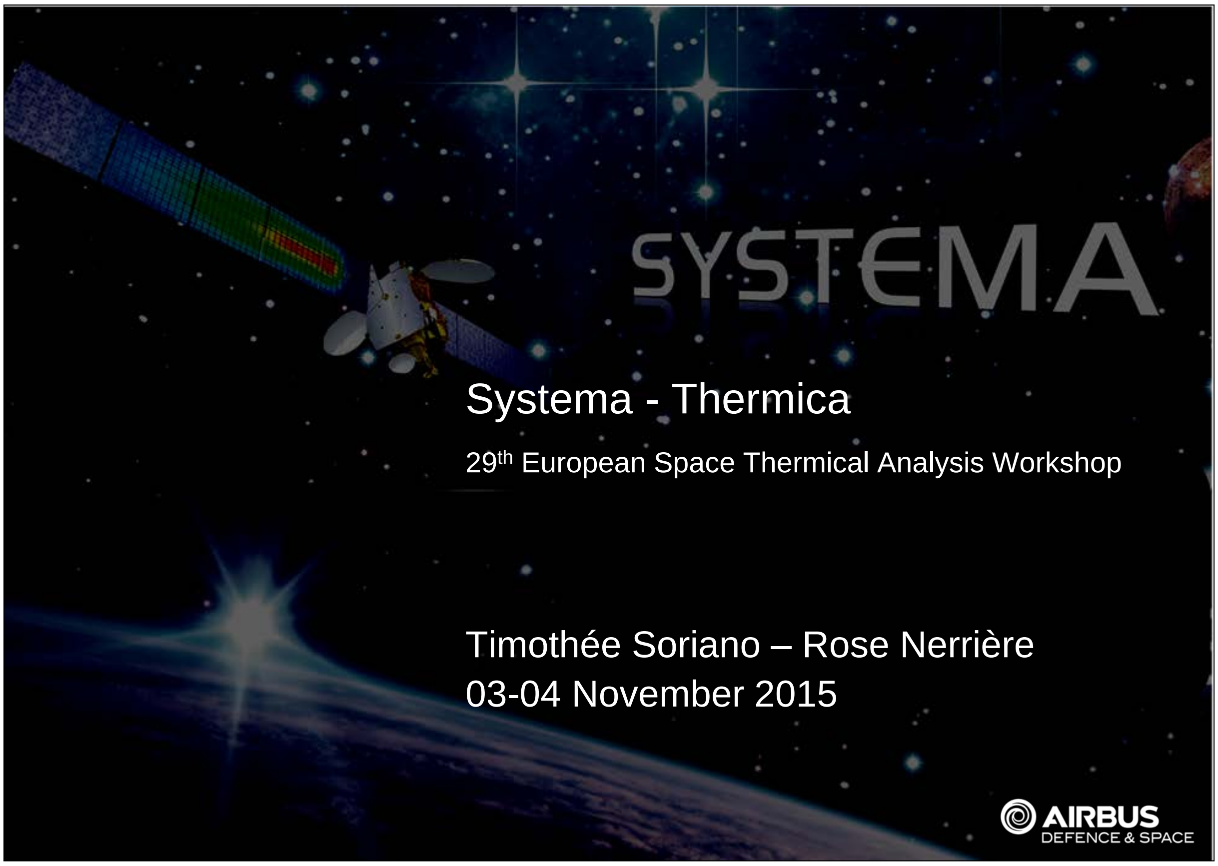
Appendix P

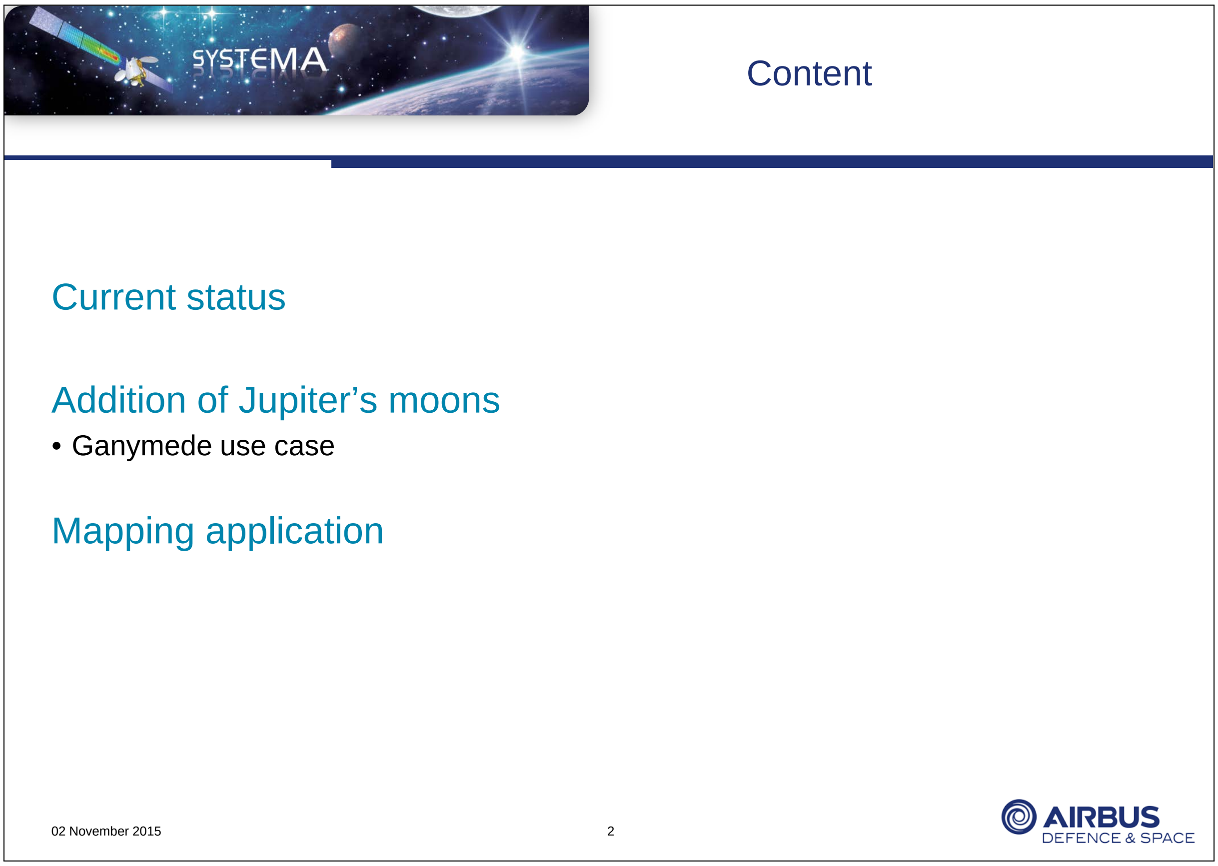
SYSTEMA — THERMICA

Timothée Soriano Rose Nerriere
(Airbus Defense and Space SAS, France)

Abstract

SYSTEMA, currently in version 4.7.1, is a framework for space physics applications including THERMICA, a package dedicated to thermal simulations.
The next version will be the 4.8.0 and will include a new schematic module which will allow the definition of power systems and will ease the thermo-electrical simulation process.
Besides, SYSTEMA has the ability to manage the solar system including different moons, like Ganymede, Europa and others for which orbits are approximated by Keplerian laws around a particular date of interest. A trajectory defined around a moon like Ganymede will lead to simulate fluxes both from the moon itself but also from other planets, like Jupiter in this example.
Finally, a new applicative module within Systema, called Mapping, offers the possibility to transfer data from one model to another one: fluxes from a Plume analysis to a thermal model, temperatures to an outgassing model or to mechanical mesh. For the temperature mapping, a new method based on a "backward RCN" has been set-up. This method is capable of interpolating temperatures within a re-built quadratic profile onto the thermal mesh and offers then a very accurate mapping consistent with the hypothesis of the thermal simulation.


SYSTEMA
Systema - Thermica
29th European Space Thermical Analysis Workshop
Timothée Soriano – Rose Nerrière
03-04 November 2015
AIRBUS
DEFENCE & SPACE


SYSTEMA
Content
Current status
Addition of Jupiter's moons
• Ganymede use case
Mapping application
02 November 2015
2
AIRBUS
DEFENCE & SPACE

Current status

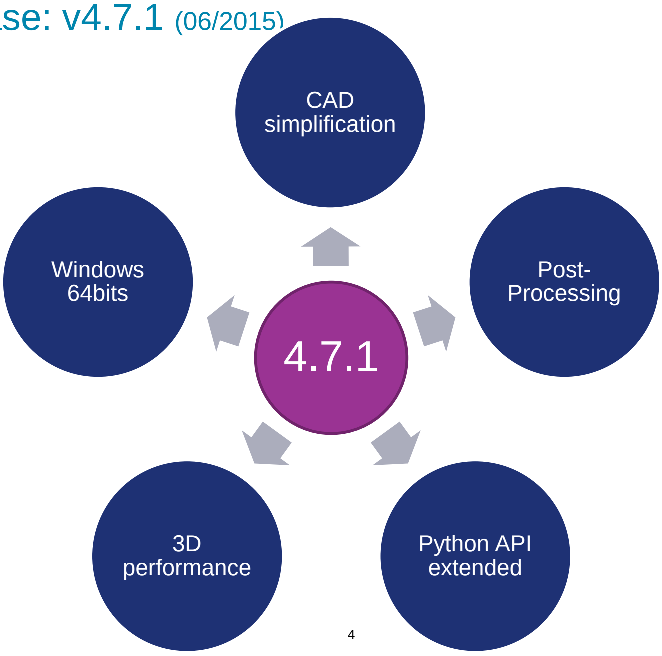
Long Term Support current version: v4.5.3 (08/2013)

02 November 2015 3

AIRBUS DEFENCE & SPACE

Current status

Latest Release: v4.7.1 (06/2015)



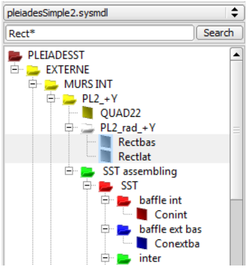
02 November 2015 4

AIRBUS DEFENCE & SPACE

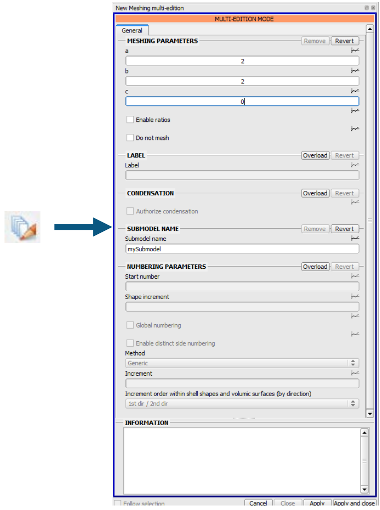
Current status

v4.7.1

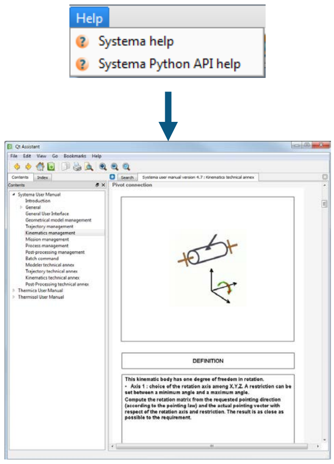
Search tool



Multi-edition on Meshing



Integrated User Manual



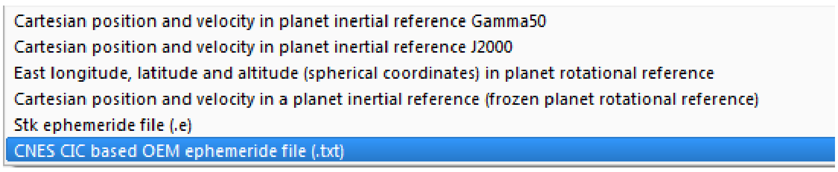
02 November 2015 5

AIRBUS DEFENCE & SPACE

Current status

v4.7.1

- Import/Export of ASCII Ephemeris files
- Follow the CIC exchange protocol: restriction of ESA standard CCSDS
- Trajectory Time-Position-Velocity



  – Import of Trajectory :
    – OEM files (Orbit Ephemeris Message) → x, y, z positions

02 November 2015 6

AIRBUS DEFENCE & SPACE

SYSTEMA

Current status

v4.7.1

- Kinematics law “Transformation defined in a file”:

Transformation matrix
Rotations in transformed axis - Z-Y'-X"
Rotations in transformed axis - X-Y'-Z"
Rotations in fixed axis - Z-Y-X
Rotations in fixed axis - X-Y-Z
STK attitude file (*.a)
CNES CIC based AEM spacecraft attitude file (*.txt)
CNES CIC based MEM moving body attitude file (*.txt)

  – Import of Kinematics :
    – AEM files for satellite attitude (Attitude Ephemeris Message) → quaternions
    – MEM files for moving bodies attitude (Mission Ephemeris Message) → rotation angle

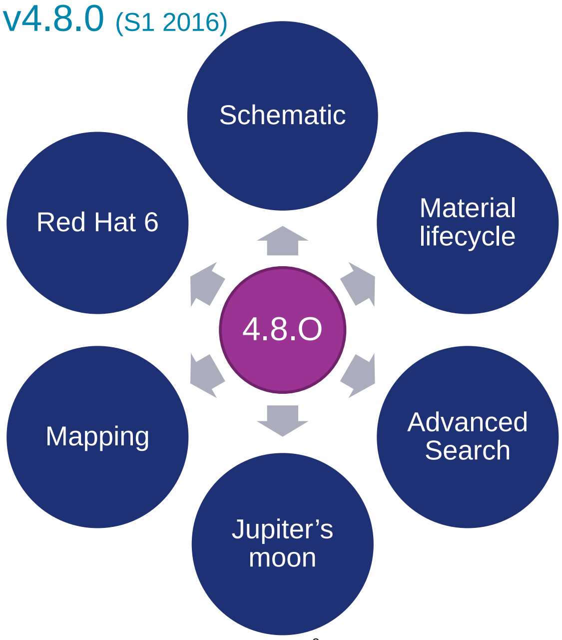
- Export of HDF5 results :
  – MEM files (Mission Ephemeris Message) → thermal results

02 November 2015 7 AIRBUS DEFENCE & SPACE

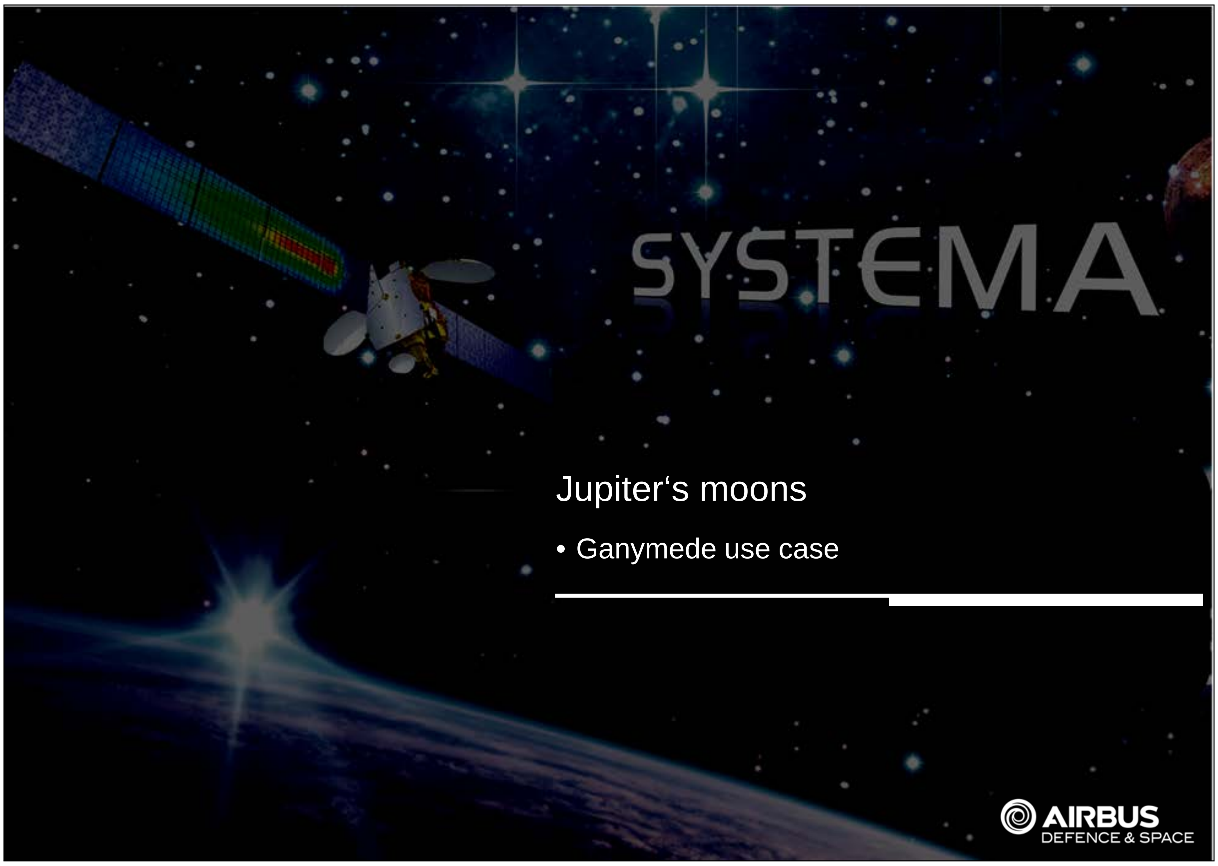
SYSTEMA

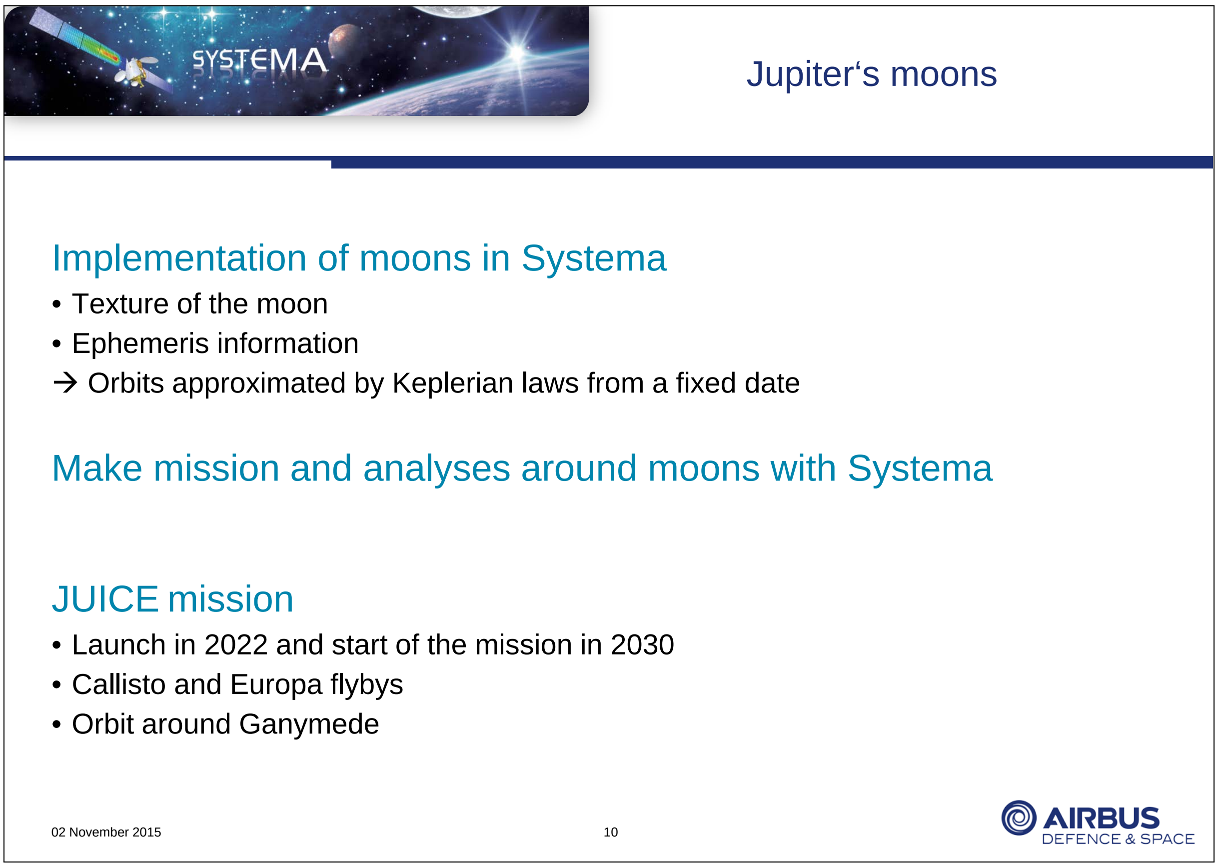
Current status

Next Release: v4.8.0 (S1 2016)



02 November 2015 8 AIRBUS DEFENCE & SPACE


SYSTEMA
Jupiter‘s moons
• Ganymede use case
AIRBUS
DEFENCE & SPACE


SYSTEMA
Jupiter‘s moons
Implementation of moons in Systema
• Texture of the moon
• Ephemeris information
→ Orbits approximated by Keplerian laws from a fixed date
Make mission and analyses around moons with Systema
JUICE mission
• Launch in 2022 and start of the mission in 2030
• Callisto and Europa flybys
• Orbit around Ganymede
02 November 2015
10
AIRBUS
DEFENCE & SPACE

SYSTEMA

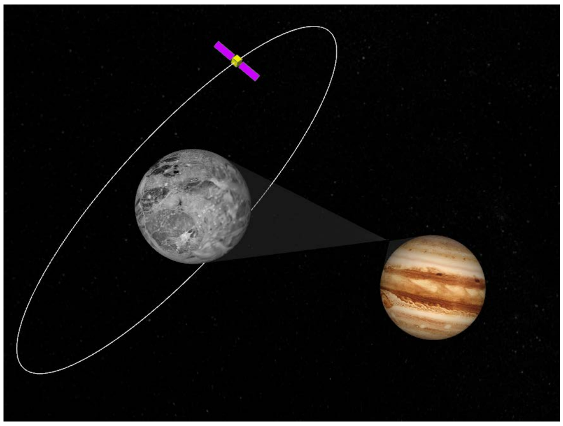
Jupiter‘s moons

Ganymede

- Available since version 4.7

Europa / Callisto

- Available in 4.8.0



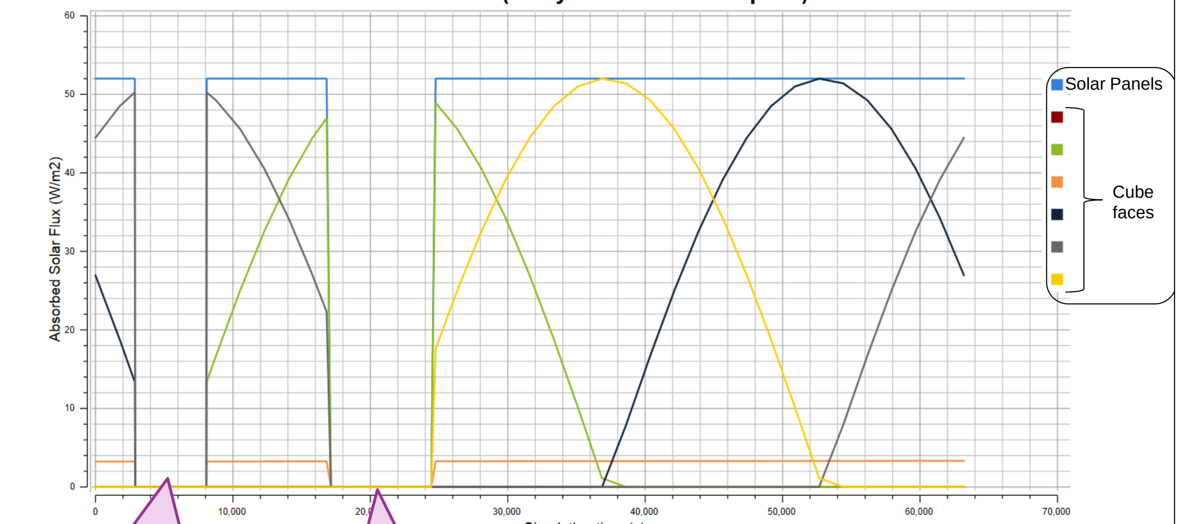
02 November 2015 11

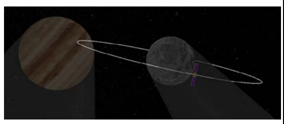
AIRBUS DEFENCE & SPACE

SYSTEMA

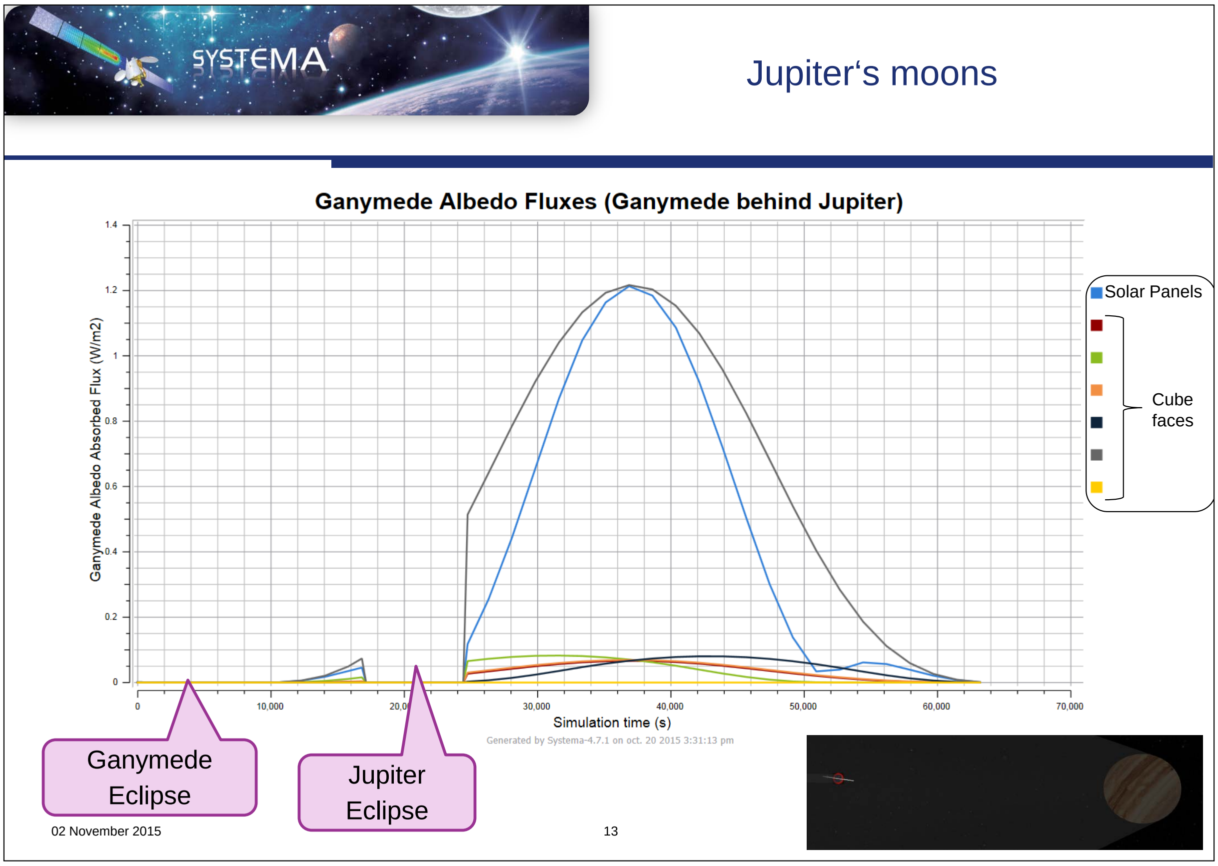
Jupiter‘s moons

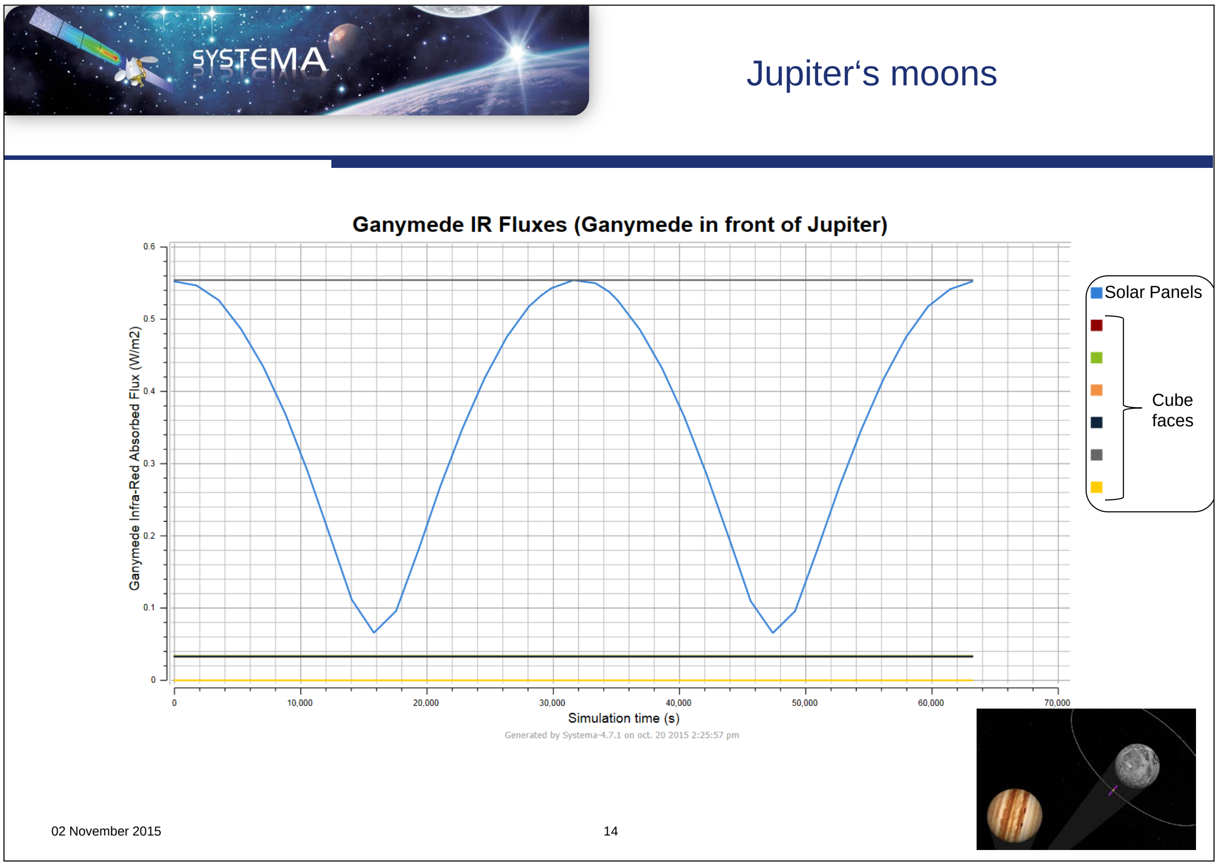
Solar Fluxes (Ganymede behind Jupiter)

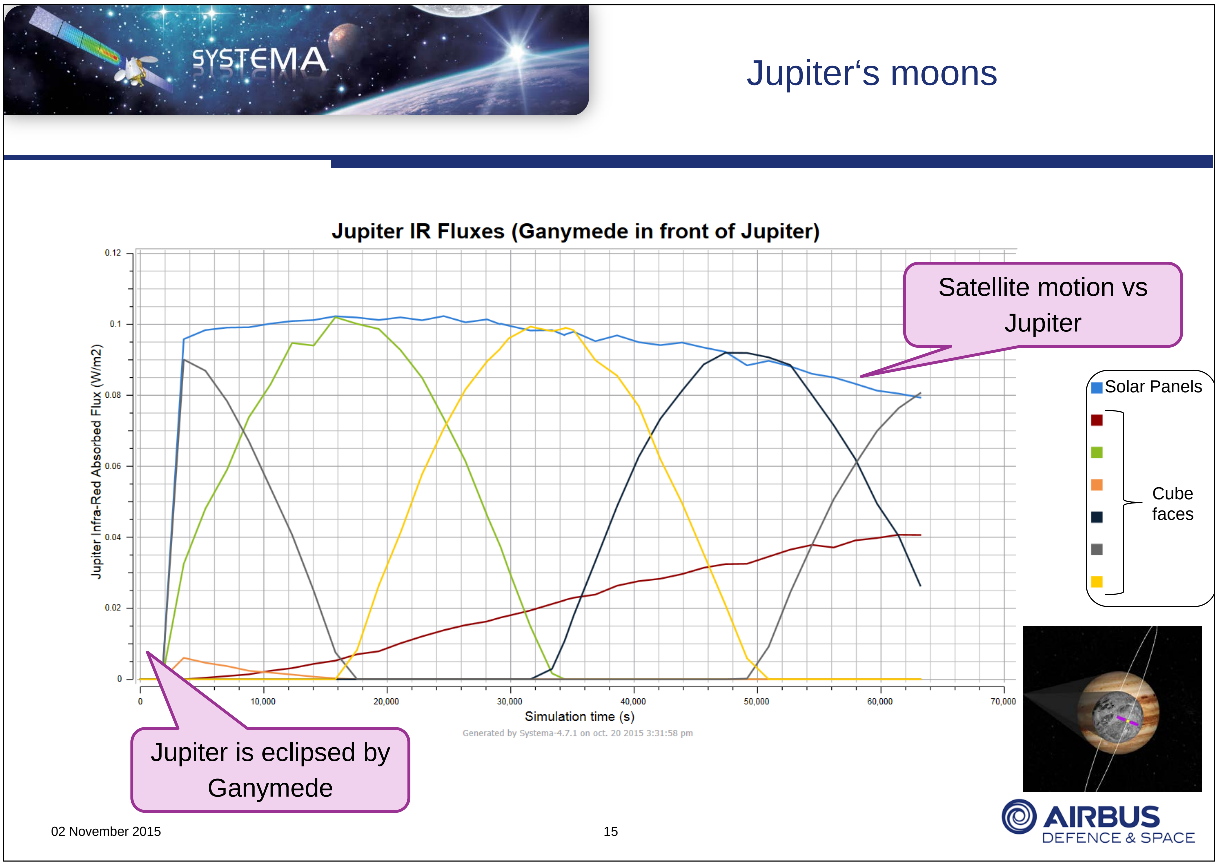


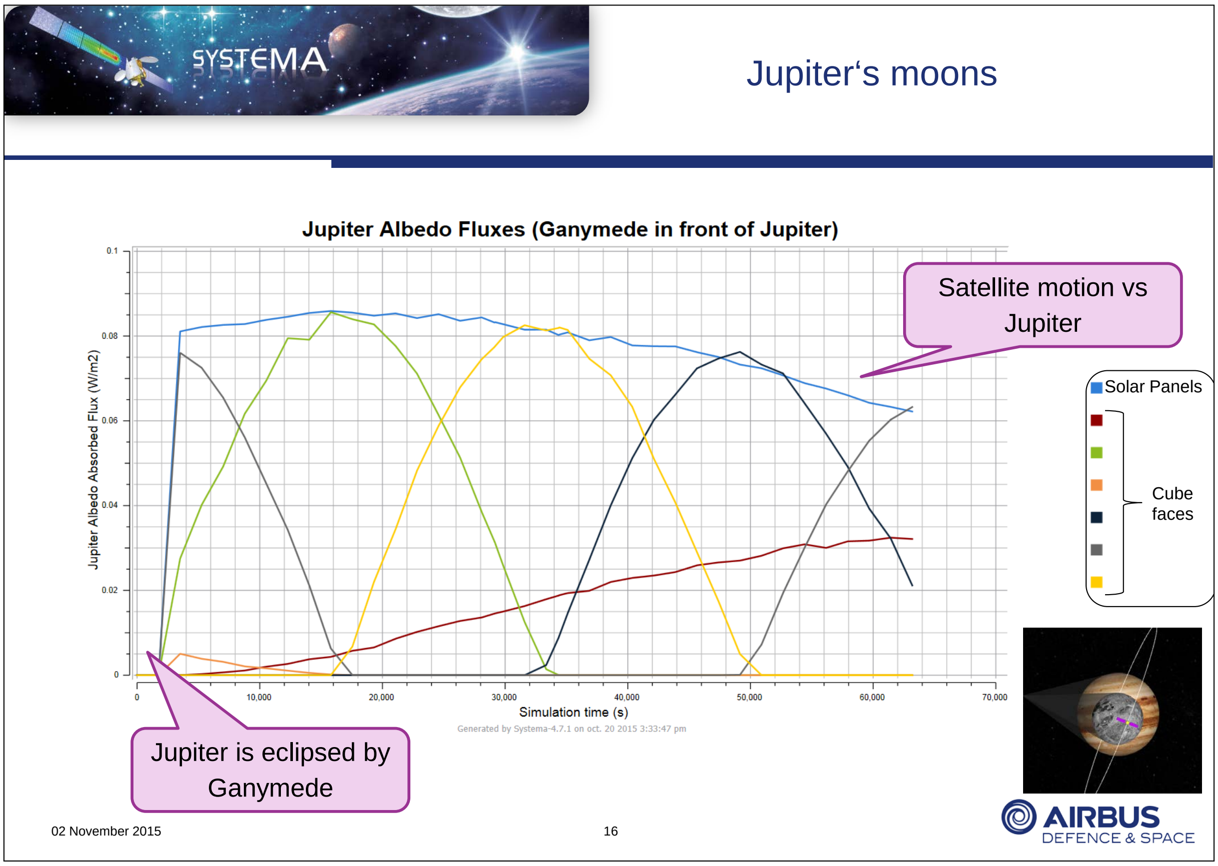


02 November 2015 12


SYSTEMA
Jupiter's moons
Ganymede Albedo Fluxes (Ganymede behind Jupiter)
Ganymede Albedo Absorbed Flux (W/m2)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10,000
30,000
40,000
50,000
60,000
70,000
Simulation time (s)
Generated by Systema-4.7.1 on oct. 20 2015 3:31:13 pm
Solar Panels
Cube faces
Ganymede Eclipse
Jupiter Eclipse
02 November 2015
13


SYSTEMA
Jupiter's moons
Ganymede IR Fluxes (Ganymede in front of Jupiter)
Ganymede Infra-Red Absorbed Flux (W/m2)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
Simulation time (s)
Generated by Systema-4.7.1 on oct. 20 2015 2:25:57 pm
Solar Panels
Cube faces
02 November 2015
14

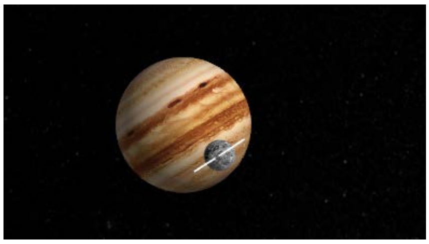

SYSTEMA
Jupiter‘s moons
Jupiter IR Fluxes (Ganymede in front of Jupiter)
Jupiter Infra-Red Absorbed Flux (W/m2)
Simulation time (s)
Satellite motion vs Jupiter
Solar Panels
Cube faces
Jupiter is eclipsed by Ganymede
02 November 2015
15
AIRBUS
DEFENCE & SPACE


SYSTEMA
Jupiter‘s moons
Jupiter Albedo Fluxes (Ganymede in front of Jupiter)
Jupiter Albedo Absorbed Flux (W/m2)
Simulation time (s)
Satellite motion vs Jupiter
Solar Panels
Cube faces
Jupiter is eclipsed by Ganymede
02 November 2015
16
AIRBUS
DEFENCE & SPACE

Jupiter‘s moons

Conclusions

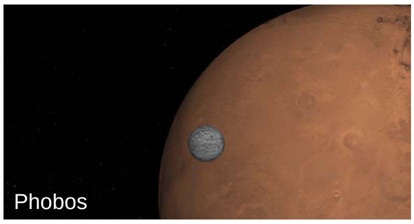
- Relative positions of planet / moon / sun
- Sun eclipses from both Ganymede and Jupiter
- Jupiter eclipse from Ganymede
- Ganymede and Jupiter fluxes simulated



Realistic simulations around any moons are possible

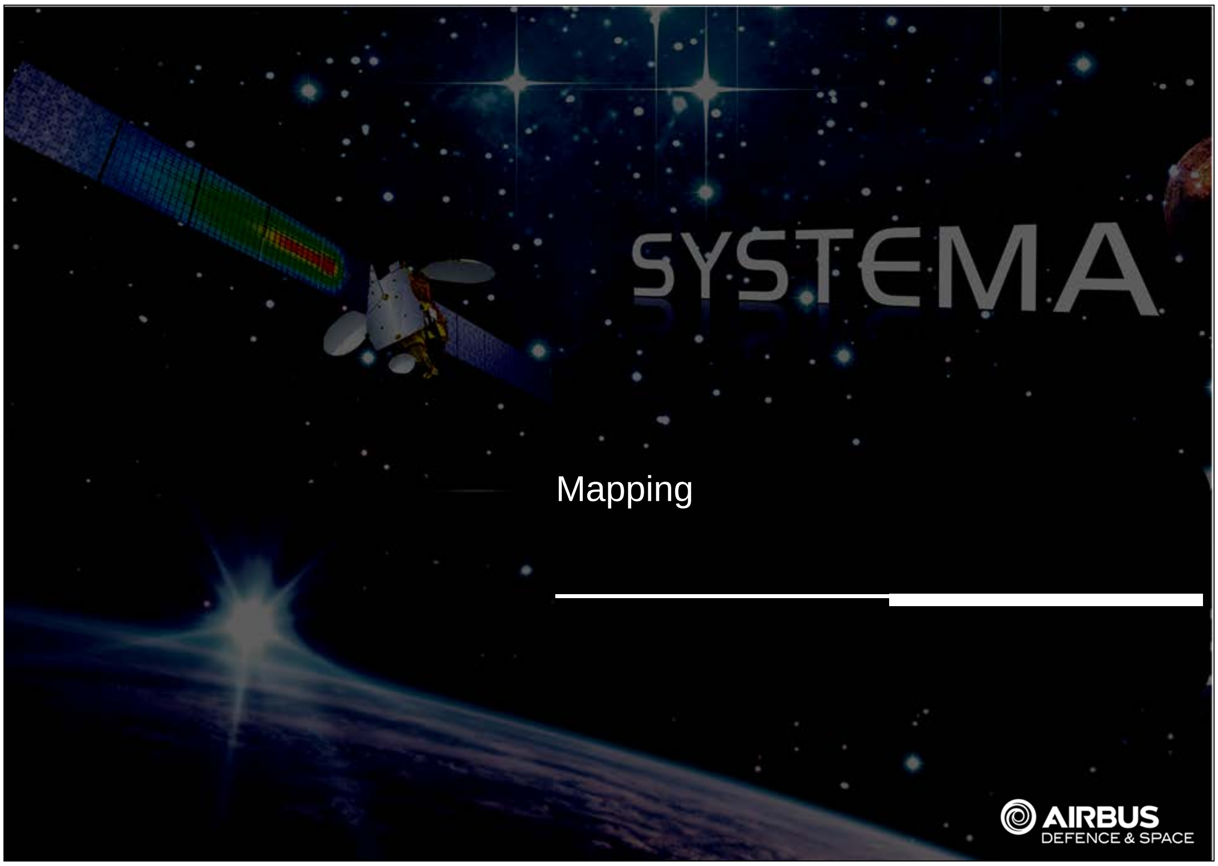
In the future

- update existing moon’s properties
- add new moons



02 November 2015 17

AIRBUS DEFENCE & SPACE

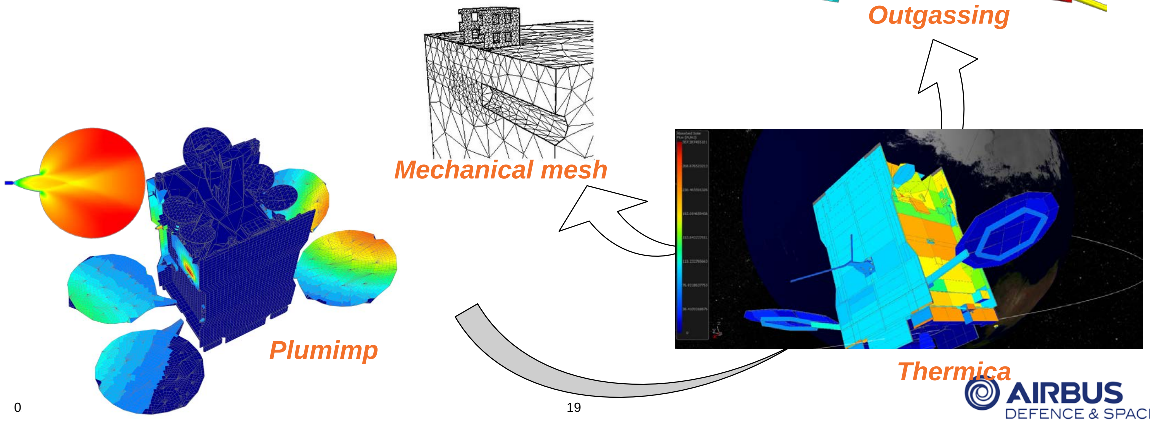


SYSTEMA

Mapping

Context: Multi-physics analysis

- **Need to transfer data**
  - Temperatures from *Thermal analysis* to *Mechanical mesh*
  - Fluxes from *Plume analysis* to *Thermal model*
  - Temperatures from *Thermal analysis* to *Outgassing model*



0 19

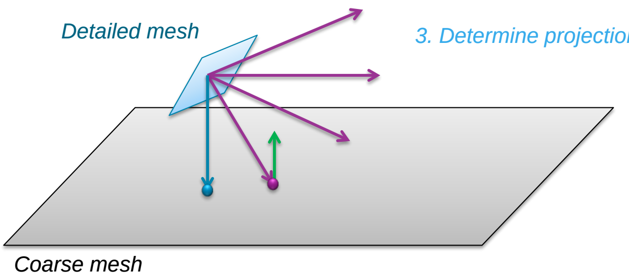
AIRBUS DEFENCE & SPACE

SYSTEMA

Mapping

Geometrical associations

- **By projection from detailed to coarse model**
  - Detailed elements are projected to the nearest geometry of the coarse model (by ray-tracing)
  - The projection is normal to the coarse geometry
  - Correspondences between mesh are generated
  - Including parametric coordinates of projected points



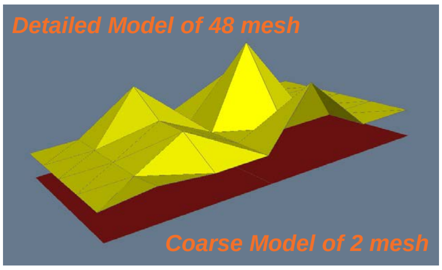
02 November 2015 20

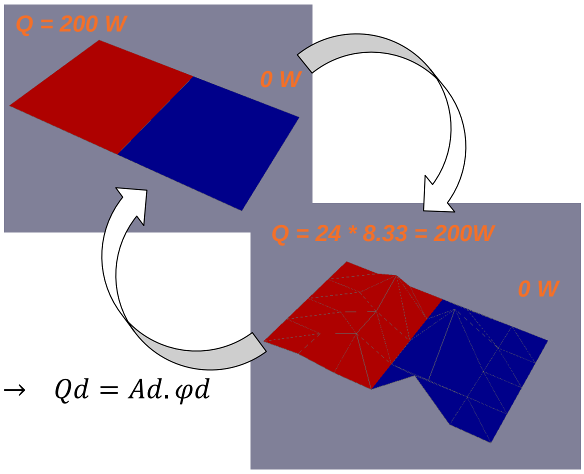
AIRBUS DEFENCE & SPACE

Mapping

Mapping of fluxes

- **According to cross-section of projection**





$$Qc \rightarrow \varphi c = \frac{Qc}{Ac} \Longrightarrow \varphi d = \varphi c.cos\theta \rightarrow Qd = Ad.\varphi d$$

02 November 2015 21

AIRBUS DEFENCE & SPACE

Mapping

Mapping of temperatures

- **By a backward RCN method**

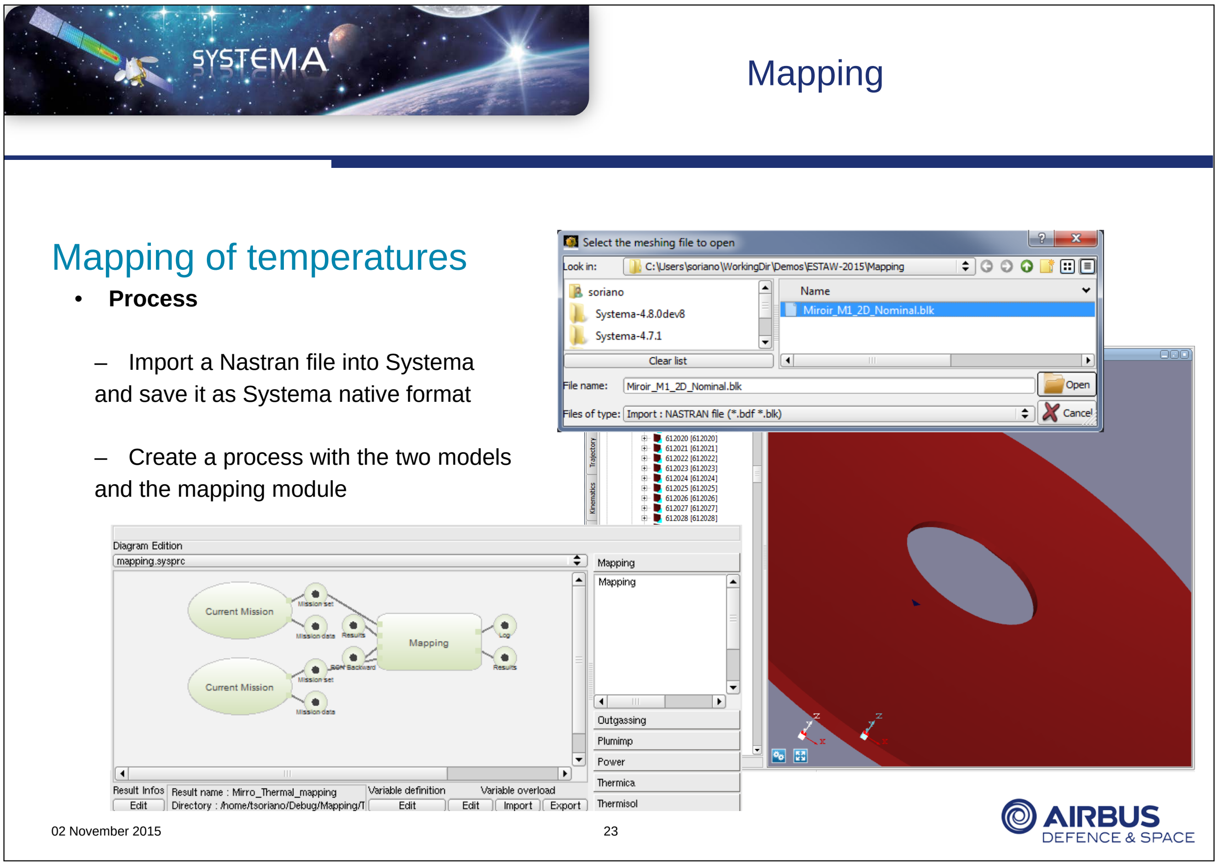
  – The RCN method (Reduced Conductive Network) is an innovative algorithm that deals with the conduction in accordance with radiative and external fluxes ray-tracing methods. It is based on a finite volume integration of conductive fluxes computed through a model reduction of a detailed sub-mesh model.

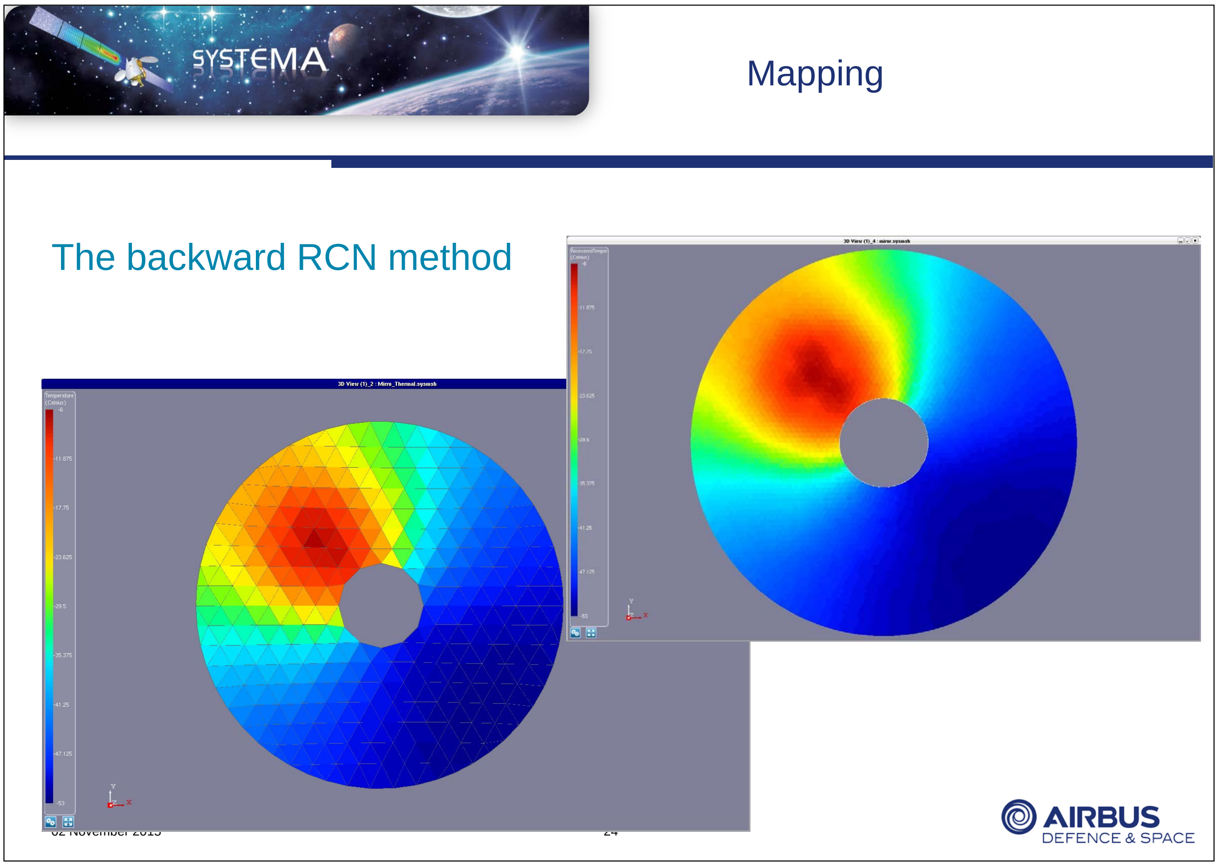
  – The model reduction used by the RCN algorithm may also export “backward matrices” allowing to recover a detailed temperature profile from temperatures computed on the thermal model.

  – Using the RCN method for the conduction allows then to rebuild an accurate and detailed temperature profile and so to perform a temperature mapping of a very good quality

02 November 2015 22

AIRBUS DEFENCE & SPACE

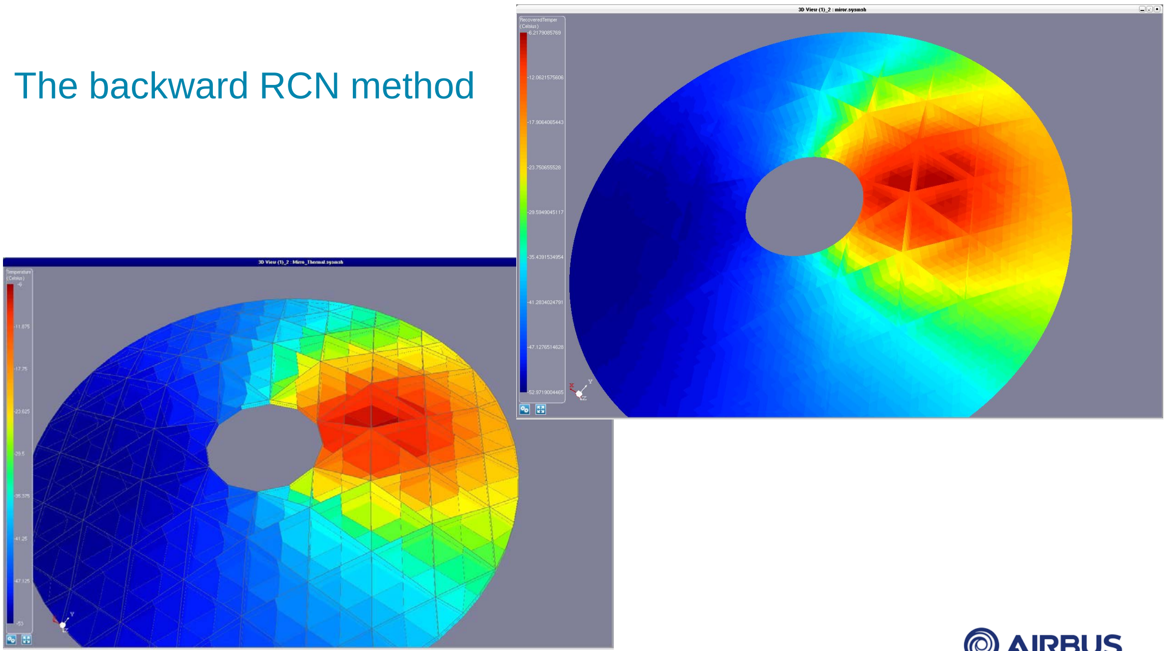

SYSTEMA
Mapping
Mapping of temperatures
• Process
– Import a Nastran file into Systema and save it as Systema native format
– Create a process with the two models and the mapping module
Select the meshing file to open
Look in: C:\Users\soriano\WorkingDir\Demos\ESTAW-2015\Mapping
soriano
Systema-4.8.0dev8
Systema-4.7.1
Clear list
Name
Miroir_M1_2D_Nominal.blk
File name: Miroir_M1_2D_Nominal.blk
Files of type: Import : NASTRAN file (*.bdf *.blk)
Open
Cancel
Diagram Edition
mapping.sysprc
Current Mission
Current Mission
Mapping
Mapping
Mapping
Outgassing
Plumimp
Power
Thermica
Thermisol
Result Infos
Result name : Mirro_Thermal_mapping
Directory : /home/tsoriano/Debug/Mapping/T
Variable definition
Variable overload
Edit
Edit
Edit
Import
Export
02 November 2015
23
AIRBUS
DEFENCE & SPACE


SYSTEMA
Mapping
The backward RCN method
AIRBUS
DEFENCE & SPACE

SYSTEMA

Mapping

The backward RCN method



02 November 2015 25

AIRBUS DEFENCE & SPACE

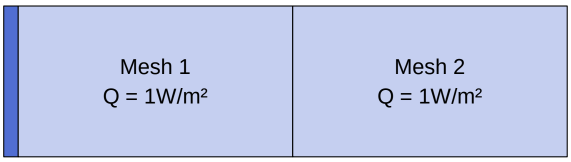
SYSTEMA

Mapping

Consistency of the RCN Conduction and RCN backward Mapping

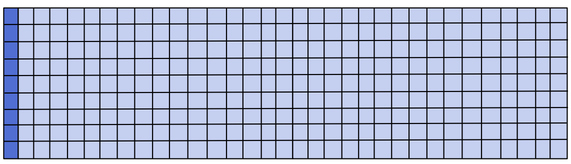
- **Coarse model**

Boundary @ 0°C



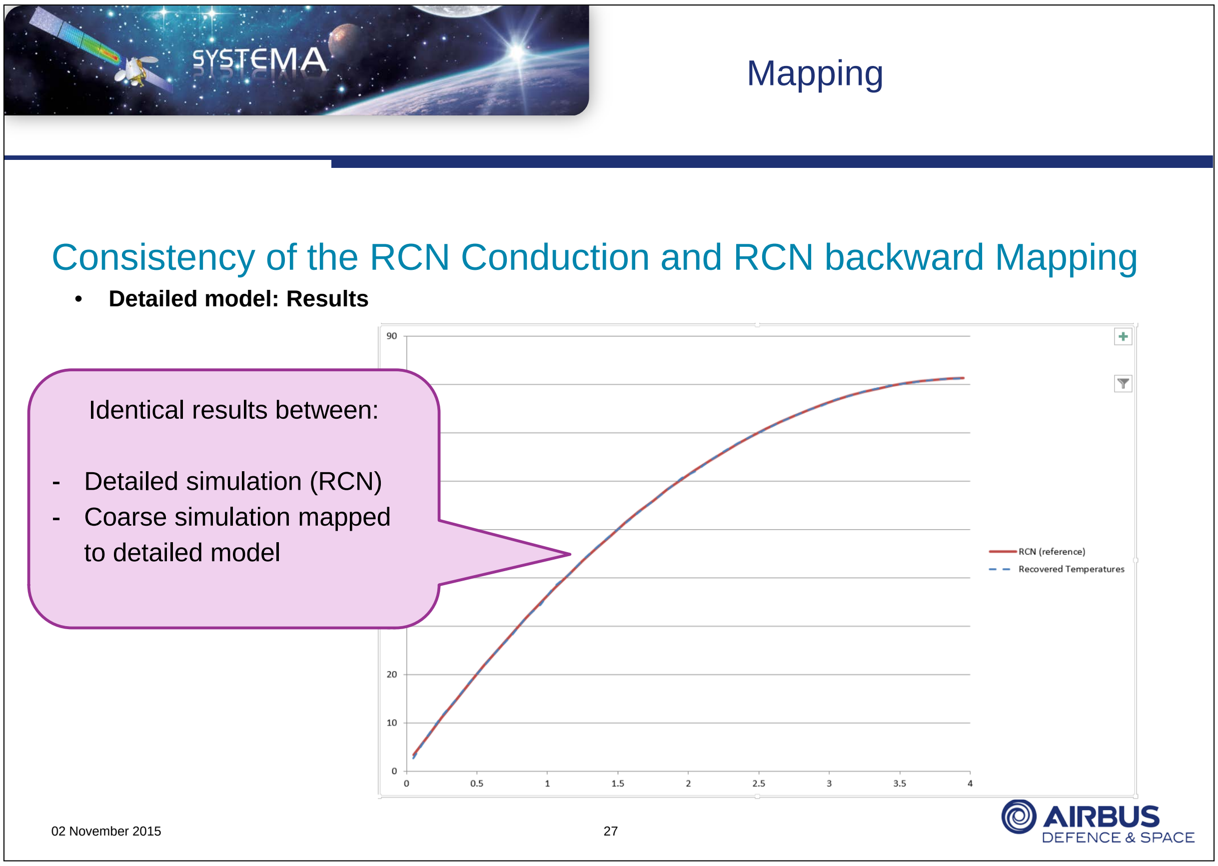
  – Computed average temperatures with the RCN conduction: T1 = 34.66 °C T2 = 74.66 °C

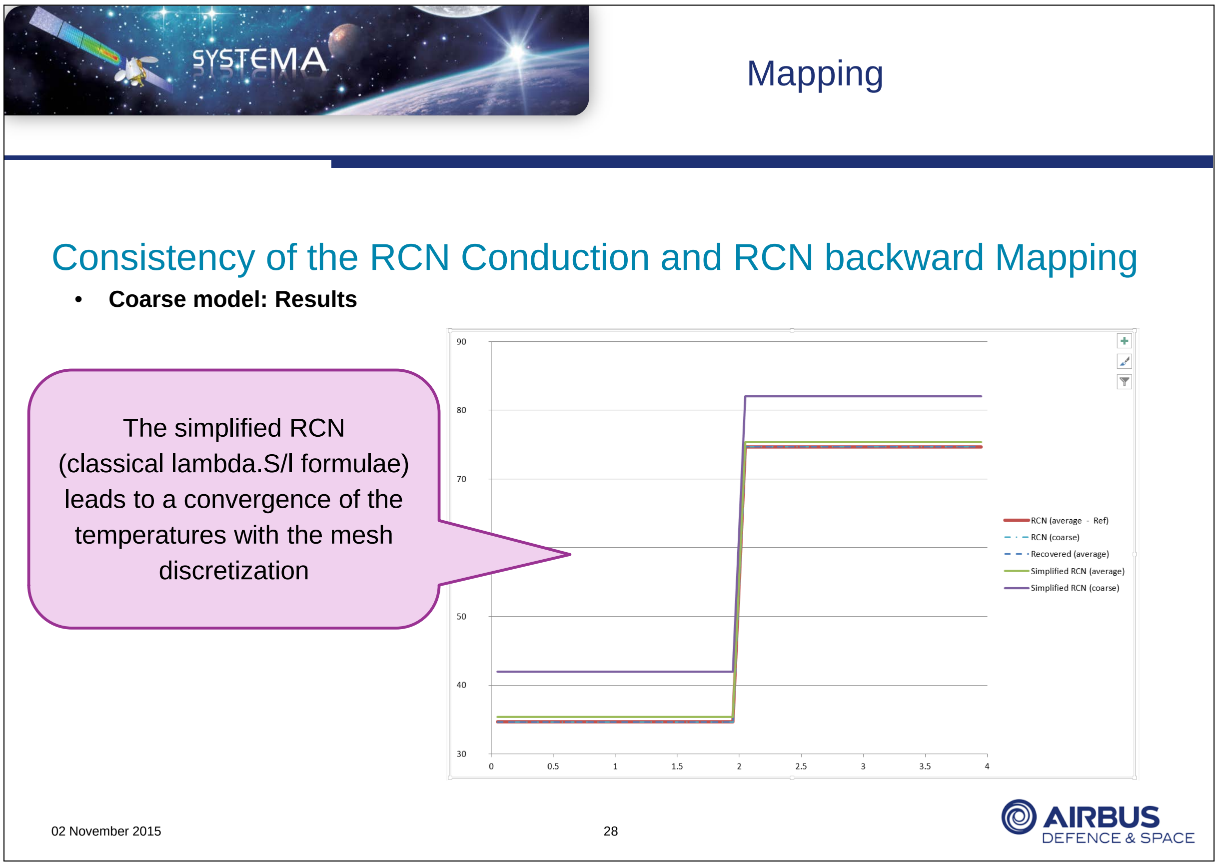
- **Detailed model**



02 November 2015 26

AIRBUS DEFENCE & SPACE


SYSTEMA
Mapping
Consistency of the RCN Conduction and RCN backward Mapping
• Detailed model: Results
Identical results between:
- Detailed simulation (RCN)
- Coarse simulation mapped to detailed model
RCN (reference)
Recovered Temperatures
02 November 2015
27
AIRBUS DEFENCE & SPACE


SYSTEMA
Mapping
Consistency of the RCN Conduction and RCN backward Mapping
• Coarse model: Results
The simplified RCN (classical lambda.S/l formulae) leads to a convergence of the temperatures with the mesh discretization
RCN (average - Ref)
RCN (coarse)
Recovered (average)
Simplified RCN (average)
Simplified RCN (coarse)
02 November 2015
28
AIRBUS DEFENCE & SPACE

Mapping

Conclusion

- **The new Mapping module allows to transfer data (temperatures, fluxes…) between different models**
  - Projected areas may be used to be conservative on the powers
  - Backward RCN brings a complete solution and do not involve any extrapolation of temperatures (the temperature profile obtained is such as the really considered at temperature integration level)

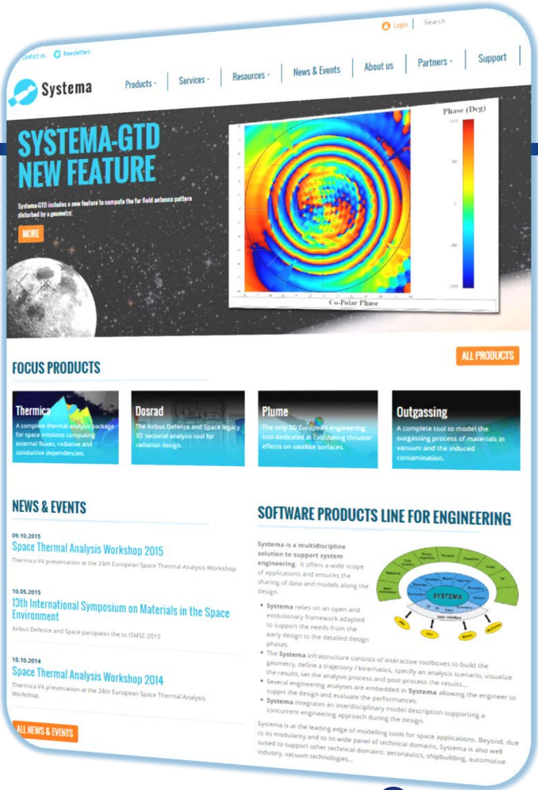
02 November 2015 29

AIRBUS DEFENCE & SPACE

SYSTEMA
THERMICA
THERMISOL

Visit our web site :

www.systema.airbusdefenceandspace.com



Contact:
timothee.soriano@airbus.com
rose.nerriere@airbus.com

02 November 2015 30

AIRBUS DEFENCE & SPACE