



Technische Universität München



University of
Strathclyde

Advanced Space
Concepts Laboratory

New Methodologies for the Thermal Modelling of CubeSats

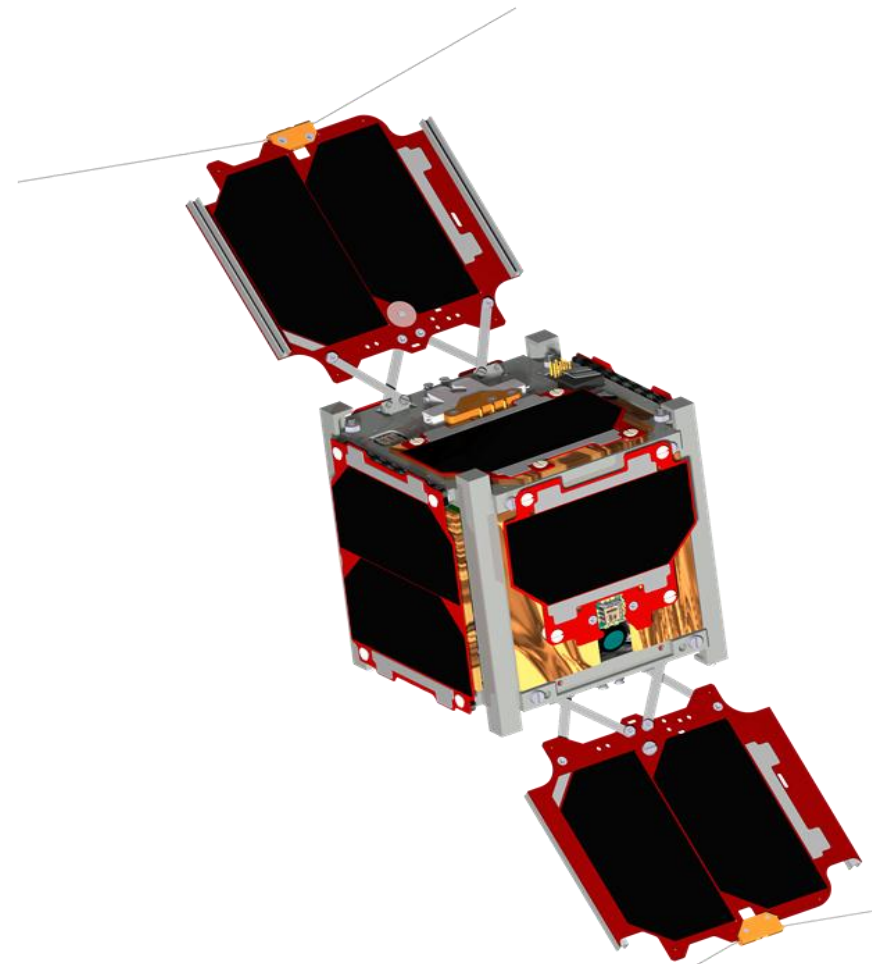
Philipp Reiss

15 August 2012 | Small Satellites Conference | Logan (Utah), USA

Why do we need Thermal Analysis for CubeSats?

Thermal characteristics of CubeSats

- . Few **space-qualified** components
 - > Narrow operational temperature range
- . Highly **integrated** electronics
 - > High internal heat loads
- . **Surface** covered with solar panels
 - > Given surface properties (thermal control)
- . Low Earth **Orbit**
 - > High number of thermal cycles
- . Limited attitude **control**
 - > Limited pointing variation (thermal control)



How can we perform Thermal Analysis for CubeSats?

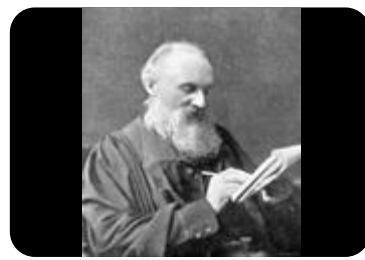
Thermal Software

Conventional

Is designed for conventional larger s/c



Requires experience and practise

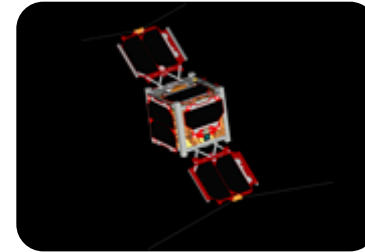


Requires expensive licenses



What if... CubeSat-specific

Specialized on CubeSat configurations



Easy to use



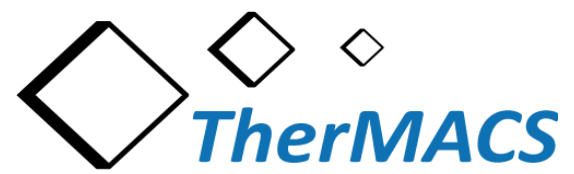
Freely available



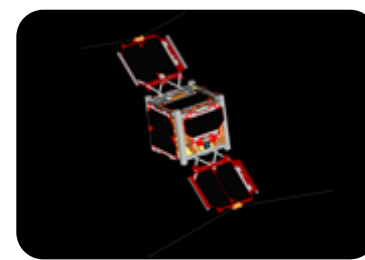
Thermal Software

This work:

Development of the
CubeSat-specific thermal analysis tool



What if... **CubeSat-specific**



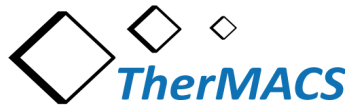
Specialized on CubeSat configurations



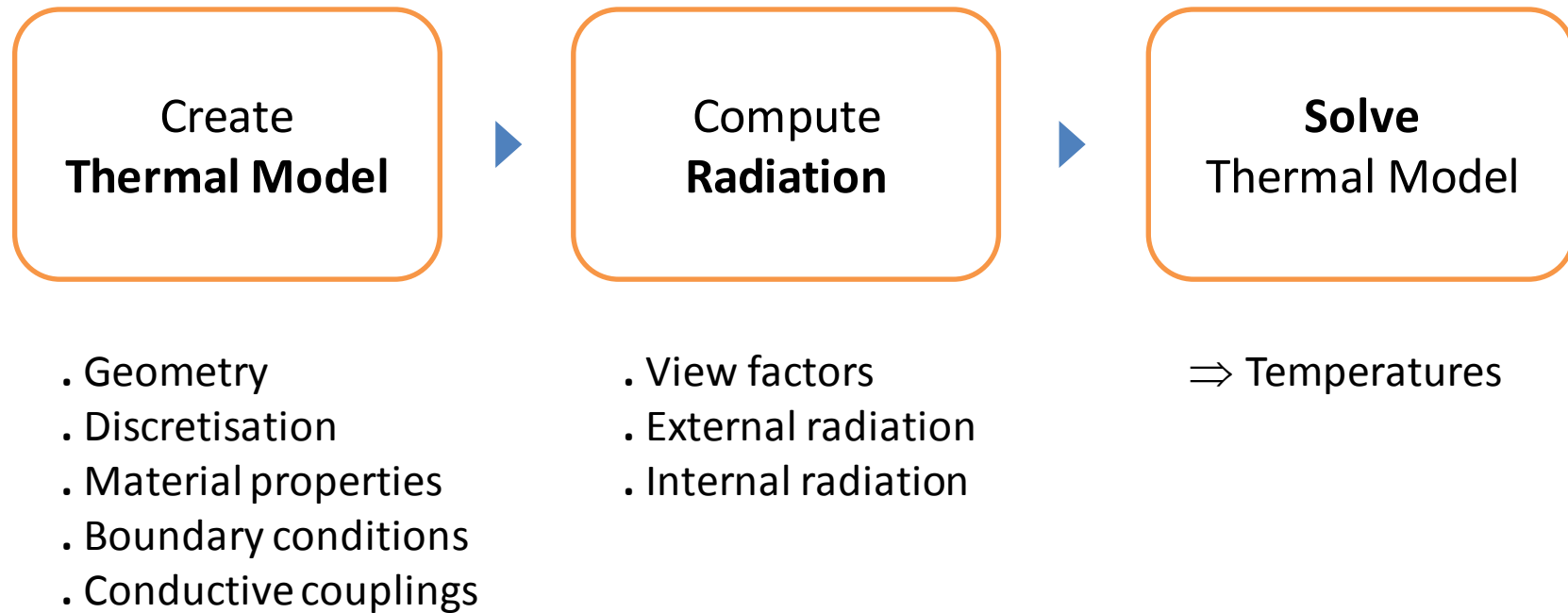
Easy to use

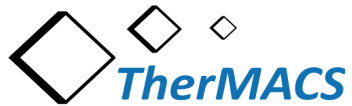


Freely available

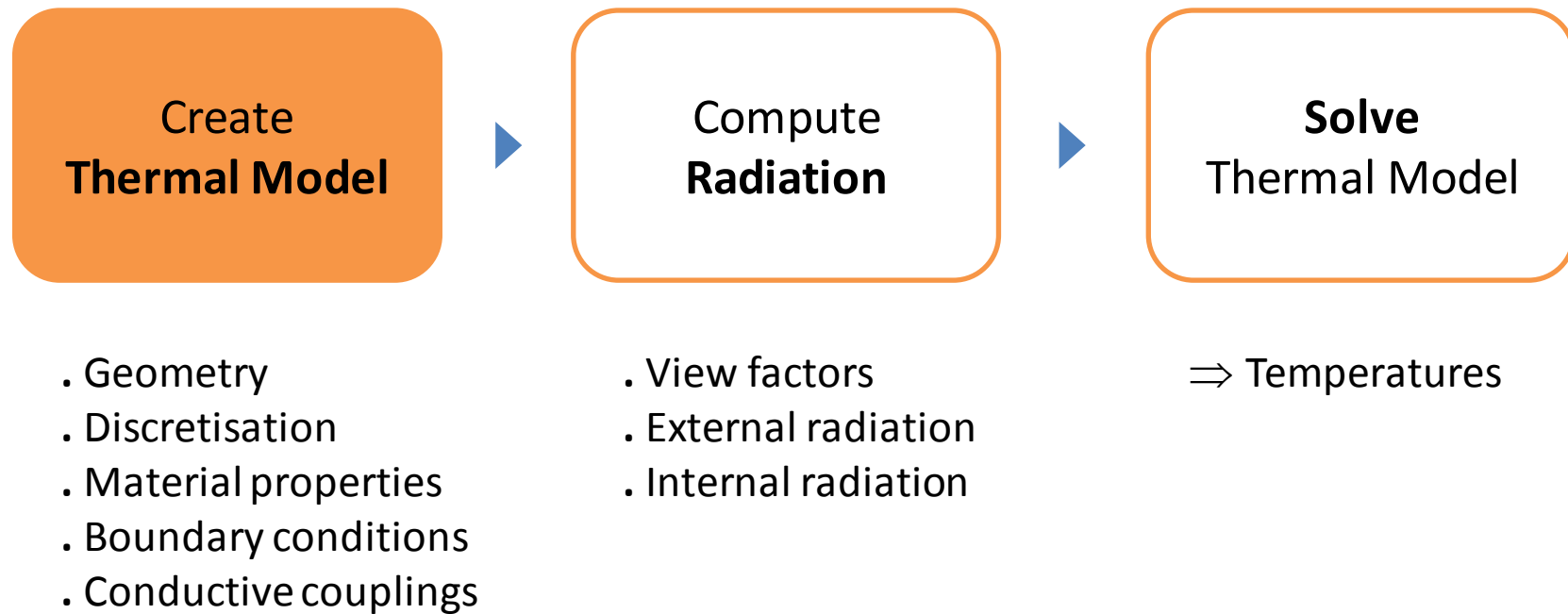


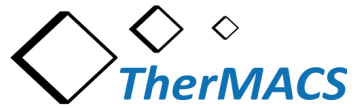
General Concept





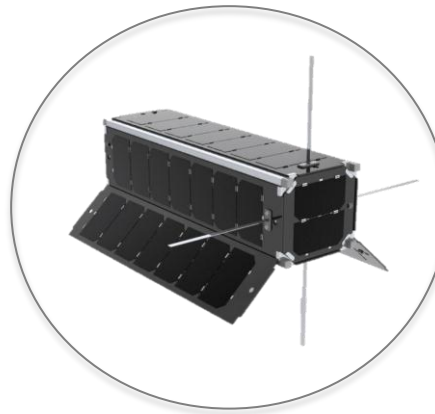
General Concept

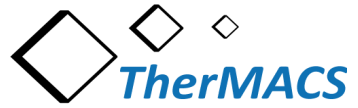




Thermal Model

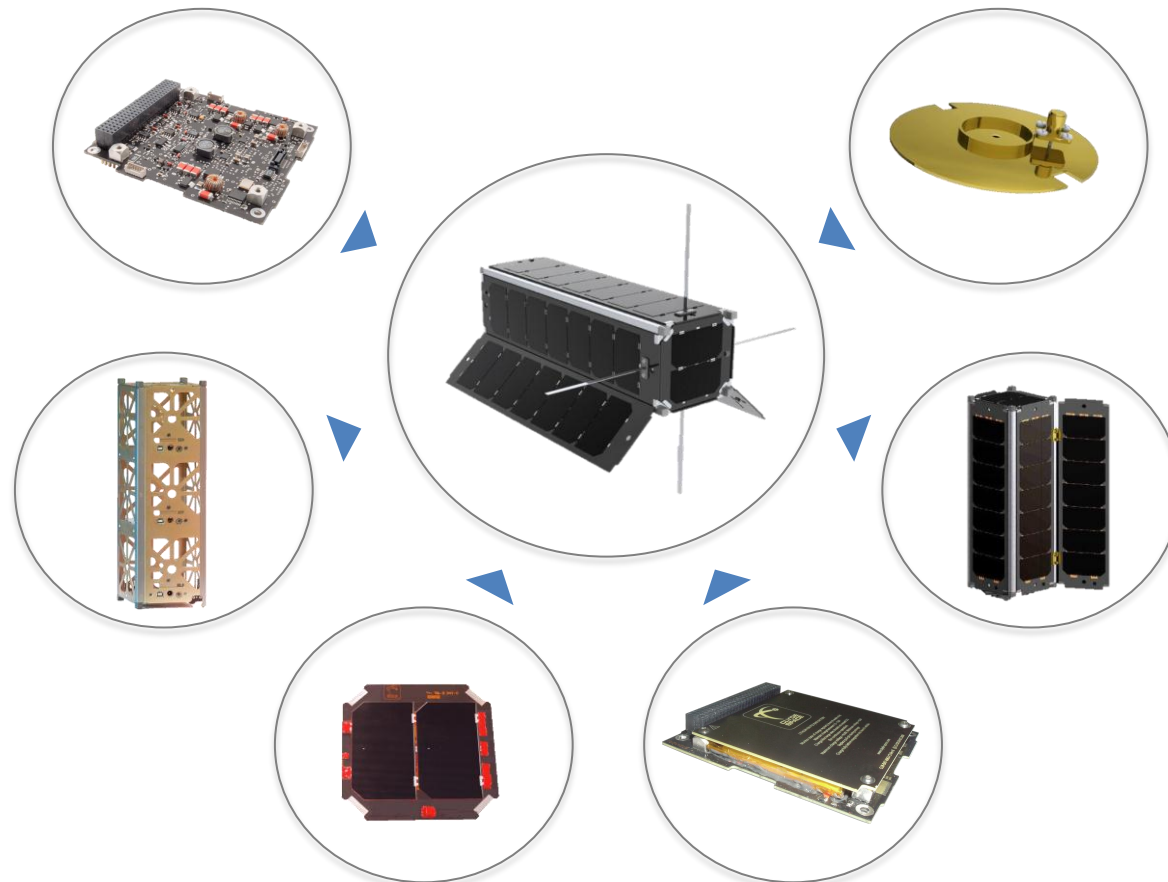
CubeSat approach





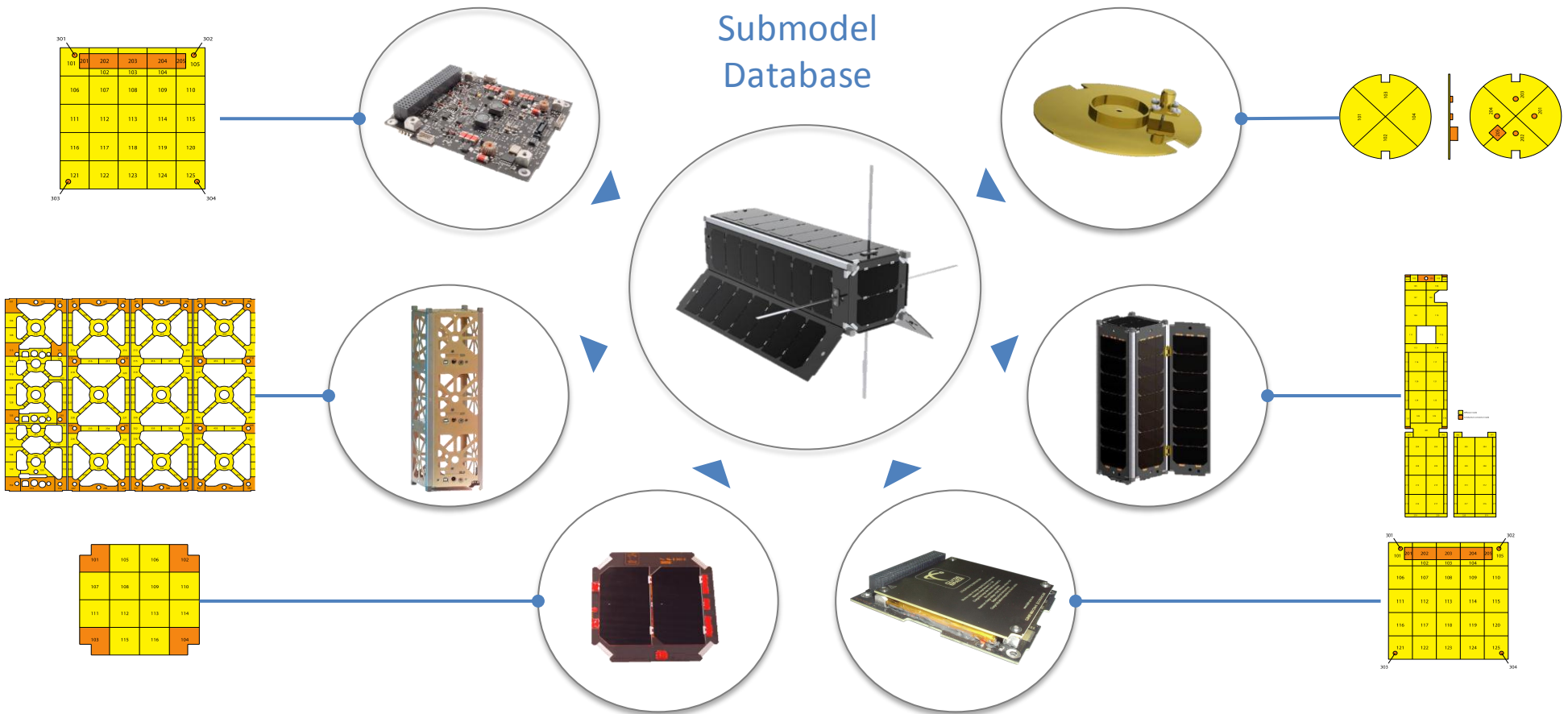
Thermal Model

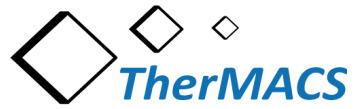
CubeSat approach





Thermal Model CubeSat approach





Thermal Model Implementation

Components

Component	Base node number (min 4 digits)
Structure_3U_Skeleton	1000
Antenna_SBand_Patch	2000
Solar_Panel_1U_TopBottom	3000
...	


- Antenna_Deployable
- Antenna_SBand_Patch
- DeepSpace
- Solar_Panel_1U_Antenna
- Solar_Panel_1U_TopBottom
- Solar_Panel_3U_Deploy_LE
- Structure_3U_Skeleton
- Structure_Panel_Clips
- Structure_Standoffs
- Structure_Test
- Template_PC104
- TestSat
- UKube_AMAC
- UKube_BAT
- UKube_C3D
- UKube_EPS
- UKube_FUNTRX_CCT
- UKube_FUNTRX_PA
- UKube_FUNTRX_RF

Configurator 1

Component	Base node number (min 4 digits)
Structure_3U_Skeleton	1000
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...	

- Antenna_Deployable
- Antenna_SBand_Patch
- DeepSpace
- Solar_Panel_1U_Antenna
- Solar_Panel_1U_TopBottom
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- UKube_FUNTRX_CCT
- UKube_FUNTRX_PA
- UKube_FUNTRX_RF

Component Preview



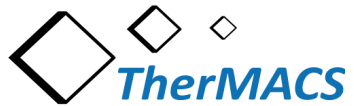
Structure_3U_Skeleton

add Component

delete Component

Apply Proceed...

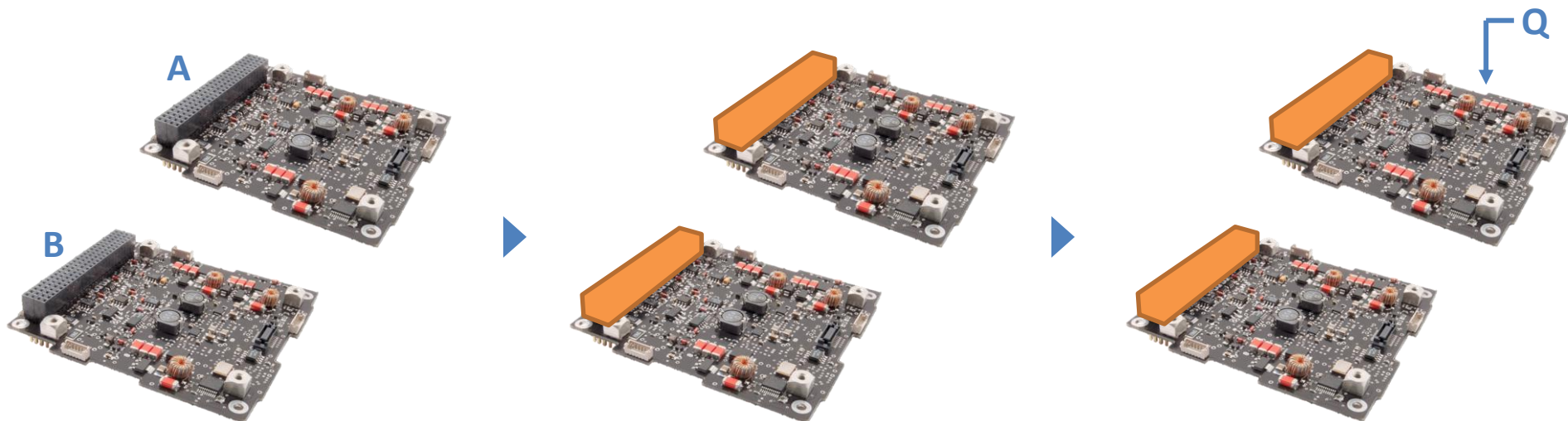


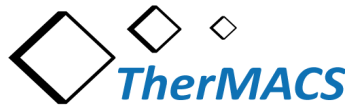


Thermal Model

Modelling process

- 1| Select **components** from database
- 2| Specify nodes being in **thermal contact**
- 3| Assign **boundary conditions**

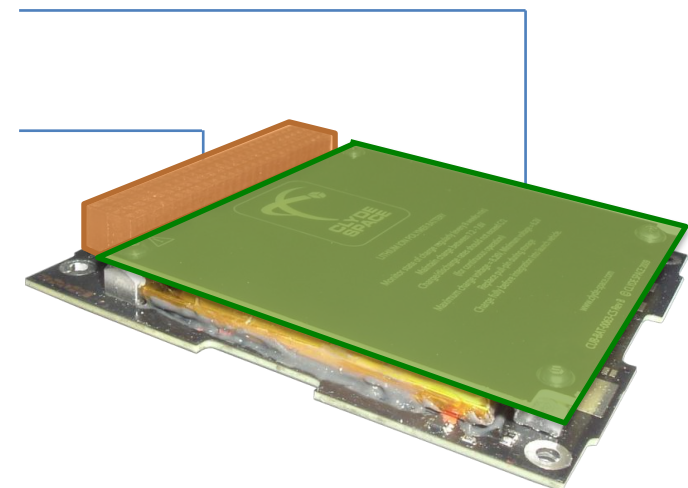




Thermal Model

Heat exchange factors

- Internal heat exchange factors **pre-defined**
 - > **Non-geometric** nodes [c_p, m]
- External heat exchange factors **auto-generated**
 - > **Radiative** contact nodes [$c_p, m, A, \alpha, \varepsilon$]
 - > **Conductive** contact nodes [c_p, m, A, x, k]

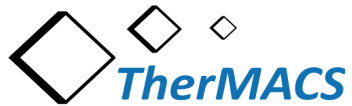




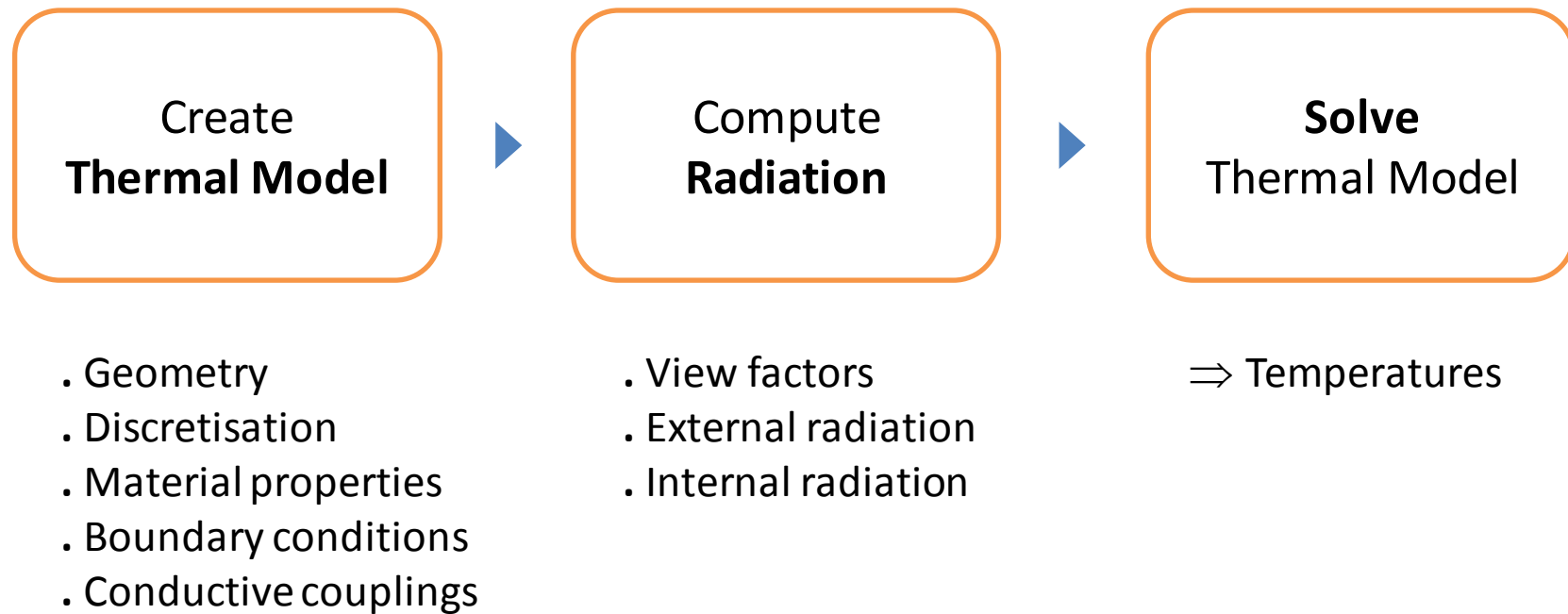
Thermal Model

Advantages

- . **Modular** thermal model with reusable submodels [database]
- . **Individual** submodels [independent from final configuration]
- . **Direct** definition of internal thermal couplings [estimates/measurements]
- . **Automatic** computation of external thermal couplings



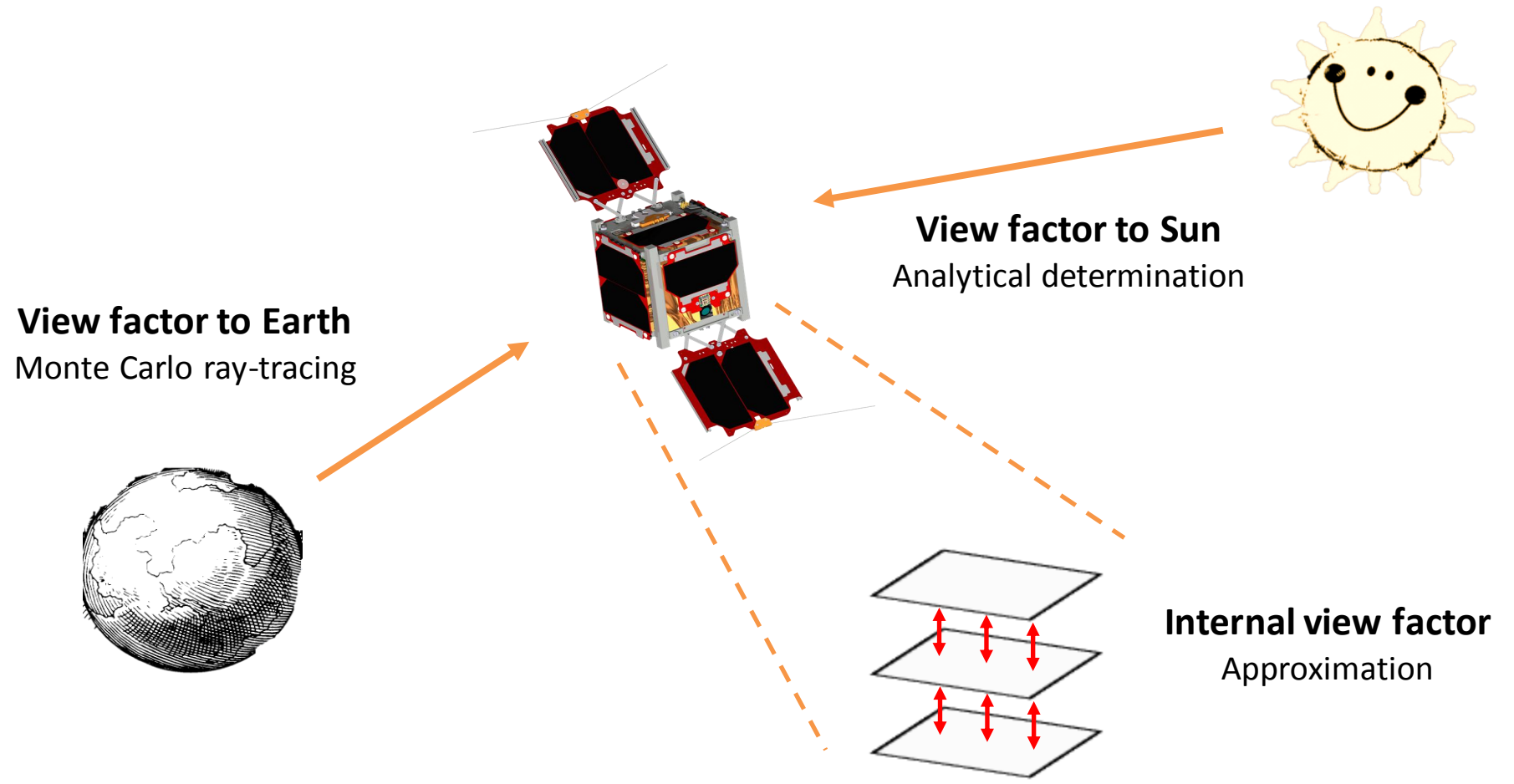
General Concept

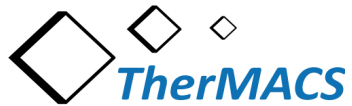




Radiation Module

View Factor

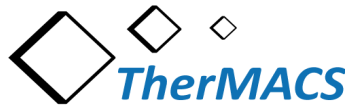




Tool Features

- . Implemented in **MATLAB**[®]
- . Offers a step-by-step **guide**
- . **Modular** modelling with database components
- . **Radiation** module
- . **User** defines:
 - .. **boundary** conditions
 - .. satellite **attitude**
 - .. simulation **parameters**
- . **Post-Processing** & plot features

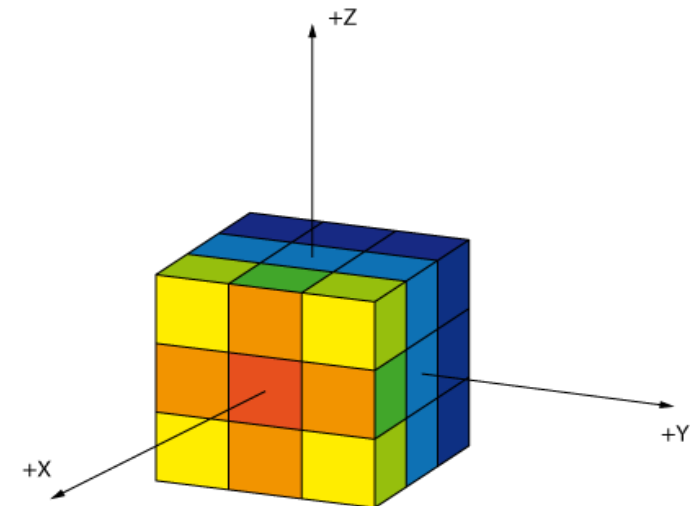




Validation

Benchmark with ESATAN TMS

- . Example satellite with **108 nodes**
- . **Polar** Low Earth Orbit
- . **360 steps** per orbit
- . Results compared to **ESATAN TMS**:
 - > Relative error for radiative case results **<12%**
 - > Absolute error for steady state temperatures max **-0.16/+0.04K**
 - > Computation time for one orbit **87% faster**





Initial Requirements

Specialized on CubeSat configurations?



- ⇒ Component database
- ⇒ Individual modelling

Easy to use?



- ⇒ Easy model setup
- ⇒ Step by step guide

Freely available?



- ⇒ Open source
- ⇒ Anyone can extend the component database

Thank you!

**New Methodologies for the
Thermal Modelling of CubeSats**

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