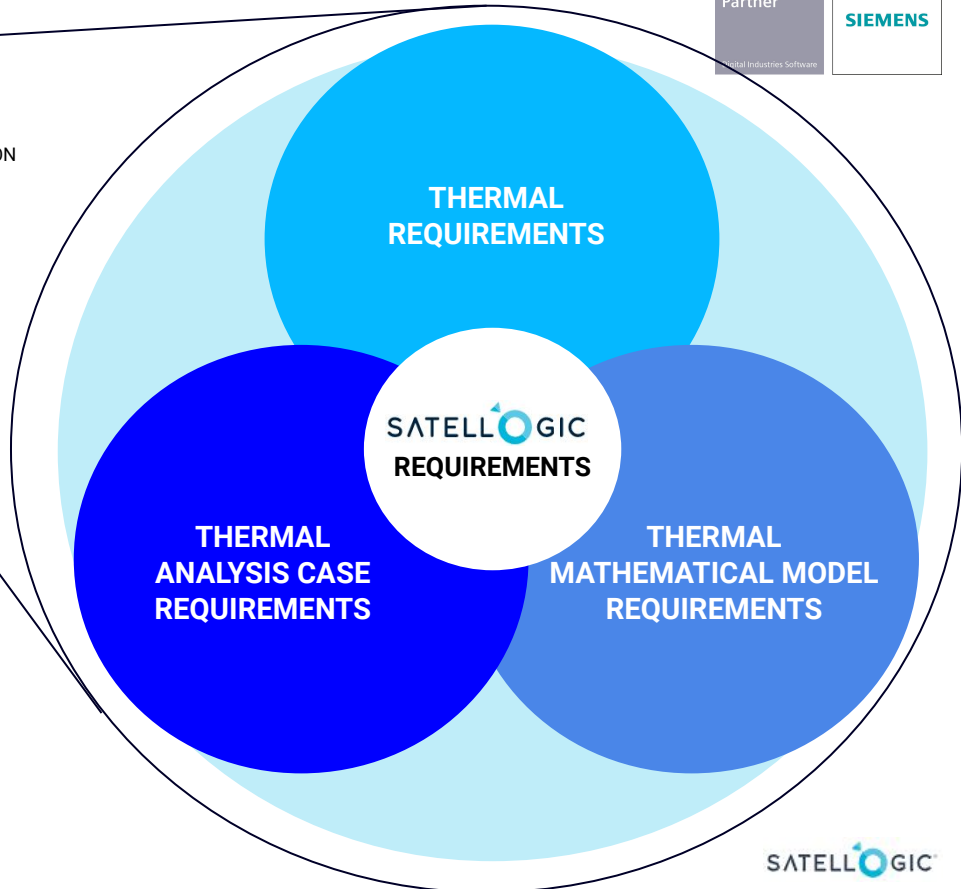


REQUIREMENTS

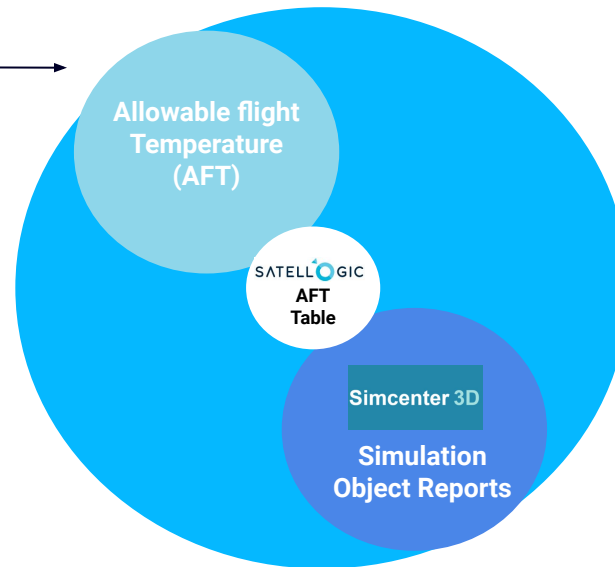
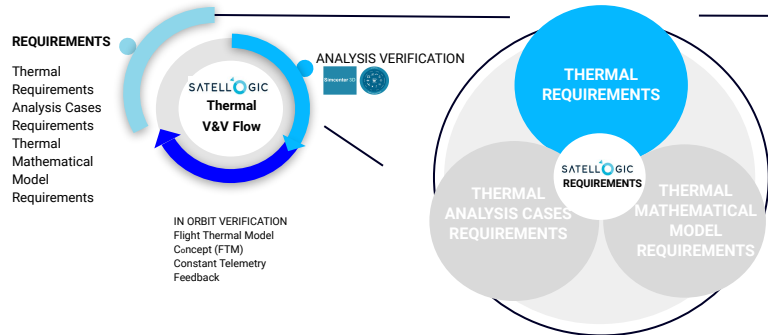
- Thermal Requirements
- Analysis Cases
- Requirements
- Thermal Mathematical
- Model Requirements



IN ORBIT VERIFICATION
Flight Thermal Model Concept (FTM)
Constant Telemetry Feedback



Thermal Requirements



Case	Device	Group Report Name Simcenter 3D	Time Cold	Time Hot	AFT min	AFT max	Min Temp	Max Temp	Design Margin Cold	Design Margin Hot	Pass Cold	Pass Hot
700012_m1Yp_0930_JS_034	Ramon	TRP_Comms_Ramon	1027	3565	0	66.2	-34.2	-27.7	-34.2	93.9	FAIL	ok!

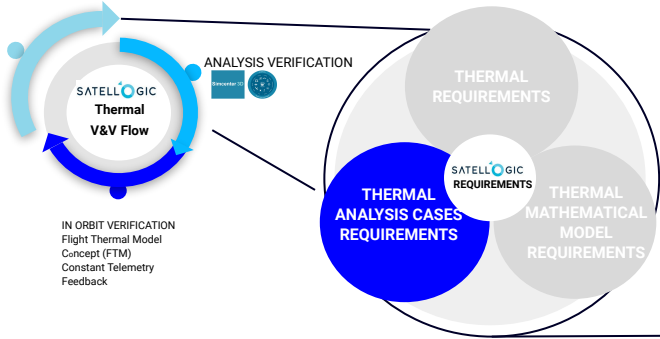
The AFT Table will be used to verify the requirements by analysis comparing the simulation object report temperature **Simcenter 3D** Vs. the AFT Table automatically

Thermal Analysis Cases Requirements



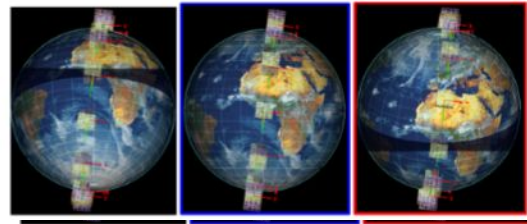
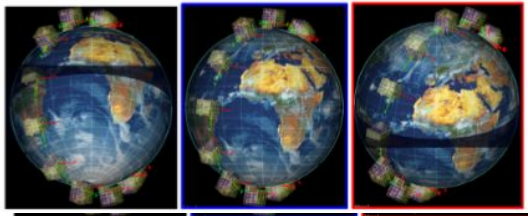
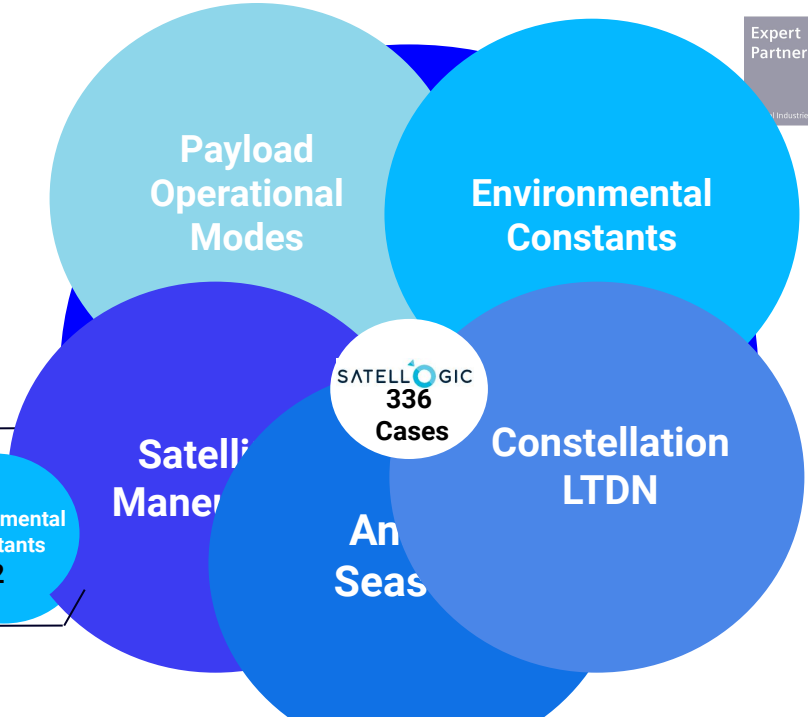
REQUIREMENTS

Thermal Requirements
Analysis Cases Requirements
Thermal Mathematical Model Requirements

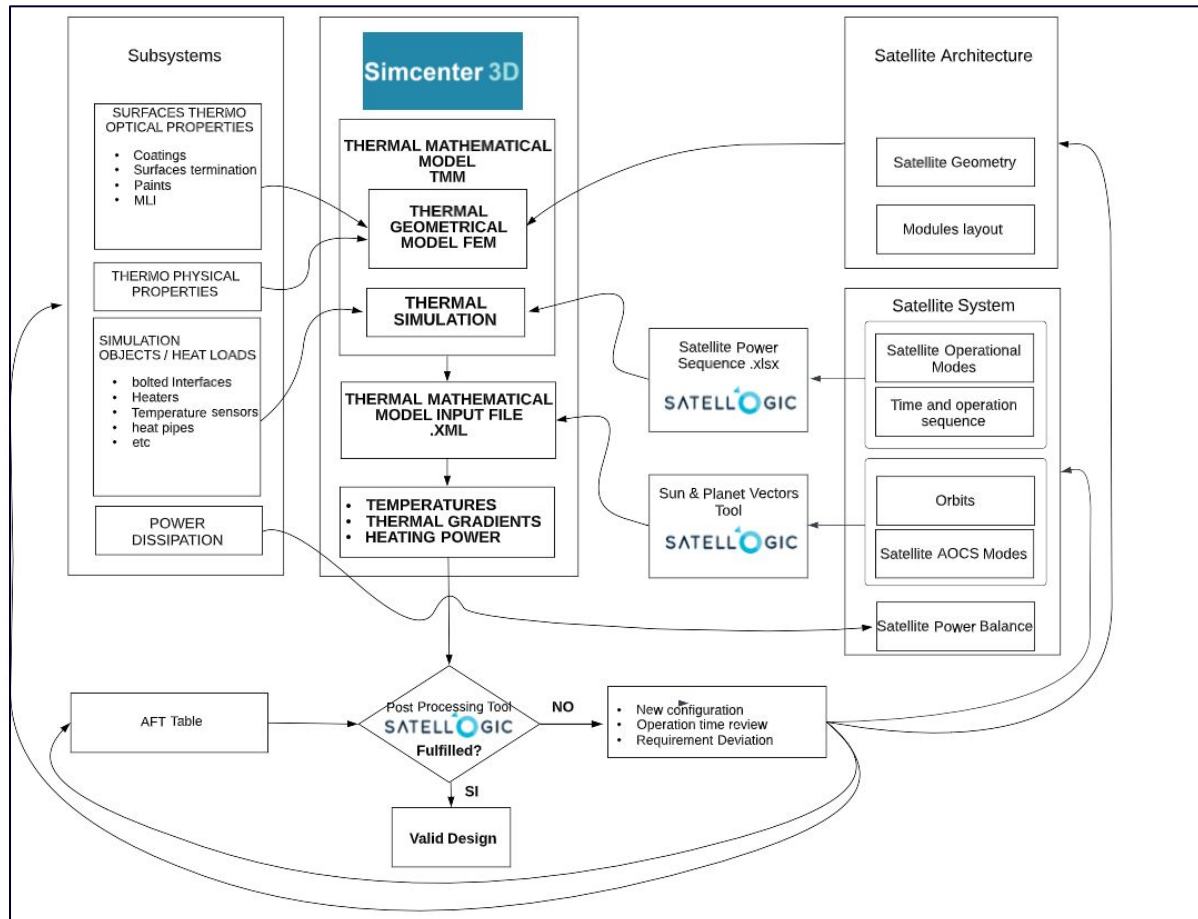


336

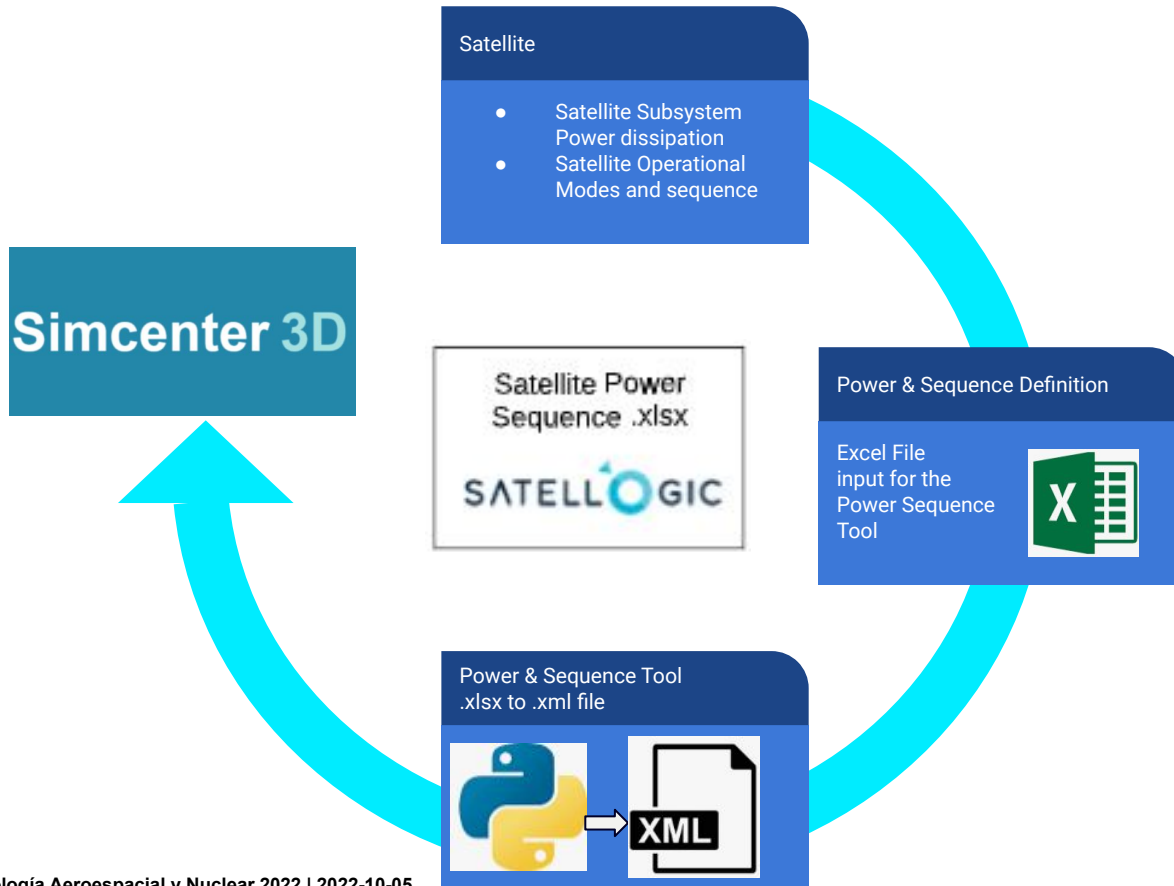
Thermal Analysis Cases



Thermal Model Requirements



Power Sequence Tool



Sun & Planet Vectors Tool



Simcenter 3D

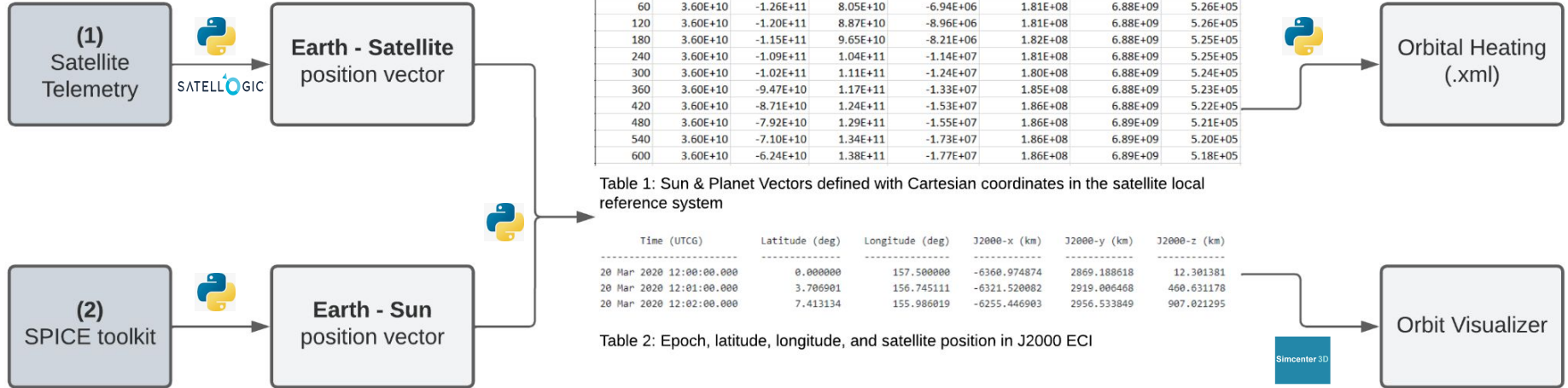
Satellogic AOCs Module
Satellite Sun & Planet Vectors for differents satellite Maneuver



Sun & Planet Vector Tool
AOCs Tool to Maya input file

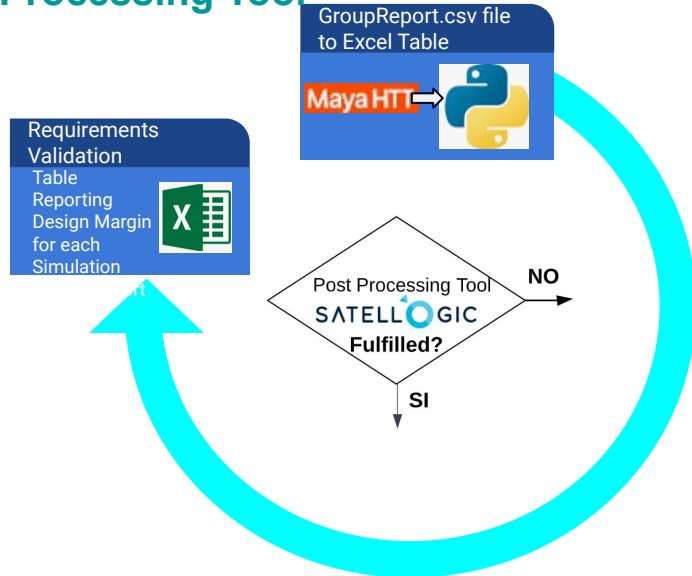
Maya input file to Maya Solver

Orbit Telemetry to Space System Thermal Tool



<https://naif.jpl.nasa.gov/naif/>

Requirements Validation Processing Tool

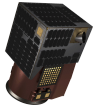
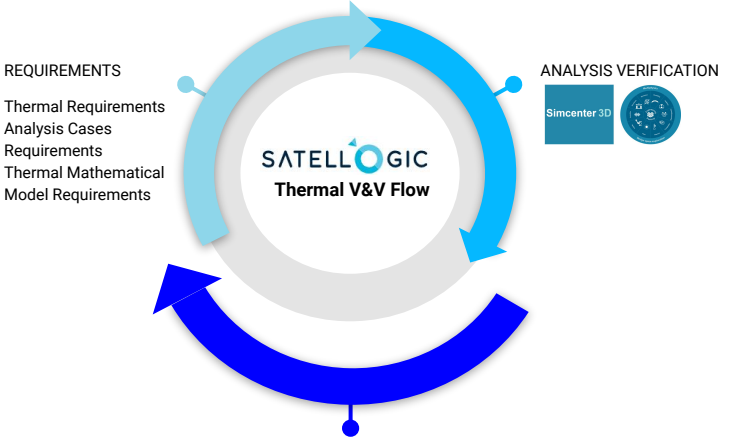


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700012_m1Yp_0930_JS_034	Ramon	TRP_Comms_Ramon	1027	3565	0	66.2	-34.2	-27.7	-34.2	93.9	FAIL	ok!

The AFT Table will be used to verify the requirements by analysis comparing the simulation object report temperature **Simcenter 3D** Vs. the AFT Table automatically

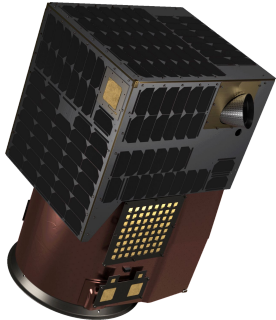
In Orbit Verification & Validation Strategy

In Orbit Verification & Validation Philosophy



IN ORBIT VALIDATION
We **replace** the concept of **Thermal Model (TM)** by the **Flight Thermal Model Concept (FTM)**
Constant Telemetry Feedback

▶ **26 Operational satellites**

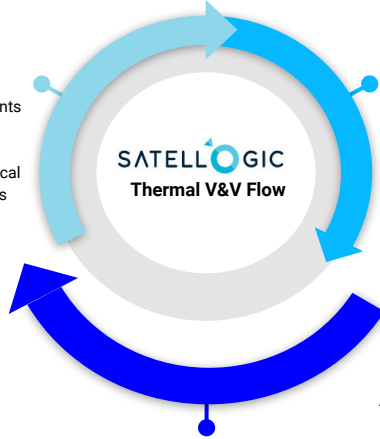


▶ **FTM** Flight thermal Model

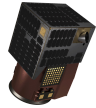
In Orbit Verification & Validation Philosophy



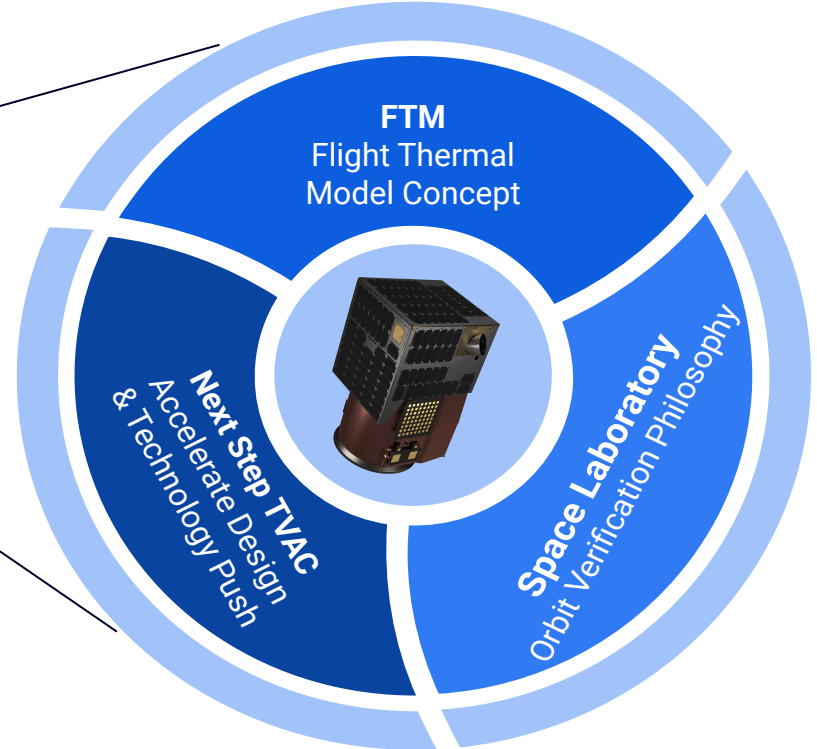
REQUIREMENTS
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Thermal Mathematical
Model Requirements



ANALYSIS VERIFICATION
Simcenter 3D



IN ORBIT VALIDATION
We **replace** the concept of **Thermal Model (TM)**
by the **Flight Thermal Model Concept (FTM)**
Constant Telemetry Feedback



In Orbit Verification & Validation Philosophy



**Maximum
Technology Push**

Space Laboratory - No TVAC Test in the AIT Flow

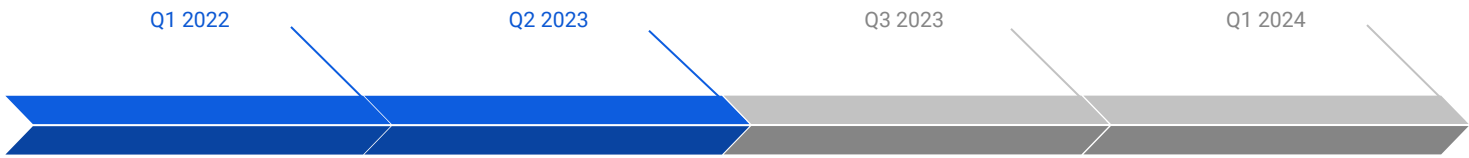
- No TVAC Test in the AIT Flow allows us:
- **Decreasing the cost per Satellite**
 - **Increasing the velocity of production**
 - **Cheaper FTM**

Space Laboratory - FTM Flight Thermal Model Concept

- Using the Space as a Laboratory allows:
- **Fast Design interaction with Flight**
 - **Increasing the Technology Push**
 - **Strong TMM models and Thermal Engineering**
 - **Test New Thermal HW**
 - **Constant Research**

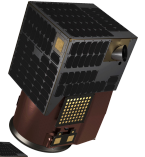
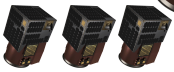
Next Step

Experimental TVAC between Launches



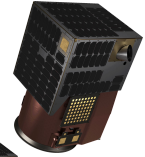
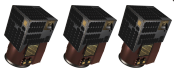
MK4G FTM

4 MK4

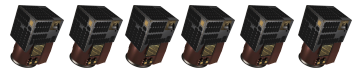


MK5C FTM

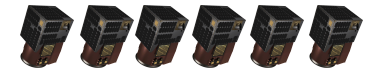
4 MK5C



6 MK5C



6 MK5C



Space Systems Thermal CAD, FEM and SIM files flow

Thermal Model Requirements Implementation. Files and procedure. *Introduction*

Parameters Management

Thermal_Couplings.xlsx



CC.exp

Thermo_Optical_prop.xlsx



TO.exp

PW_Condition_Sequence.xlsx



PW_Seq.xml

Allowable_Flight_Temp.xlsx

CAE Thermal Discipline

Global_Parameters.prt



Material_Library.xml



CAD Mechanical Discipline

Module 1

M1_p1.prt
M1_p2.prt
M1_ASM.prt

Module 2

M2_p1.prt
M2_p2.prt
M2_p3.prt
M2_ASM.prt

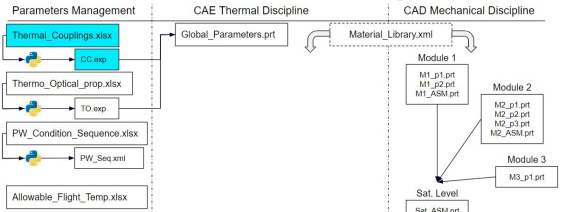
Module 3

M3_p1.prt

Sat. Level

Sat_ASM.prt

Thermal Model Requirements Implementation. Thermal Couplings.



CC.exp file

Summary

Thermal Couplings Log

Thermal

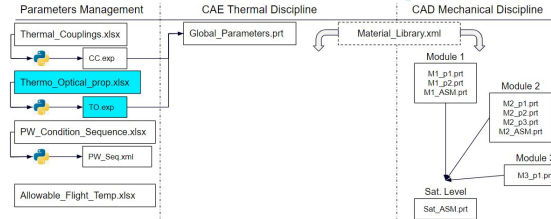
Thermal Couplings Summary

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4  [dc/W]CC_STR_1CFT_2ATTR=0.2472297902008
5  [dc/W]CC_MIC_1MSTG_2PZT=2.26072362346442
6  [dc/W]CC_MIC_1FSTG_2MOT=4.24412390502321
7  [W/m-dc]CC_MIC_1FSTG_2STRIP=1.434782086069565
8  [dc/W]CC_MIC_1STG_2RAIL=0.425638615551834
9  [dc/W]CC_MIC_1RAIL_2RAIL=5.91426
10 [dc/W]CC_MIC_1FSTG_2ENCH=14.0998908565659
11 [dc/W]CC_MIC_1STG_2ENCI=5.54847309776768
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13 [dc/W]CC_MIC_1MSTG_X_2TA=0.108901256639182
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15 [dc/W]CC_MIC_1TA_2PCB3=3.3104853046586
16 [dc/W]CC_MIC_1TA_2VITA=3.31998137324886
17 [dc/W]CC_MIC_1TA_2GMAX=1.23415039920392
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19 [dc/W]CC_MIC_1BASE_2MSTG_Z=14.9828153564319
20 [dc/W]CC_MIC_1SUP_2BASE=5.61172586888283
21 [dc/W]CC_MIC_1FLEX_CABLE_2CONN=15.1983051886687
22 [dc/W]CC_PCB3_IU4_J_2U4_B=6.14
23 [dc/W]CC_PCB3_IU7_C_2U7_B=7.3
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25 [dc/W]CC_PCB3_IU20_C_2U20_B=3.15581854043393
26 [dc/W]CC_PCB3_IU10_C_2U10_B=19.7120949074074
27 [dc/W]CC_PCB3_IU25_C_2U25_B=19.7120949074074
28 [dc/W]CC_BAP_1TA2_2CUBE=0.357142857142857
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30 [dc/W]CC_BAP_1TA2_2PCB2=23.389553296213
31 [dc/W]CC_BAP_1TA2_2PCB1=21.3638739251
32 [dc/W]CC_BAP_1TA1_2PCB1=26.5544102582383
33 [dc/W]CC_BAP_1TA1_2PCB2=496.204466024483
34 [dc/W]CC_BAP_1PCB1_2SATA_STOF=59.6501846515917
35 [dc/W]CC_BAP_1PCB1_2SATA_CONN=37.5324881401078
36 [dc/W]CC_BAP_1PCB1_2PCB2_CONN=42.867772013767
37 [dc/W]CC_BAP_1PCB1_2Q7_STOF=52.7369993508332
38 [dc/W]CC_BAP_1PCB1_2Q7_CONN=26.4366742158157
    
```

N	O	P	Q
Model #1 (Detailed)			
	Correction Factor	Used value	Global Param. Formula
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2.604	1	1.736	[dc/W]CC_STR_1CFT_2TAK_SUP=1.73629197485849
0.371	1	0.247	[dc/W]CC_STR_1CFT_2ATTR=0.2472297902008
3.391	1	2.261	[dc/W]CC_MIC_1MSTG_2PZT=2.26072362346442
6.366	1	4.244	[dc/W]CC_MIC_1FSTG_2MOT=4.24412390502321
0.717	1	1.435	[W/m-dc]CC_MIC_1FSTG_2STRIP=1.434782086069565
0.638	1	0.426	[dc/W]CC_MIC_1STG_2RAIL=0.425638615551834
22.500	0.394	5.914	[dc/W]CC_MIC_1RAIL_2RAIL=5.91426
21.138	1	14.091	[dc/W]CC_MIC_1FSTG_2ENCH=14.0998908565659
8.323	1	5.548	[dc/W]CC_MIC_1STG_2ENCI=5.54847309776768
1.624	0.394	0.427	[dc/W]CC_MIC_1FSTG_2MSTG=0.426872457951268
0.163	1	0.109	[dc/W]CC_MIC_1MSTG_X_2TA=0.108901256639182
0.176	1	0.117	[dc/W]CC_MIC_1MSTG_X_2TA_S2p1=0.117178842128528
123.466	1	82.310	[dc/W]CC_PCB3_IU4_J_2U4_B=6.14
4.980	1	3.320	[dc/W]CC_PCB3_IU7_C_2U7_B=7.3
1.851	1	1.234	[dc/W]CC_PCB3_IU6_C_2U6_B=2.56410256410256
1.624	0.394	0.427	[dc/W]CC_PCB3_IU20_C_2U20_B=3.15581854043393
15.596	1.409	14.983	[dc/W]CC_PCB3_IU10_C_2U10_B=19.7120949074074
8.418	1	5.612	[dc/W]CC_BAP_1TA2_2CUBE=0.357142857142857
22.797	1	15.198	[dc/W]CC_BAP_1CUBE_2TA_HP=0.37593984962406
6.447	1	6.140	[dc/W]CC_BAP_1TA2_2PCB2=23.389553296213
9.125	1	7.300	[dc/W]CC_BAP_1TA2_2PCB1=21.3638739251
3.205	1	2.564	[dc/W]CC_BAP_1TA1_2PCB1=26.5544102582383
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			[dc/W]CC_BAP_1PCB1_2Q7_CONN=26.4366742158157

Thermal Model Requirements Implementation. Thermo Optical Properties.



TO.exp file

```

1 |TO_SS_Machined_A=0.47
2 |TO_SS_Machined_E=0.14
3 |TO_Vel_Blak_A=0.99
4 |TO_Vel_Blak_E=0.95
5 |TO_Aeroglace_Z306_A=0.95
6 |TO_Aeroglace_Z306_E=0.9
7 |TO_Silver_CVD_A=0.04
8 |TO_Silver_CVD_E=0.02
9 |TO_Al_polished_A=0.14
10 |TO_Al_polished_E=0.03
11 |TO_Al_heavily_oxidized_A=0.13
12 |TO_Al_heavily_oxidized_E=0.3
13 |TO_Alodyne_Al12024_A=0.373
14 |TO_Alodyne_Al12024_E=0.09
15 |TO_Alodyne_Al16061_A=0.373
16 |TO_Alodyne_Al16061_E=0.09
17 |TO_Electrodag_501_A=0.965
18 |TO_Electrodag_502_E=0.829
19 |TO_Graphite_Epoxy_A=0.903
20 |TO_Graphite_Epoxy_E=0.857
21 |TO_RT_duroid_5880_A=0.78
22 |TO_RT_duroid_5880_E=0.9
23 |TO_PCB_SM_on_Cu_A=0.62
24 |TO_PCB_SM_on_Cu_E=0.84
25 |TO_PCB_SM_on_core_A=0.81
26 |TO_PCB_SM_on_core_E=0.9
27 |TO_ENTG_A=0.23
28 |TO_ENTG_E=0.03
29 |TO_Invar_A=0.2
30 |TO_Invar_E=0.09
31 |TO_Kapton_3mil_A=0.46
32 |TO_Kapton_3mil_E=0.81
33 |TO_Kapton_foil_on_Al_A=0.482
34 |TO_Kapton_foil_on_Al_E=0.87
35 |TO_Black_Anodized_A=0.86
36 |TO_Black_Anodized_E=0.86
37 |TO_MLI_eff_CFRP_E=0.01
38 |TO_MLI_eff_SP_E=0.01
    
```

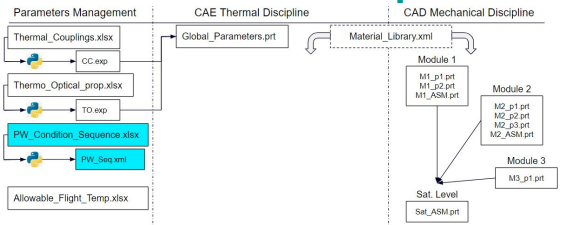
Properties Summary

	G	H	I	J	K	L	M	N
		Select	State	Model #1 (Detailed)				
		BOL	EOC	Correction Factor	Used value	Global Param.	Formula	
Coupling name	Units	Value	BOL	EOC				
Machined_A		0.470	0.470	0.140	1	0.470	TO_SS_Machined_A=0.47	
Machined_E		0.140	0.140	0.140	1	0.140	TO_SS_Machined_E=0.14	
Blak_A		0.990	0.990	0.990	1	0.990	TO_Vel_Blak_A=0.99	
Blak_E		0.950	0.950	0.950	1	0.950	TO_Vel_Blak_E=0.95	
oglace_Z306_A		0.950	0.950	0.950	1	0.950	TO_Aeroglace_Z306_A=0.95	
oglace_Z306_E		0.900	0.900	0.900	1	0.900	TO_Aeroglace_Z306_E=0.9	
ver_CVD_A		0.040	0.040	0.040	1	0.040	TO_Silver_CVD_A=0.04	
ver_CVD_E		0.020	0.020	0.020	1	0.020	TO_Silver_CVD_E=0.02	
polished_A		0.140	0.140	0.140	1	0.140	TO_Al_polished_A=0.14	
polished_E		0.030	0.030	0.030	1	0.030	TO_Al_polished_E=0.03	
heavily_oxidized_A		0.130	0.130	0.130	1	0.130	TO_Al_heavily_oxidized_A=0.13	
heavily_oxidized_E		0.300	0.300	0.300	1	0.300	TO_Al_heavily_oxidized_E=0.3	
Alodyne_Al12024_A		0.373	0.373	0.373	1	0.373	TO_Alodyne_Al12024_A=0.373	
Alodyne_Al12024_E		0.090	0.090	0.090	1	0.090	TO_Alodyne_Al12024_E=0.09	
Alodyne_Al16061_A		0.373	0.373	0.373	1	0.373	TO_Alodyne_Al16061_A=0.373	
Alodyne_Al16061_E		0.090	0.090	0.090	1	0.090	TO_Alodyne_Al16061_E=0.09	
Electrodag_501_A		0.965	0.965	0.965	1	0.965	TO_Electrodag_501_A=0.965	
Electrodag_502_E		0.829	0.829	0.829	1	0.829	TO_Electrodag_502_E=0.829	
Graphite_Epoxy_A		0.903	0.903	0.903	1	0.903	TO_Graphite_Epoxy_A=0.903	
Graphite_Epoxy_E		0.857	0.857	0.857	1	0.857	TO_Graphite_Epoxy_E=0.857	
RT_duroid_5880_A		0.780	0.780	0.780	1	0.780	TO_RT_duroid_5880_A=0.78	
RT_duroid_5880_E		0.900	0.900	0.900	1	0.900	TO_RT_duroid_5880_E=0.9	
PCB_Solder_Mask_over_copper foil		0.620	0.620	0.620	1	0.620	TO_PCB_SM_on_Cu_A=0.62	
PCB_Solder_Mask_over_copper foil		0.840	0.840	0.840	1	0.840	TO_PCB_SM_on_Cu_E=0.84	
PCB_Solder_Mask_over_copper foil		0.810	0.810	0.810	1	0.810	TO_PCB_SM_on_core_A=0.81	
PCB_Solder_Mask_over_copper foil		0.900	0.900	0.900	1	0.900	TO_PCB_SM_on_core_E=0.9	

Thermo Optical properties log

Thermo Optical properties Summary

Thermal Model Requirements Implementation. PW Conditions Sequence.



Conditions (Operational modes) PW Seq.xml

Conditions

		AY	AZ	BA	BB	BC	BO	BE	BF
1	Parameter								
2	Parameter								
3	Parameter								
4	Parameter								
5	Parameter								
6	Parameter								
7	Parameter								
8	Parameter								
9	Parameter								
10	Parameter								
11	Parameter								
12	Parameter								
13	Parameter								
14	Parameter								
15	Parameter								
16	Parameter								
17	Parameter								
18	Parameter								
19	Parameter								
20	Parameter								
21	Parameter								
22	Parameter								
23	Parameter								
24	Parameter								
25	Parameter								
26	Parameter								
27	Parameter								
28	Parameter								
29	Parameter								
30	Parameter								
31	Parameter								
32	Parameter								
33	Parameter								
34	Parameter								
35	Parameter								
36	Parameter								
37	Parameter								

Sequence



```

1 <?xml version="1.0" encoding="UTF-8"?>
2
3 <ConditionSequenceExport version="1.0">
4   <ConditionSequences>
5     <ConditionSequence label="1" name="Automatic Sequence" units="Second">
6       <Description>
7         <Line>Data Source: budget</Line>
8         <Line>Condition Sequence: MaDb-RiDb-J95-2HB_n</Line>
9       </Description>
10      <TimeStep>
11        <Description></Description>
12        <Time>0</Time>
13        <Condition>6</Condition>
14      </TimeStep>
15      <TimeStep>
16        <Description></Description>
17        <Time>815</Time>
18        <Condition>6</Condition>
19      </TimeStep>
20      <TimeStep>
21        <Description></Description>
22        <Time>820</Time>
23        <Condition>34</Condition>
24      </TimeStep>
25      <TimeStep>
26        <Description></Description>
27        <Time>875</Time>
28        <Condition>34</Condition>
29      </TimeStep>
30      <TimeStep>
31        <Description></Description>
32        <Time>880</Time>
33        <Condition>35</Condition>
34      </TimeStep>
35      <TimeStep>
36        <Description></Description>
37        <Time>1595</Time>
    
```

Thermal Model Requirements Implementation. Files and procedure.

Import Expression

Parameters Management

Thermal_Couplings.xlsx



CC.exp

Thermo_Optical_prop.xlsx



TO.exp

PW_Condition_Sequence.xlsx



PW_Seq.xml

Allowable_Flight_Temp.xlsx

CAE Thermal Discipline

Global_Parameters.prt

Name	Formula	Value	Units	Dimension
Default Group			mm	Length
TO_Properties				
TO_Aeroglace_Z306_A	0.95	0.95		
TO_Alodine_1500_A	0.3	0.3		
TO_Alodine_1500_E	0.06	0.06		
TO_Alodyme_Al2024_A	0.373	0.373		
TO_Alodyme_Al2024_E	0.09	0.09		
TO_Alodyme_Al6061_A	0.373	0.373		
TO_Alodyme_Al6061_E	0.09	0.09		
TO_ANT_HBR_A	0.678181818181818	0.6781818182		
TO_ANT_HBR_E	0.738942148760331	0.7389421488		
TO_ANT_LBR_A	0.620228708979918	0.620228709		

Ctrl+E → open Expression Editor

→ Import Expressions
→ Select *.exp file

CAD Mechanical Discipline

Material_Library.xml

Module 2

M2_p1.prt
M2_p2.prt
M2_p3.prt
M2_ASM.prt

Module 3

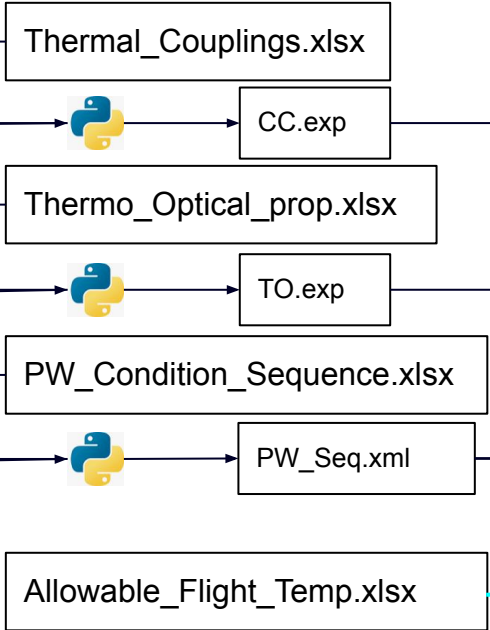
M3_p1.prt

Thermal Model Requirements Implementation. Files and procedure.

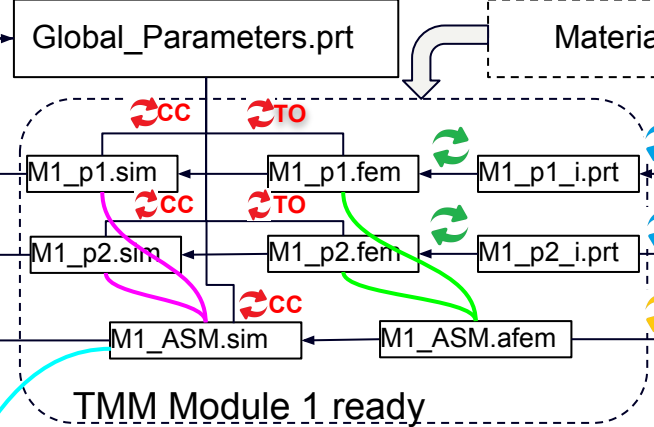
Procedure for one Module



Parameters Management

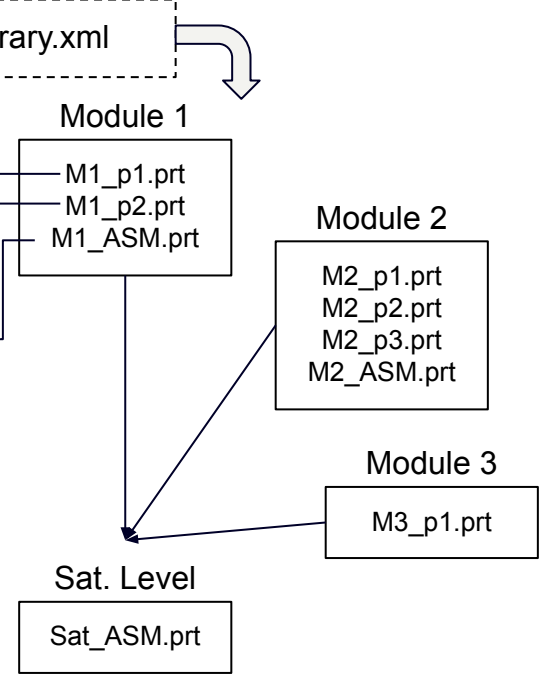


CAE Thermal Discipline

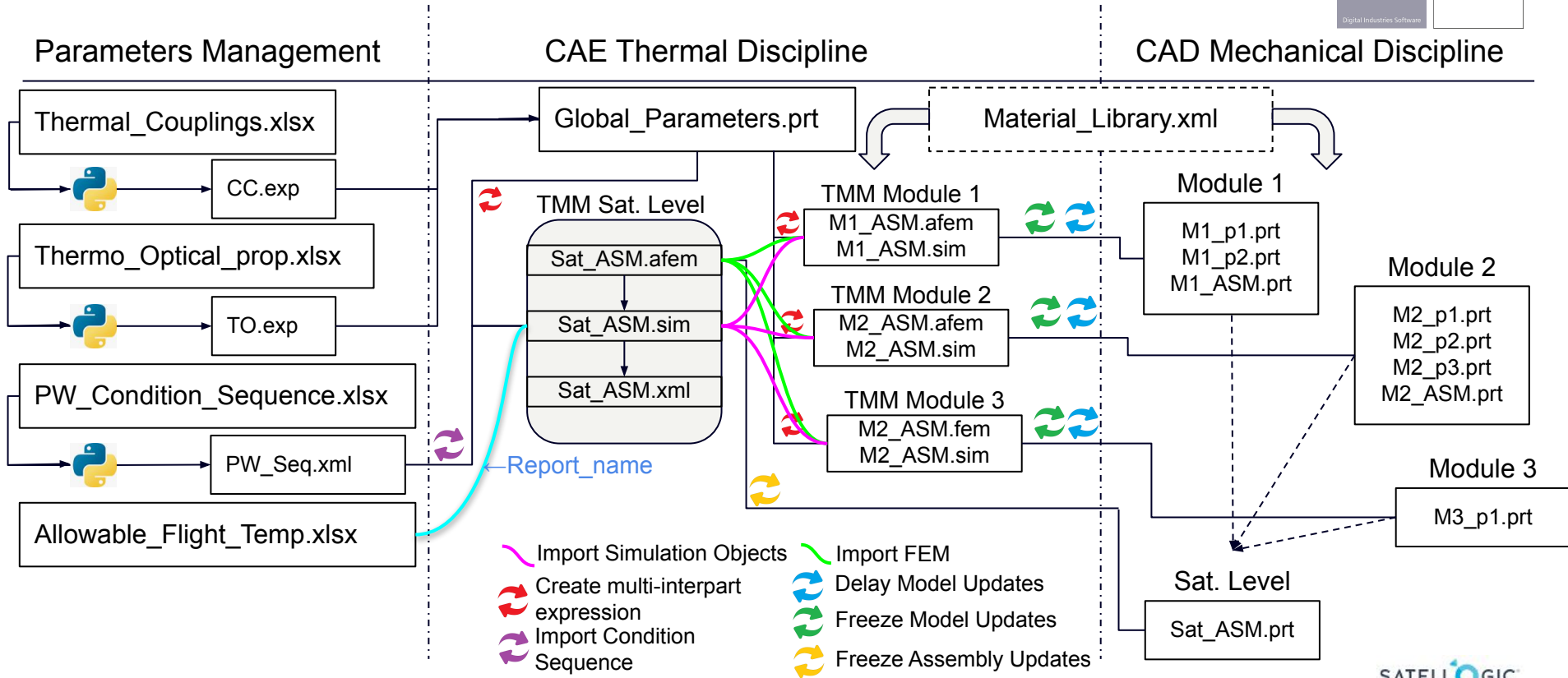


- Import Simulation Objects
- Create multi-interpart expression
- Import Condition Sequence
- Import FEM
- Delay Model Updates
- Freeze Model Updates
- Freeze Assembly Updates

CAD Mechanical Discipline



Thermal Model Requirements Implementation. Files and procedure.

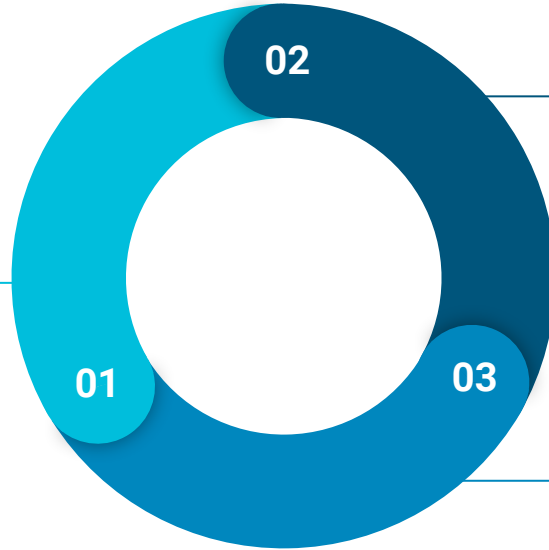
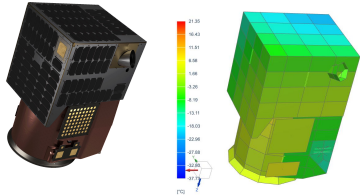


Thermal Model Correlation using Maya TMG Correlation Tool

Thermal Model Correlation using Maya TMG Correlation Tool

The Thermal model correlation is performed in three steps:

Not Correlated Model versus Orbit Telemetry



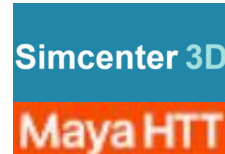
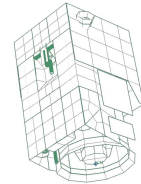
Radiation Correlation α and ϵ

Simulation file .sim
hand correlated



Conductive Correlation Tool

Simulation file .sim
TMG Correlation Tool



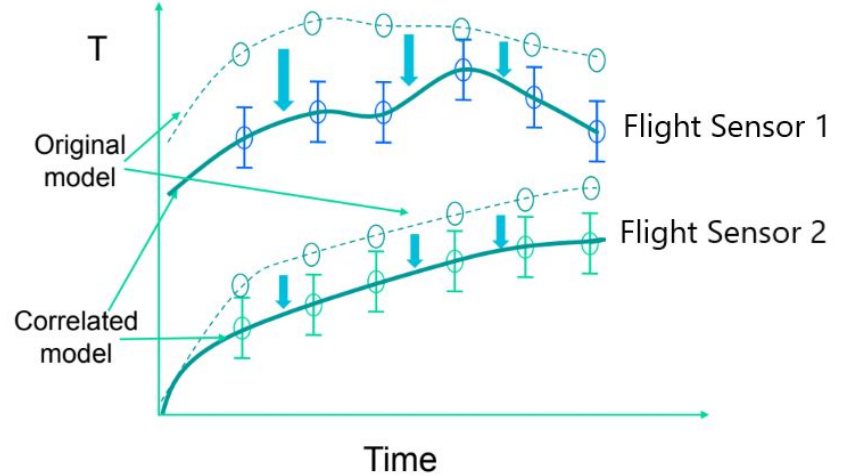
Thermal Model Correlation using Maya TMG Correlation Tool

For a set of **design variables D**, the error at each measurement point is expressed as

$$\epsilon_i = \underbrace{T_i^{model}(\vec{D})}_{\text{From TMG}} - T_i^{data}$$

A well correlated model minimizes the **functional**

$$f(\vec{D}) = \sum_{i=1}^{N_T} W_i \epsilon_i^2$$



Where N_T is the total number of data points collected and W_i is some weighting factor.

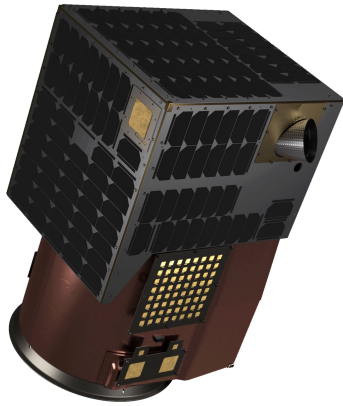
A gradient based method can be used to minimize the error function $f(\vec{D})$.
Once the gradient \vec{G} is calculated, the design variables are updated:

$$\vec{D}^{new} = \vec{D}^{old} - \alpha \vec{G}$$

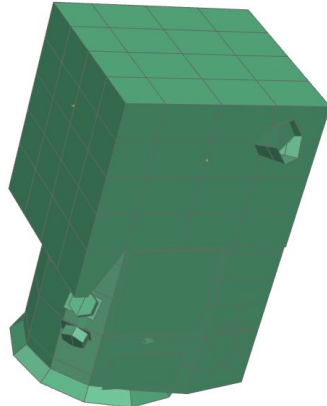
Thermal Model Correlation using Maya TMG Correlation Tool

- **33** Flight thermal sensors telemetry to correlate
- **50** conductive design variables to adjust
- Objective Function **0.5**
- **1316** nodes – conduction/radiation
- **Design Variable Multiplier Criteria. Multiplied Factor result = Min. 0.02 Max. 8.74**
- Correlation at **3** time steps, **1440s, 2820s, 4260s**
- TMG Correlation Tool perform the conductive correlation in **4 minutes**

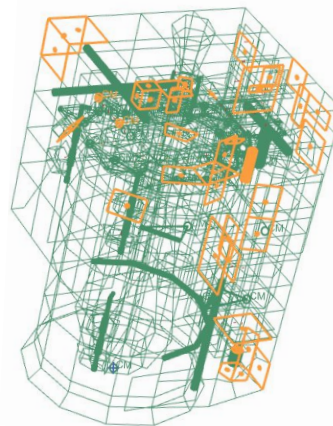
$$F = \sqrt{\frac{1}{N_{times} \times N_{targets}} \times \sum_{times} \left(\sum_{target} (T - T_{target})^2 \right)}$$



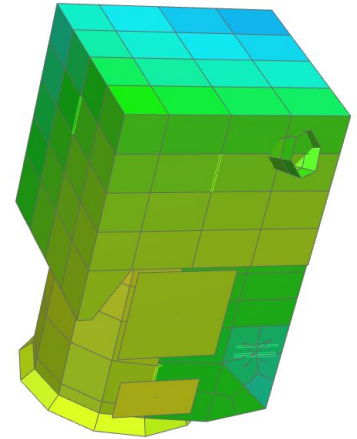
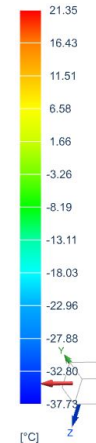
NewSat Satellite



NewSat FEM



NewSat Sensors

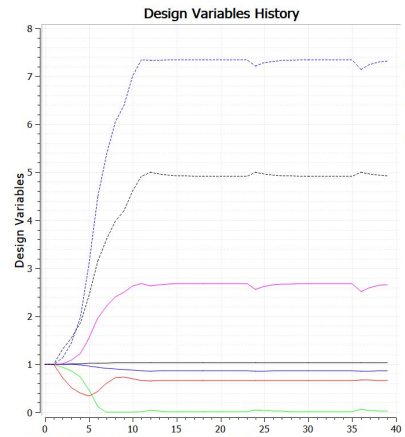
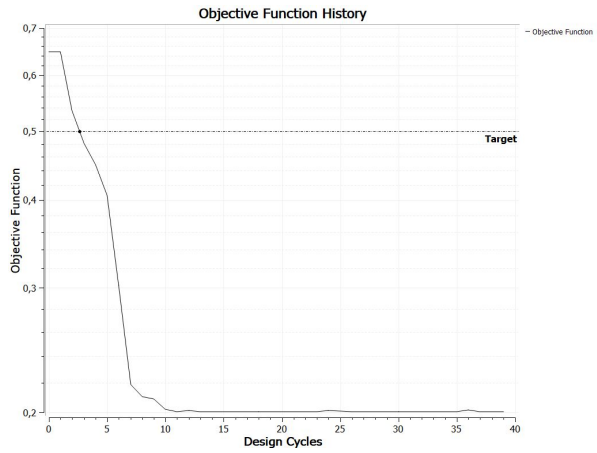


Thermal Model Correlation using Maya TMG Correlation Tool



Objective Function and Design Variables Convergence example

$$F = \sqrt{\frac{1}{N_{times} + N_{targets}} \times \sum_{times} \left(\sum_{target} (T - T_{target})^2 \right)}$$

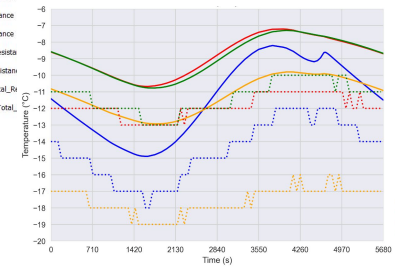


Thermal Correlation Summary:

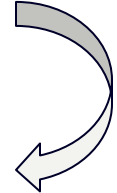
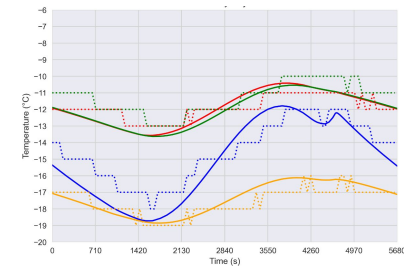
Final objective function 0.2004E+00
 Number of design cycles 39

DESIGN VARIABLE NAME	VALUE
CC_Macro_RadiatorYm_01_Total_Resistan	0.1035E+01
CC_Macro_RadiatorYm_02_Total_Resistan	0.8608E+00
CC_Macro_RadiatorYm_03_Total_Resistan	0.1956E-01
CC_SopMacroTIR_RadiatorZp_Total_Resi	0.2658E+01
CC_RadiatorZp_Ym_JoyCam_Total_Resist	0.6654E+00
CC_SopMacroTIR_Atachment_Ring_Total	0.4925E+01
MA_CC_PLMacro_Support_MacroBAP_Total	0.7313E+01

Not correlated Model



Conduction Correlation Tool



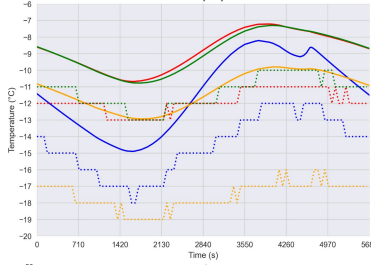
Thermal Correlation Sensors		
Sensor Name	Temperature Difference	Temperature
"TC_2271"	0.4504E+00	-0.1245E+02
"TC_2269"	0.5685E+00	-0.1557E+02
"TC_2149"	0.3409E+00	-0.1634E+02
"TC_17002"	0.4879E-01	-0.1505E+02
"TC_16001"	0.1887E+00	-0.1181E+02
"TC_16006"	0.7460E+00	-0.1725E+02
"TC_16009"	0.9536E-01	-0.1190E+02
"TC_2241"	0.1987E+00	-0.1980E+02

Thermal Model Correlation using Maya TMG Thermal Correlation Tool

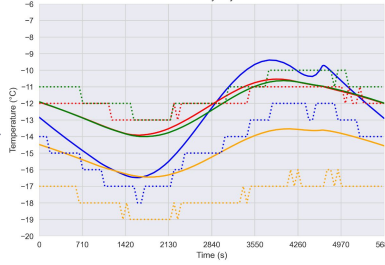


Secondary Payload

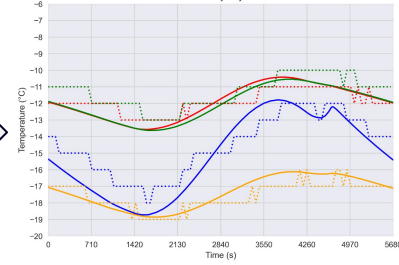
Not Correlated Model



Radiation Correlation



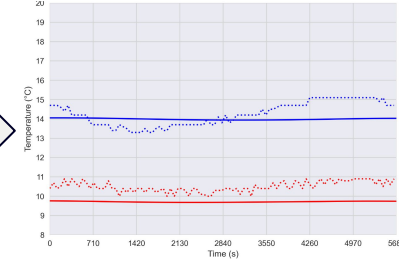
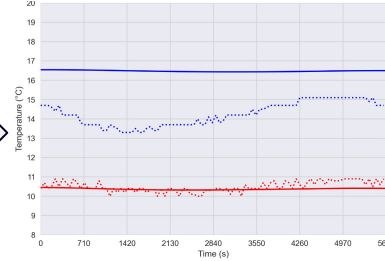
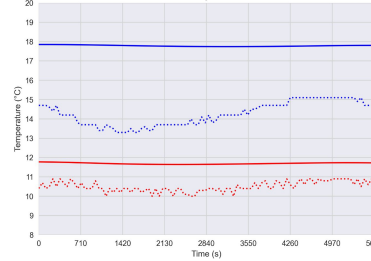
Conduction Correlation Tool



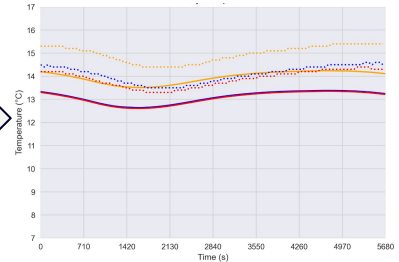
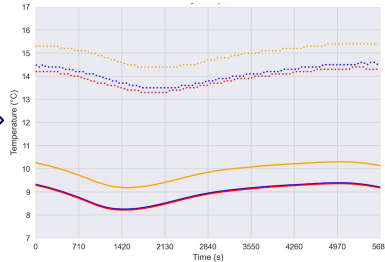
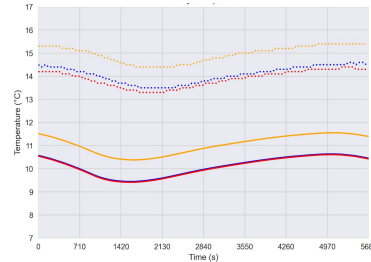
Thermal Model Not Correlated

Thermal Orbit Telemetry

Battery Pack



Gyroscopes

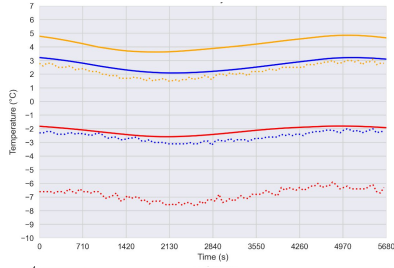


Thermal Model Correlation using Maya TMG Thermal Correlation Tool

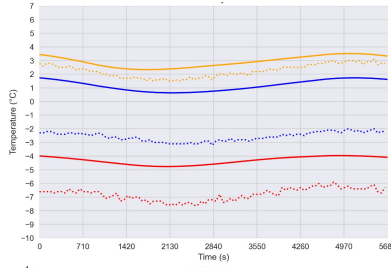


Micro Payload

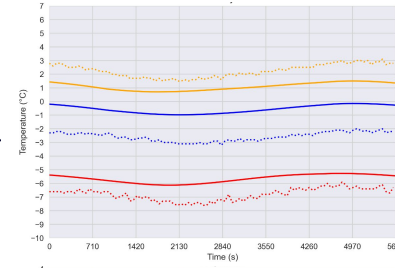
Not Correlated Model



Radiation Correlation



Conduction Correlation Tool

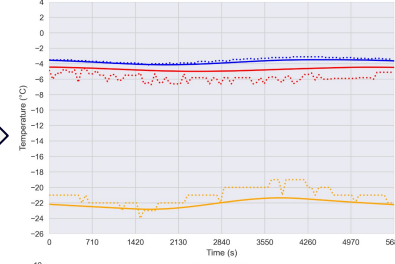
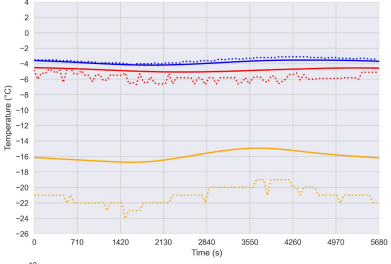
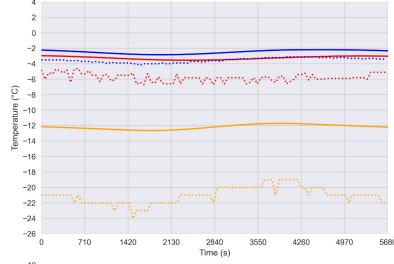


Thermal Model Not Correlated

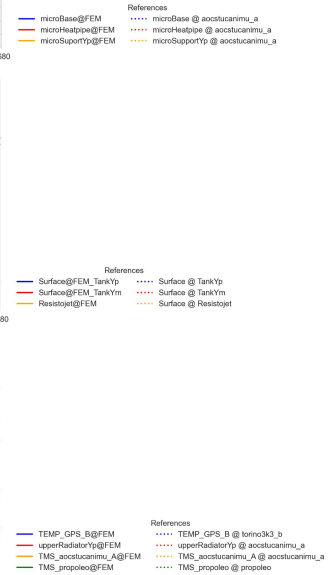
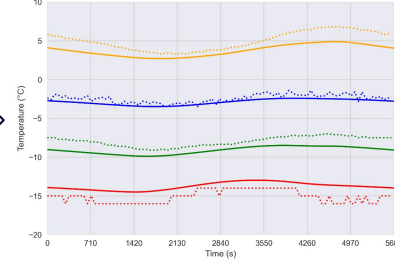
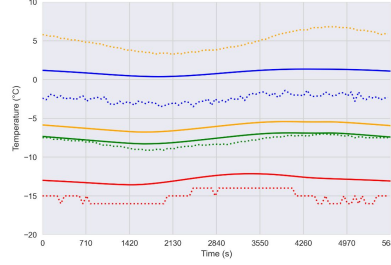
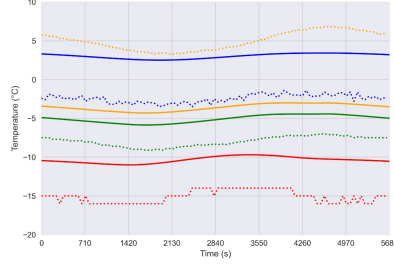
Thermal Orbit Telemetry



Propulsion Set

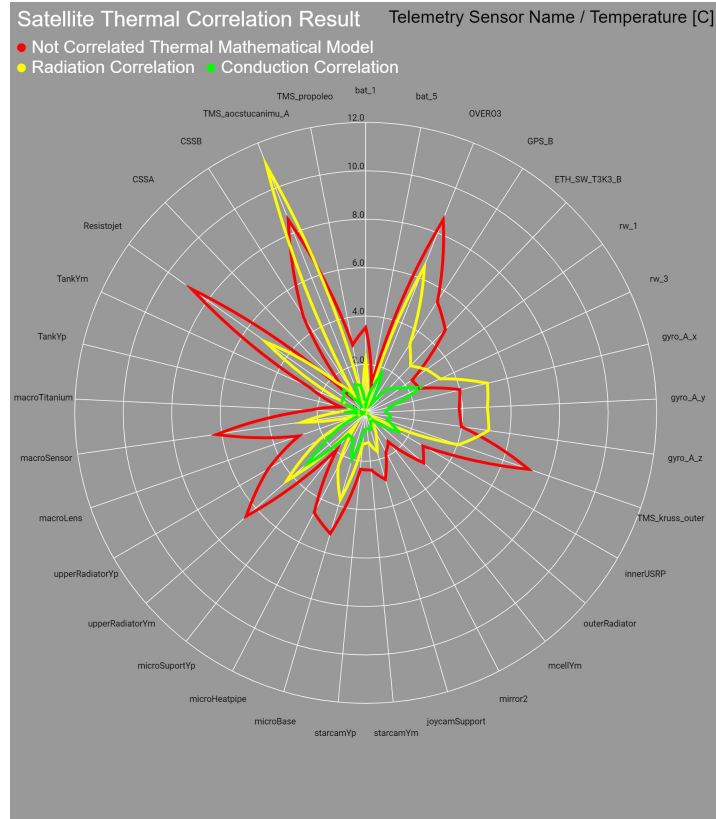


Electronic Rack



Satellite Thermal Correlation Final Temperature Error

- **Not Correlated TMM**
- **Radiation Correlation**
- **Conduction Correlation Tool**



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Leader

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