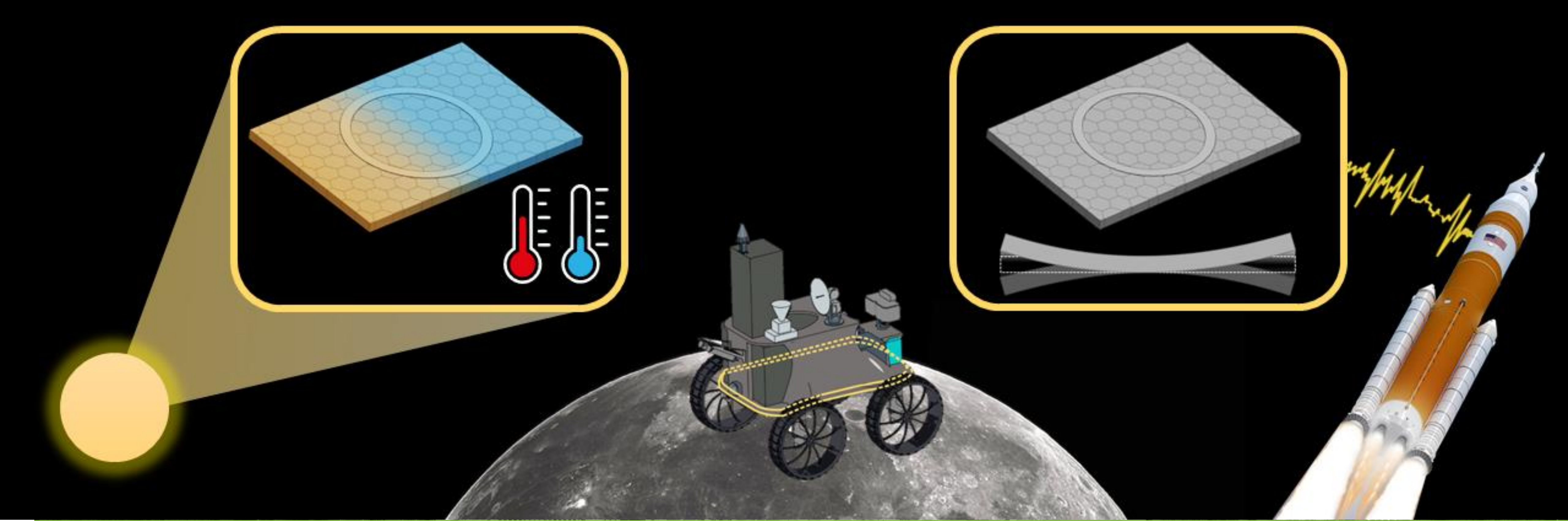


THERMAL AND STRUCTURAL PARAMETRIC STUDY OF THE SANDWICH PANEL STRUCTURE OF A THERMOPLASTIC 3D-PRINTED LUNAR ROVER

POLYTECHNIQUE MONTRÉAL
UNIVERSITÉ D'INGÉNIERIE

David Lessard, M.Sc.A

Director & co-director : Frédérick Gosselin (PhD), Marie-Josée Potvin (PhD) and Marie-Laure Dano (PhD)

Laboratory for Multi-Scale Mechanics (LM2)

31th May 2023

Fonds de recherche Nature et technologies Québec

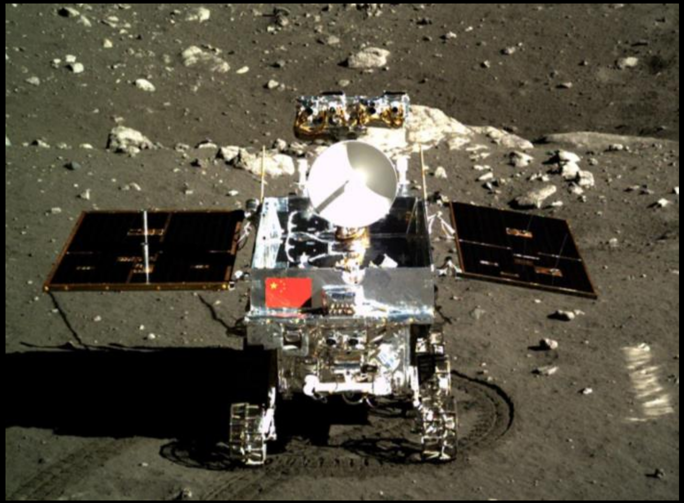
NSERC CRSNG

CSA ASC

CREPEC Centre de recherche sur les systèmes polymères et composites à haute performance

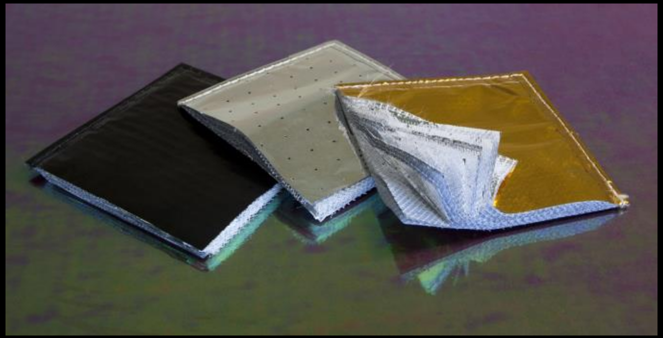
LUNAR NIGHT

Lunar rover : Yutu 1



spaceflightnow.com

Multi-layer insulation (MLI)



bronaerotech.com

15 Earth's days

-180°C

Radioisotope thermoelectric generator (RTG)

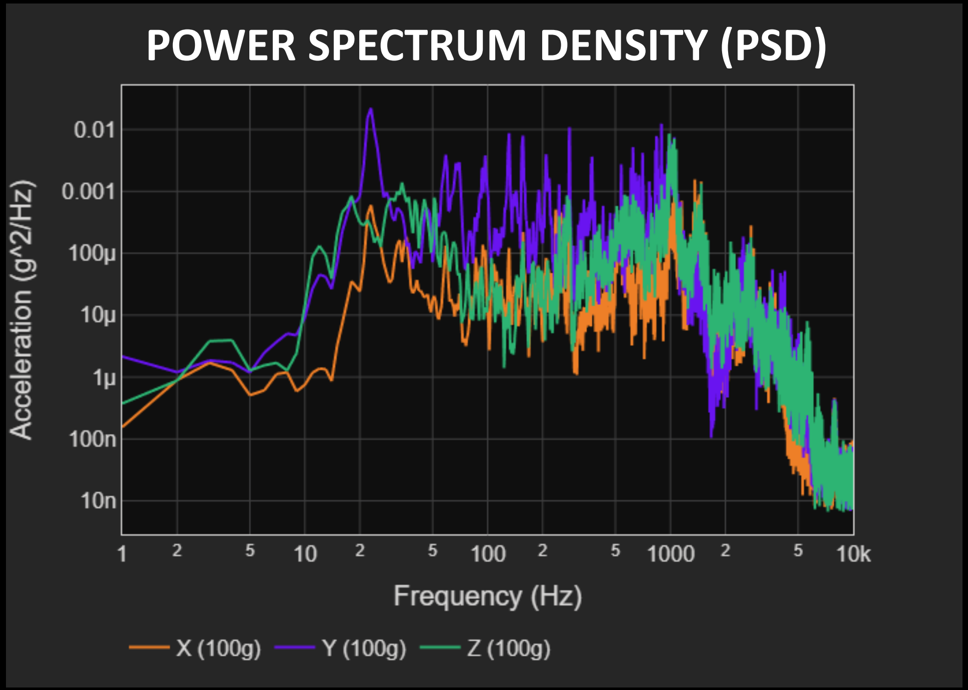
wikipedia.com\Radioisotope_thermoelectric_generator

ROCKET LAUNCH

Most constraining mechanical load case

<u>Random vibrations</u>

- *Rocket thrust*
- *Liftoff*
- *Turbulences*
- *Motor burn*
- *POGO effect*

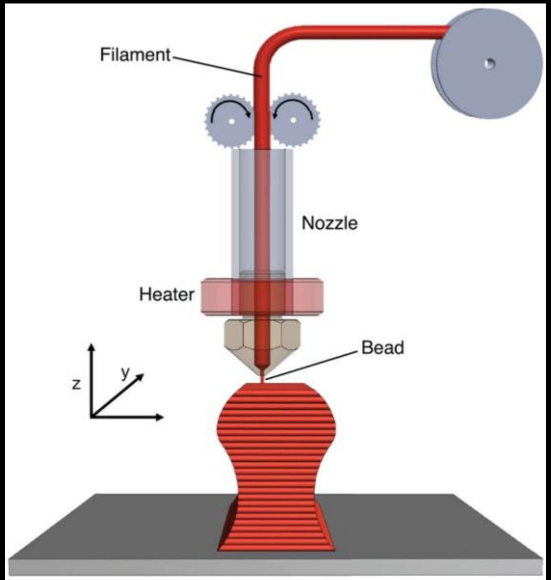


POLYETHER ETHER KETONE (PEEK)

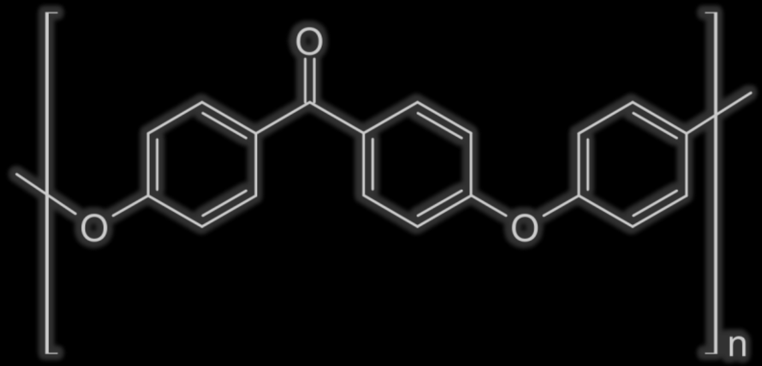
High performance thermoplastic

Low conductivity
Mechanical properties
Low density
Space grade material

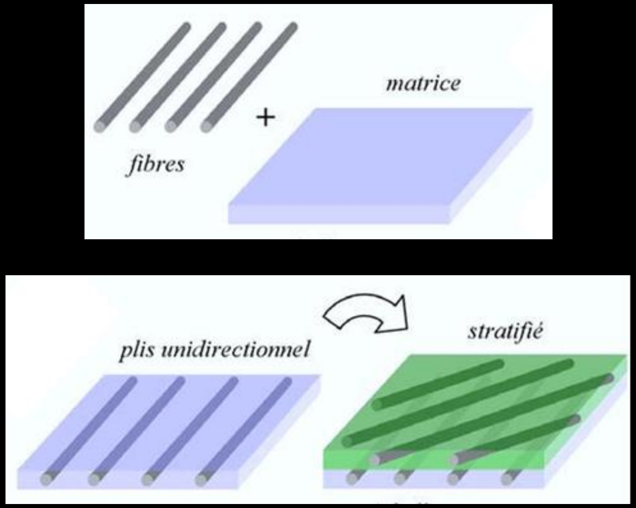
3D printing (FFF)



T. Osswald et al. (2018). Additive Manufacturing



Composites

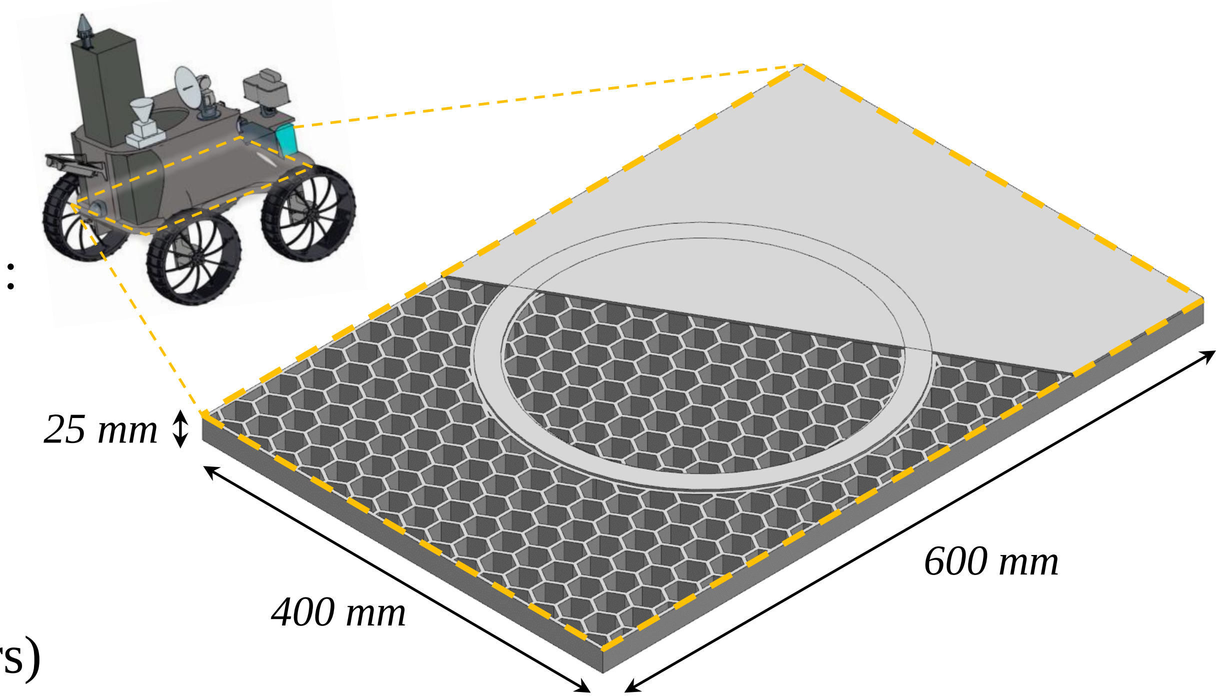


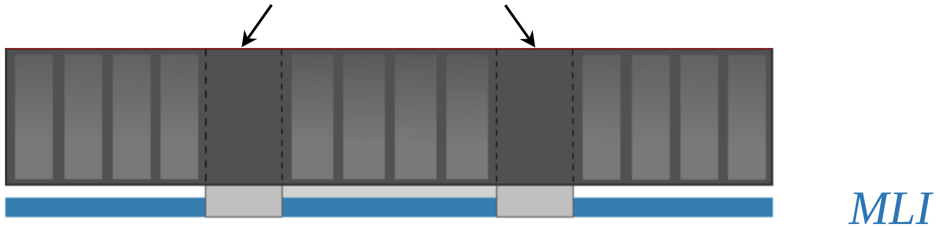
Khechai et al. (2013). ResearchGate

CASE STUDY

Sandwich panel forming the base of the rover's structure :

- Critical structural part
- 3D-printed honeycomb core (PEEK 20%m CF)
- Laminate skins (PEEK w/ continuous carbon fibers)
- Fixed to the rocket module by a reinforcement ring
- Outside of the rover covered in MLI





Side sectional view

Broggi, C. (2020). Conception et fabrication additive d'une structure bio-inspirée pour un rover lunaire en composites thermoplastiques [Mémoire de maîtrise, Polytechnique Montréal].

OBJECTIVES

Define recommendations to **reduce mass** of the sandwich panel while :

- Surviving the lunar nights **cold temperatures**

1. Thermal parametric study

- Resisting to the **random vibrations environnement** of a rocket launch

2. Structural parametric study

Broggi, C. (2020). Conception et fabrication additive d'une structure bio-inspirée pour un rover lunaire en composites thermoplastiques [Mémoire de maîtrise, Polytechnique Montréal].

OBJECTIVES

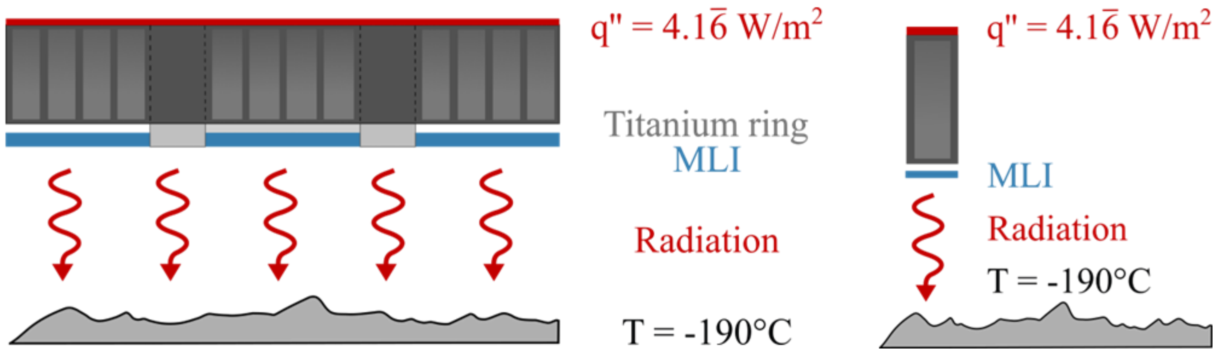
Define recommendations to **reduce mass** of the sandwich panel while :

- Surviving the lunar nights **cold temperatures**
- Resisting to the **random vibrations environnement** of a rocket launch

1. Thermal parametric study

2. Structural parametric study

Complete thermal panel ***Unit cell***



Success criteria / Effective thermal resistance :

$$R_{eff} \geq 0{,}056\ \mathrm{m^2\,K/W}$$

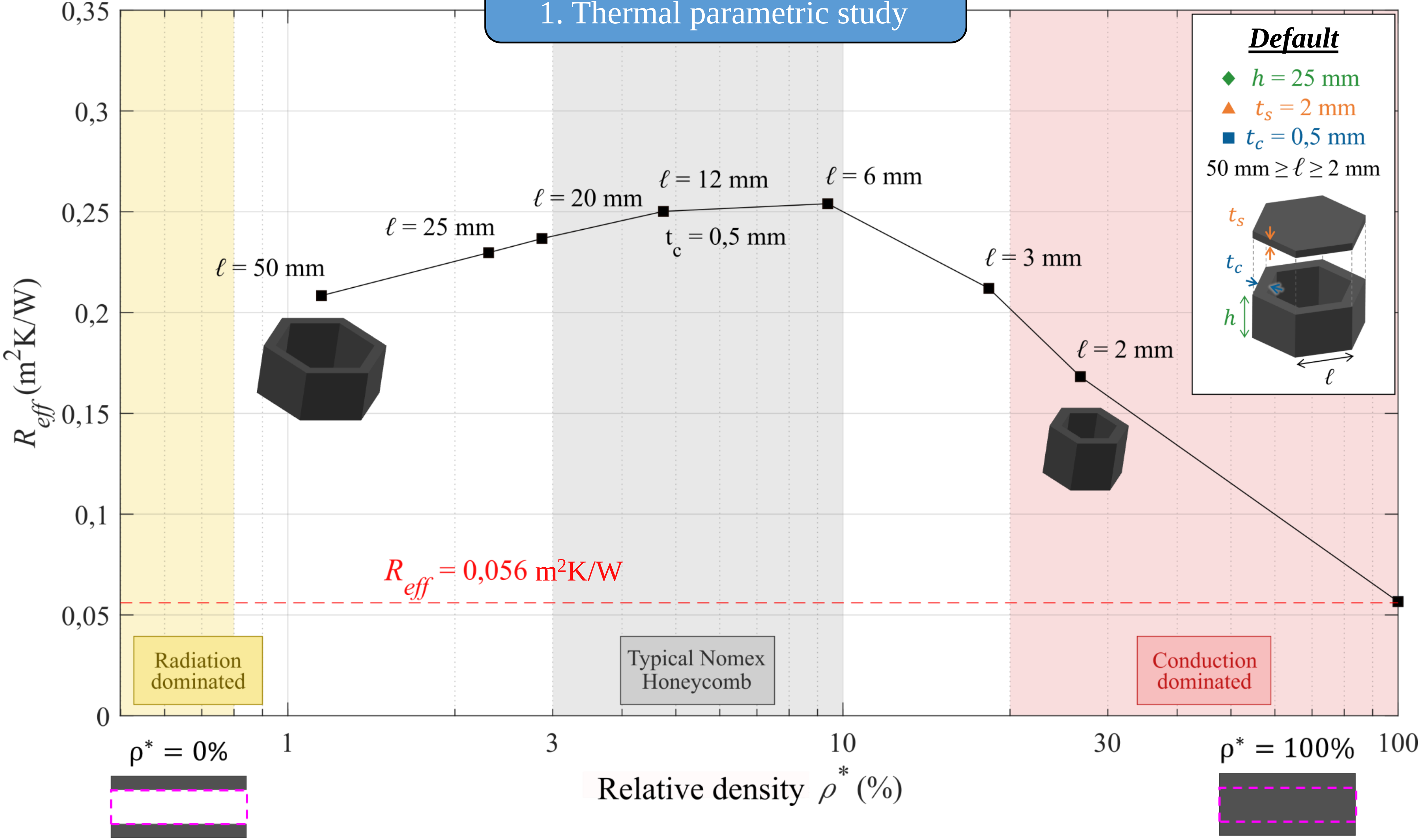
Finite element method

NX
SIEMENS

Broggi, C. (2020). Conception et fabrication additive d'une structure bio-inspirée pour un rover lunaire en composites thermoplastiques [Mémoire de maîtrise, Polytechnique Montréal].

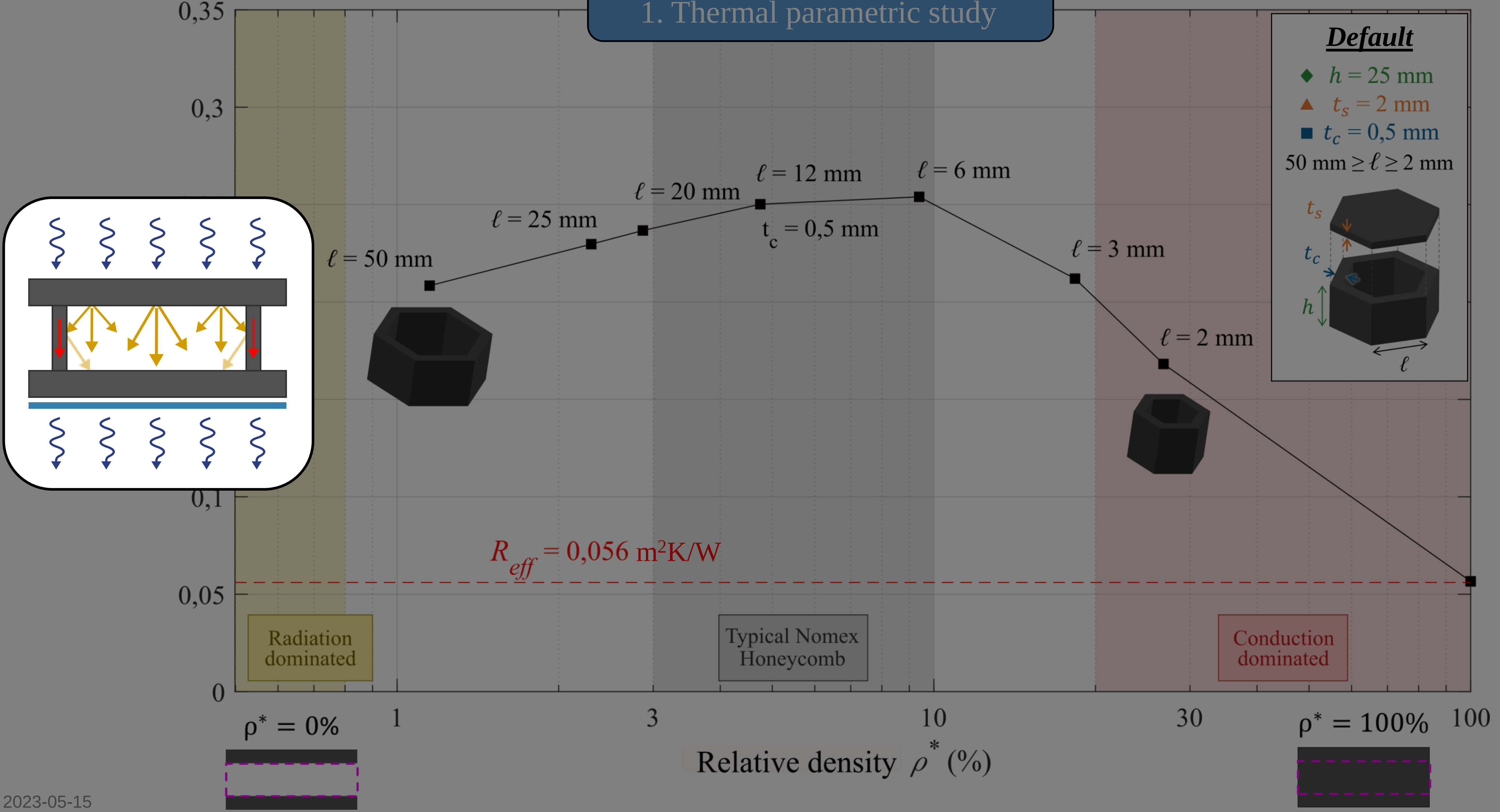
CORE’S WALL LENGTH

1. Thermal parametric study



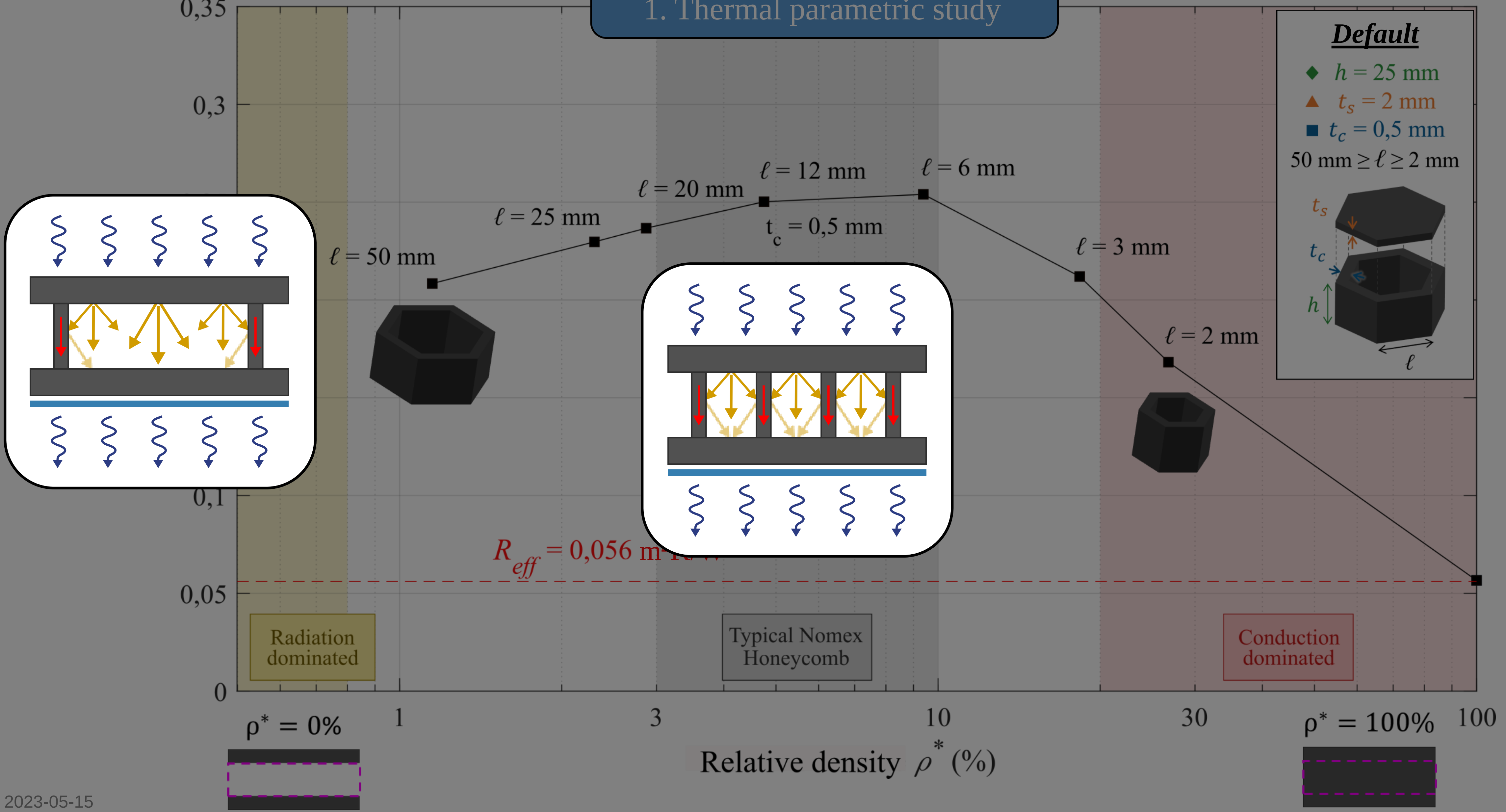
CORE'S WALL LENGTH

1. Thermal parametric study



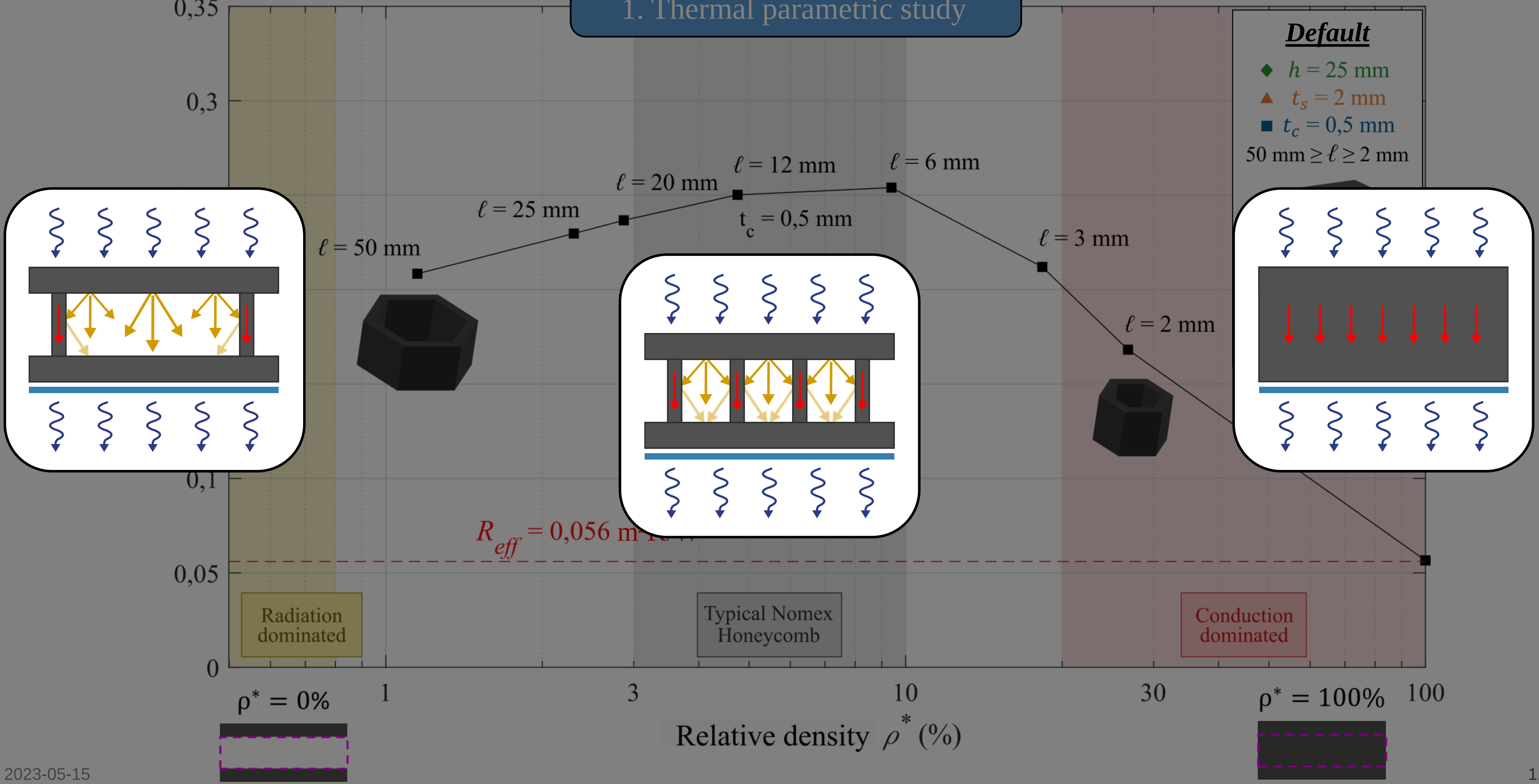
CORE'S WALL LENGTH

1. Thermal parametric study

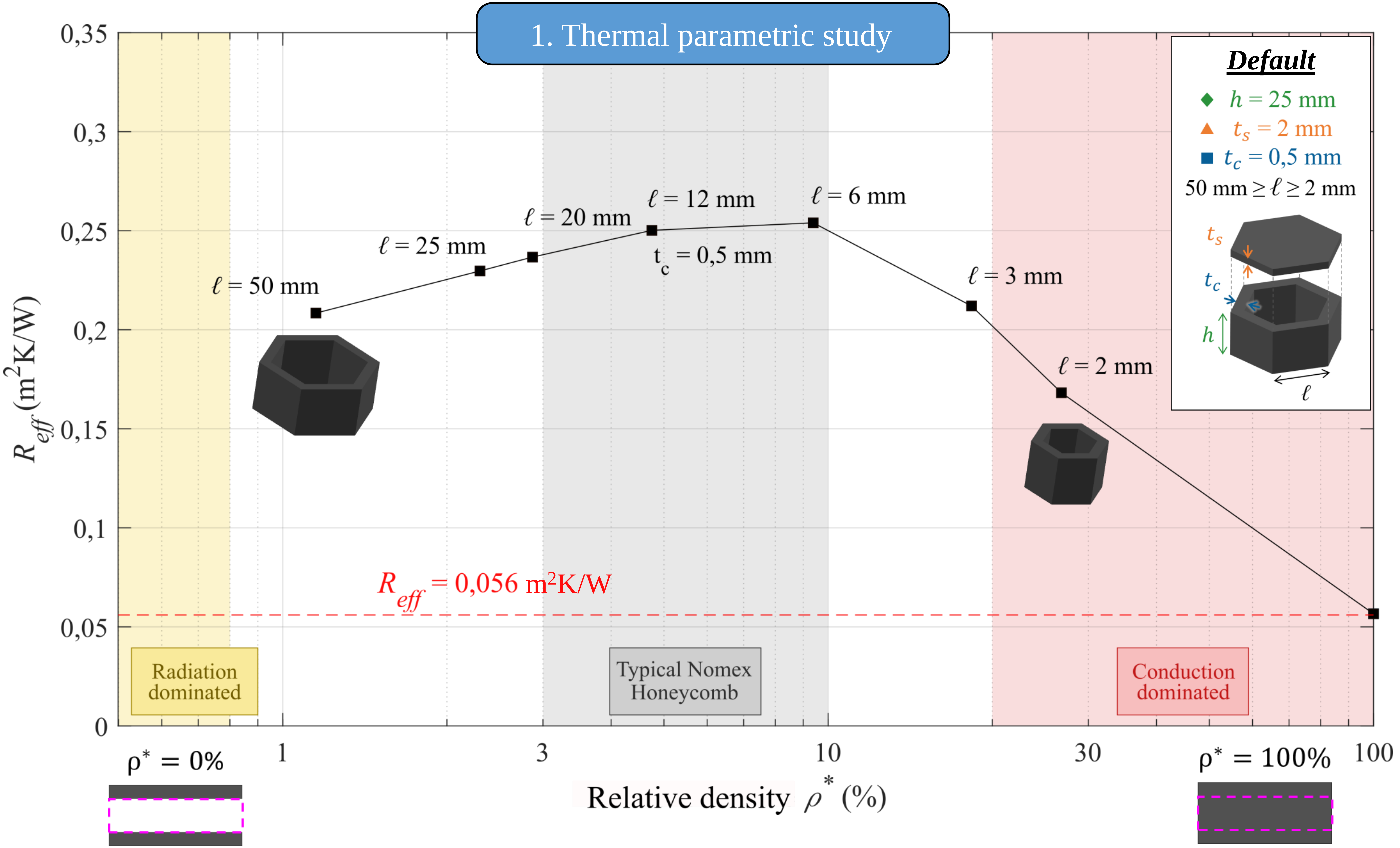


CORE'S WALL LENGTH

1. Thermal parametric study

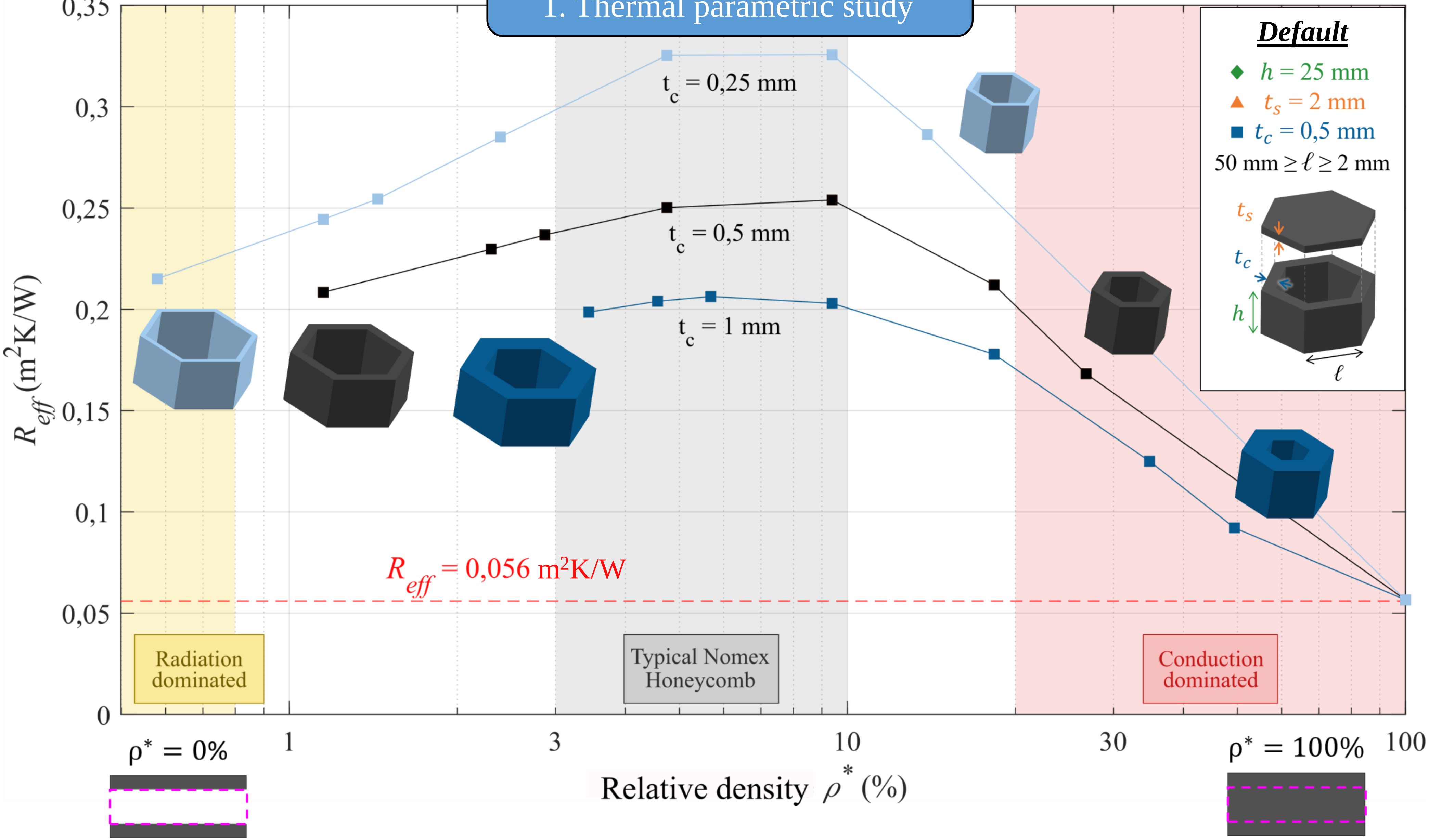


CORE'S WALL LENGTH



CORE'S WALL THICKNESS

1. Thermal parametric study



THERMAL RECOMMENDATIONS

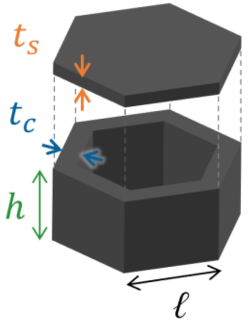
1. Thermal parametric study

To **increase thermal resistance** of the sandwich panel, we recommend to :

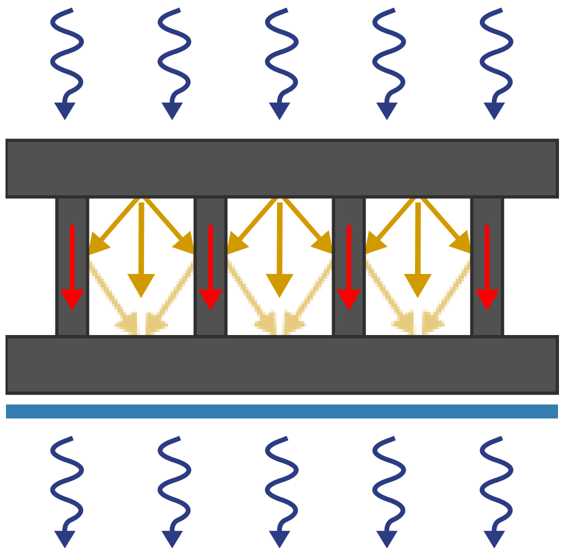
Default

- $h = 25$ mm
- $t_s = 2$ mm
- $t_c = 0{,}5$ mm

$50 \text{ mm} \geq \ell \geq 2 \text{ mm}$



t_c	↘	core's wall thickness
t_s	↘	skin thickness
h	↗	panel thickness
ℓ		$4\% < \rho^* < 8\%$
S		Regular hexagonal cells



OBJECTIVES

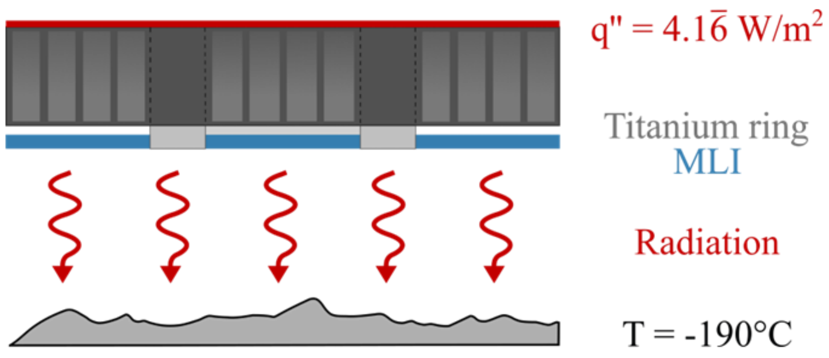
Define recommendations to **reduce mass** of the sandwich panel while :

- Surviving the lunar nights **cold temperatures**
- Resisting to the **random vibrations environnement** of a rocket launch

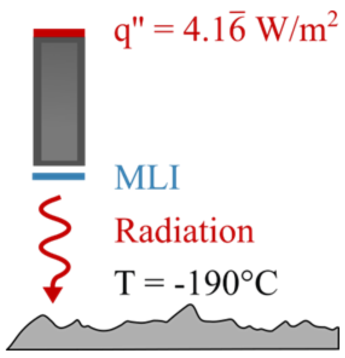
1. Thermal parametric study

2. Structural parametric study

Complete thermal panel



Unit cell



Success criteria / Effective thermal resistance :

$$R_{eff} \geq 0{,}056 \text{ m}^2\text{ K/W}$$

OBJECTIVES

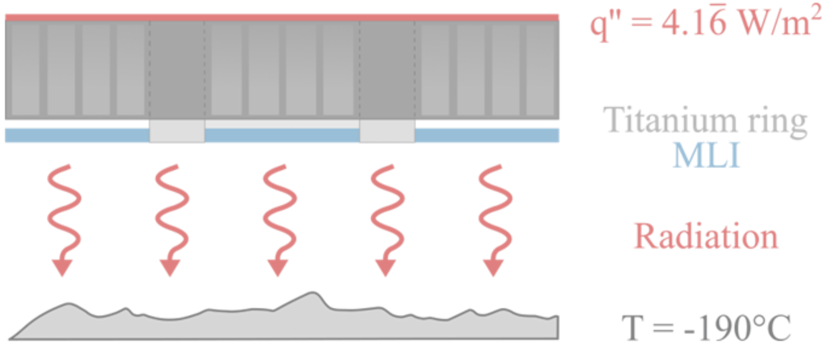
Define recommendations to **reduce mass** of the sandwich panel while :

- Surviving the lunar nights **cold temperatures**
- Resisting to the **random vibrations environnement** of a rocket launch

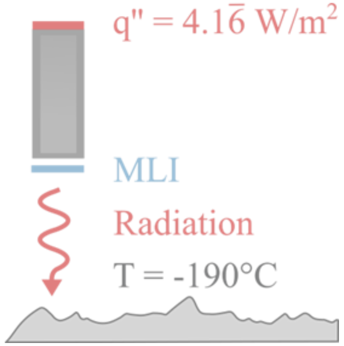
1. Thermal parametric study

2. Structural parametric study

Complete thermal panel

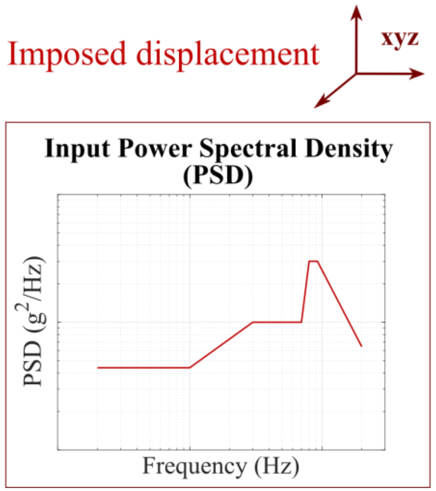


Unit cell

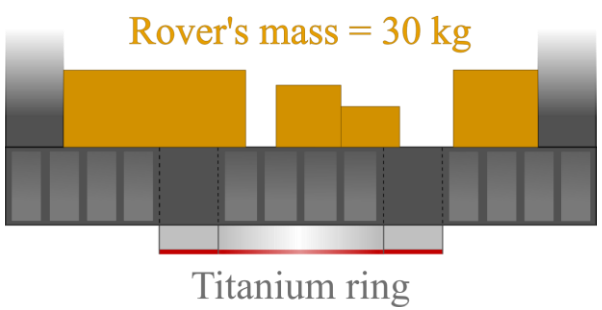


Success criteria / Effective thermal resistance :

$R_{eff} \geq 0{,}056\ \mathrm{m^2\,K/W}$

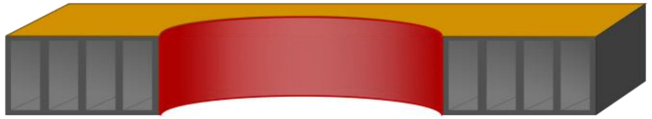


Complete structural panel



Simplified structural panel

NSM = 30 kg distributed across its surface



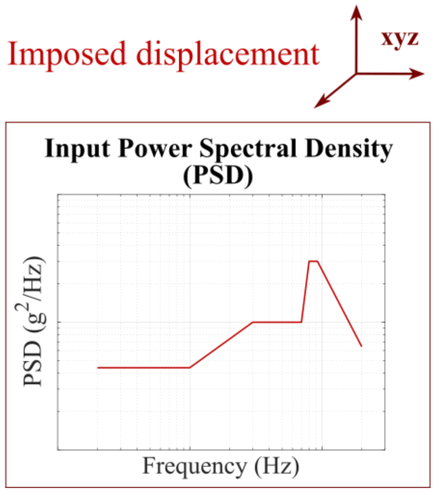
Failure criteria : Tsai-Hill < 1

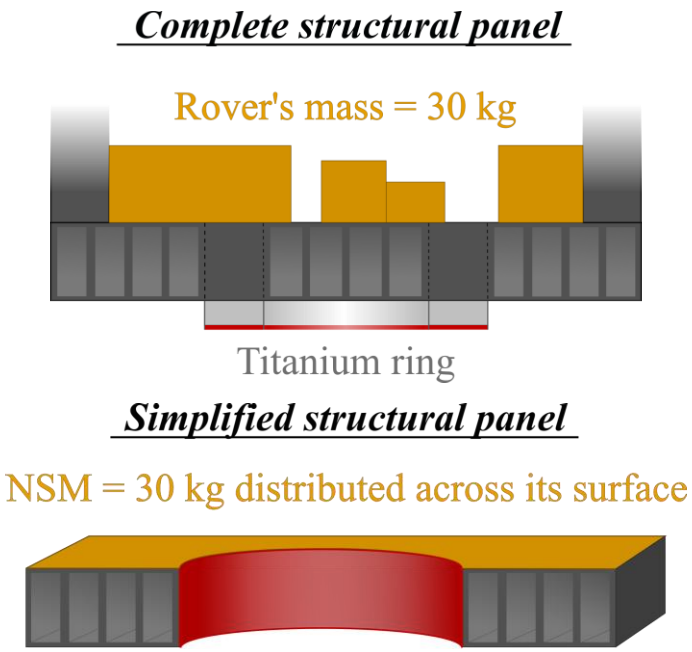
OBJECTIVES

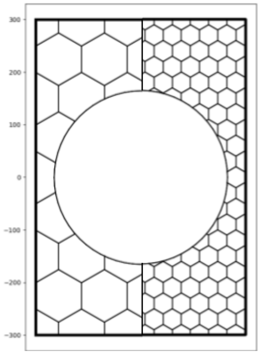
Define recommendations to **reduce mass** of the sandwich panel while :

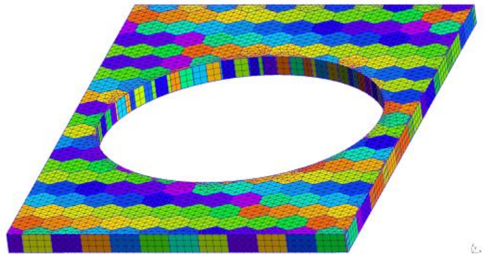
- Resisting to the **random vibrations environnement** of a rocket launch

2. Structural parametric study

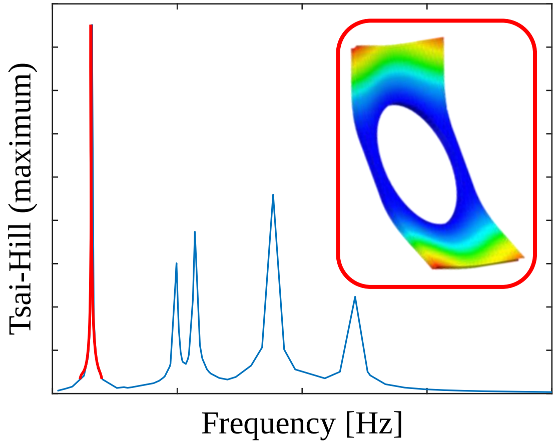








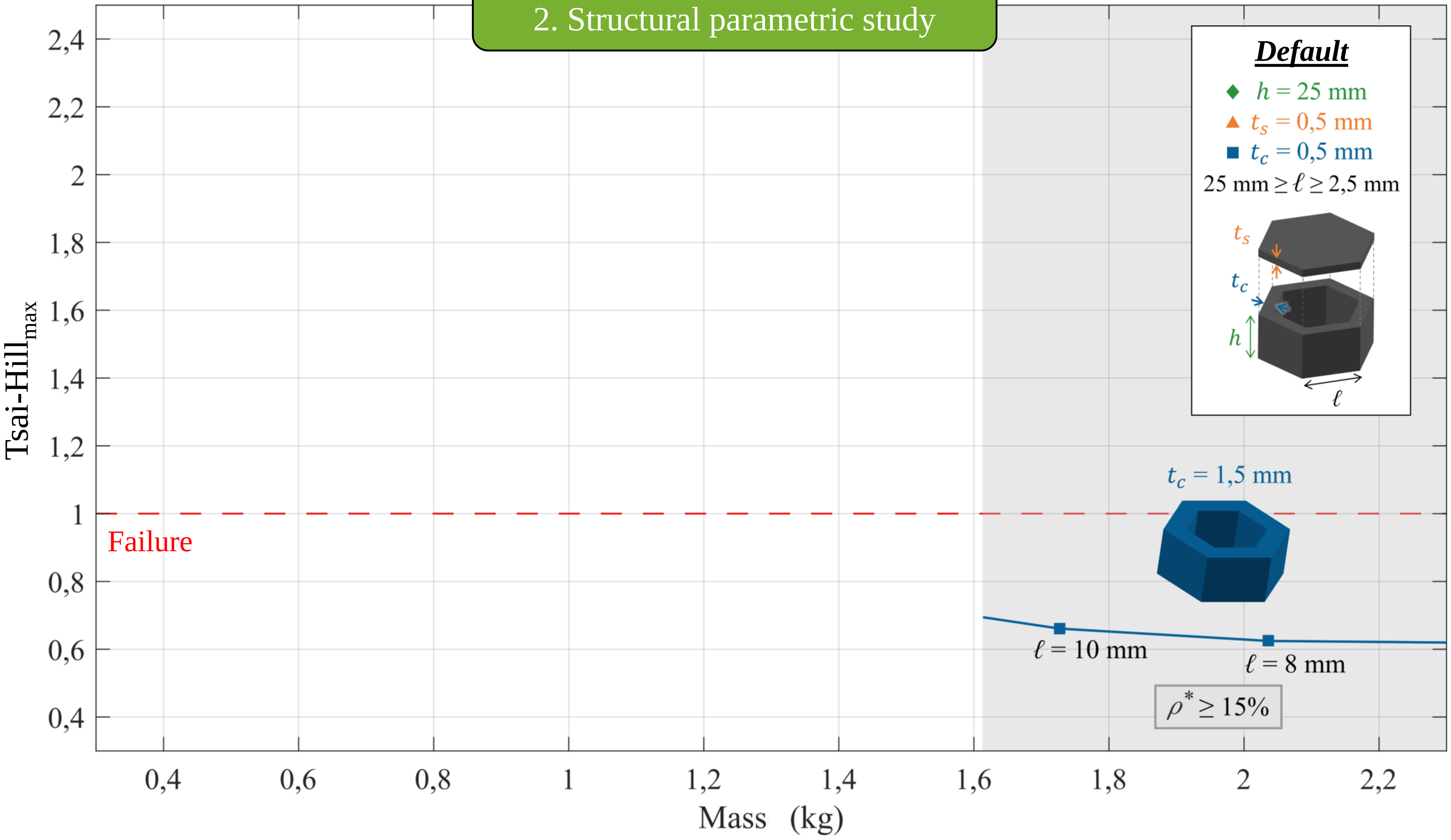
Output PSD (SOL 111)



Failure criteria : Tsai-Hill < 1

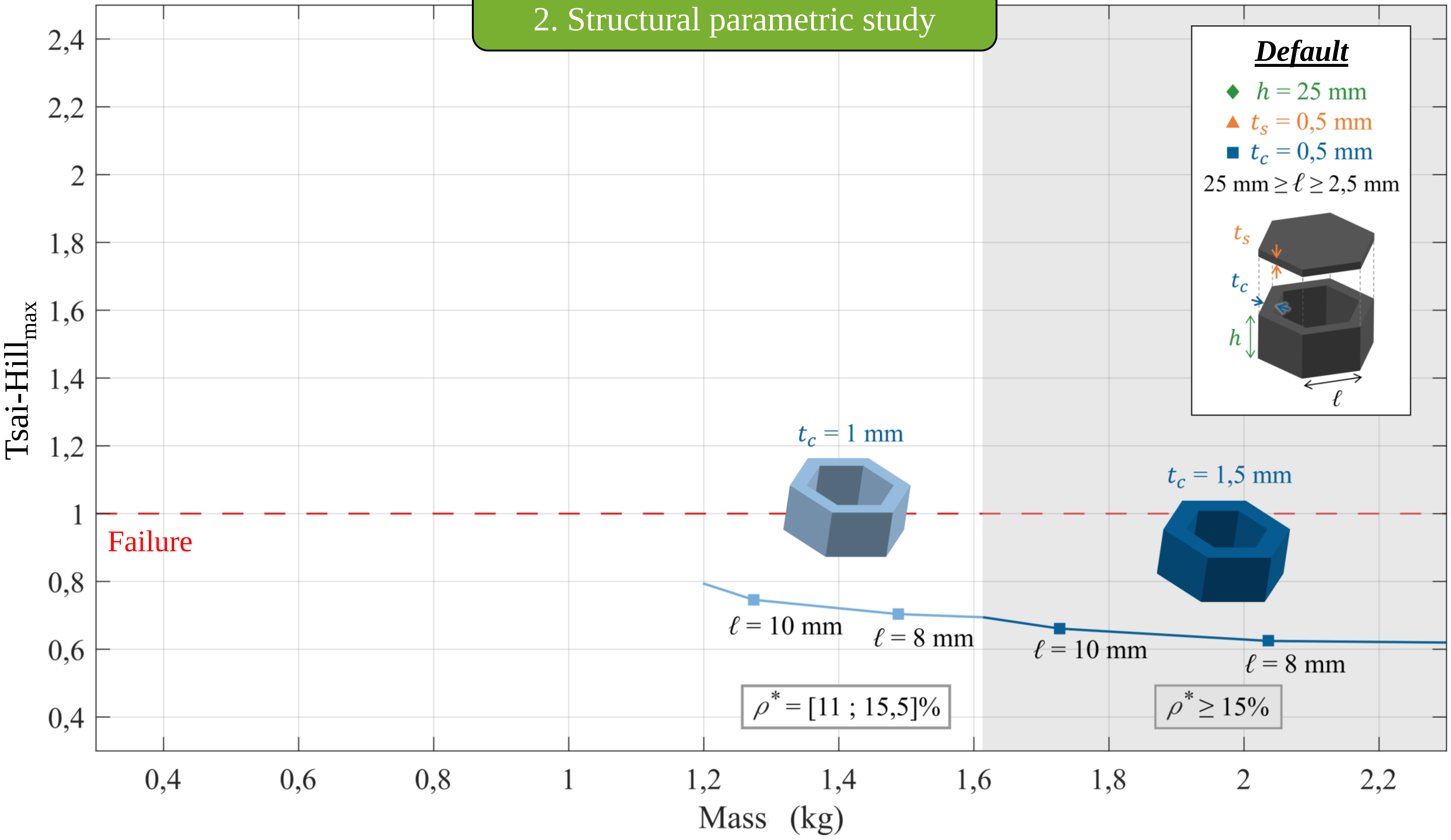
STRONGEST SPECIFIC PANEL MODELED

2. Structural parametric study



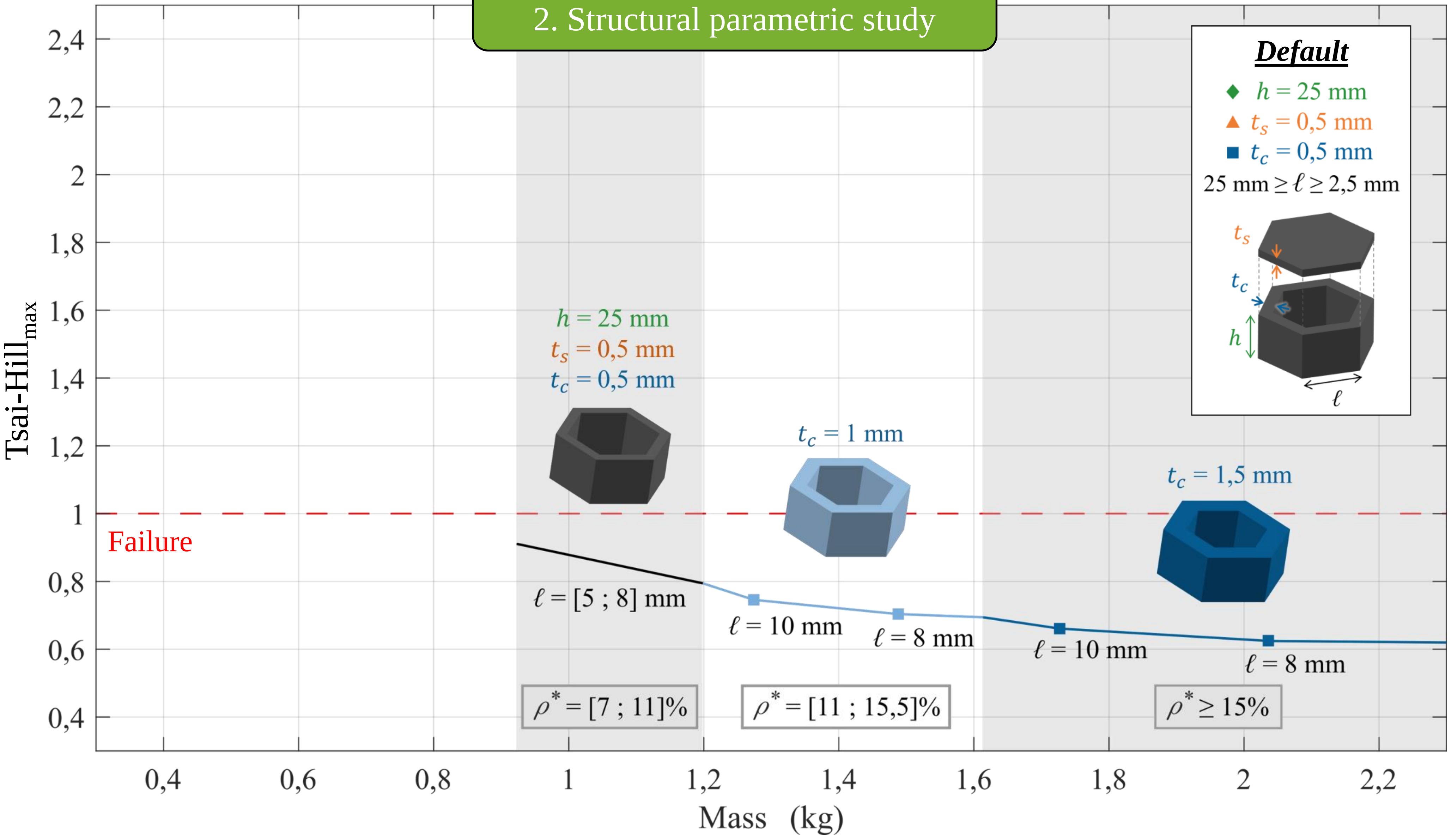
STRONGEST SPECIFIC PANEL MODELED

2. Structural parametric study



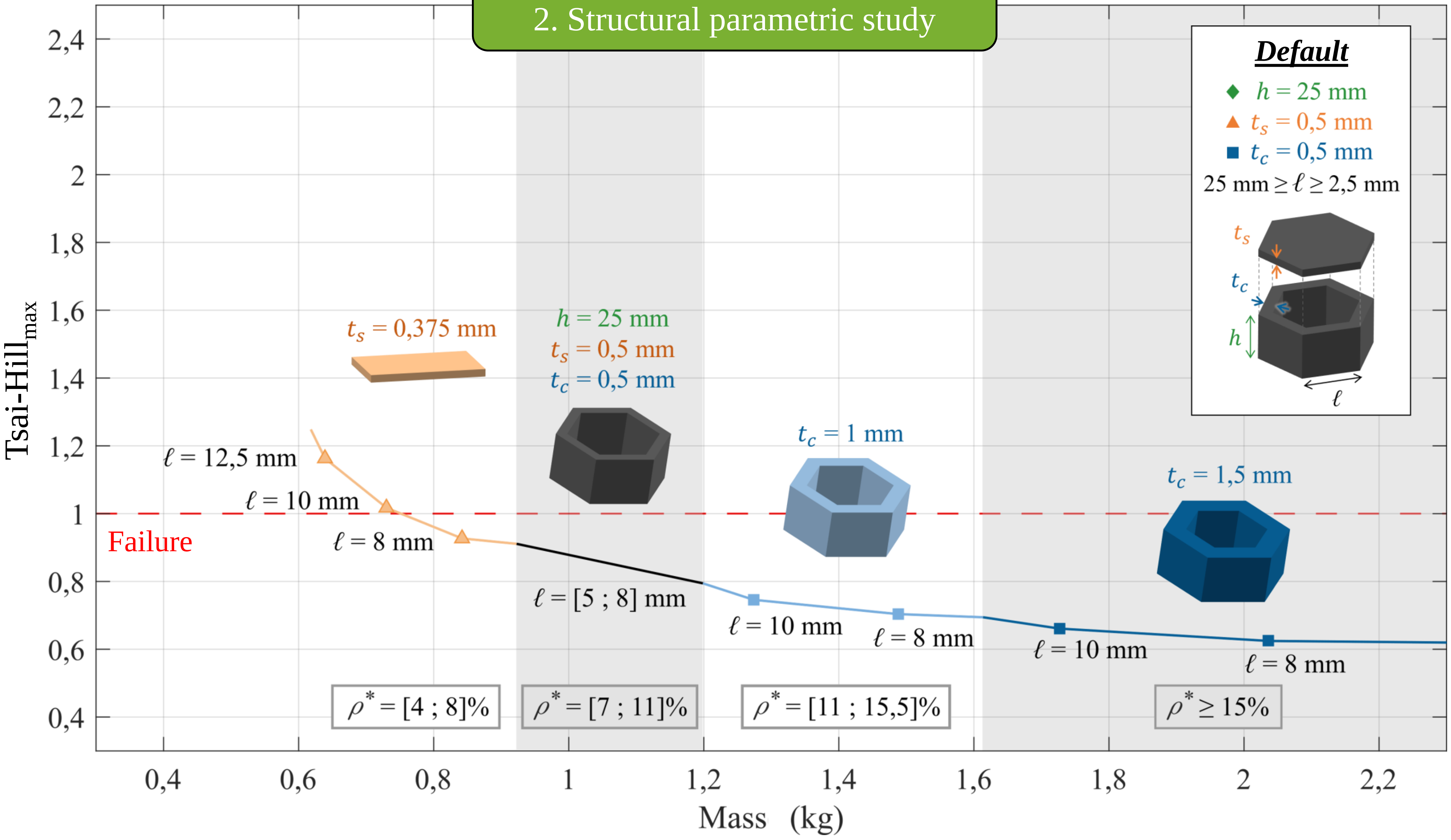
STRONGEST SPECIFIC PANEL MODELED

2. Structural parametric study



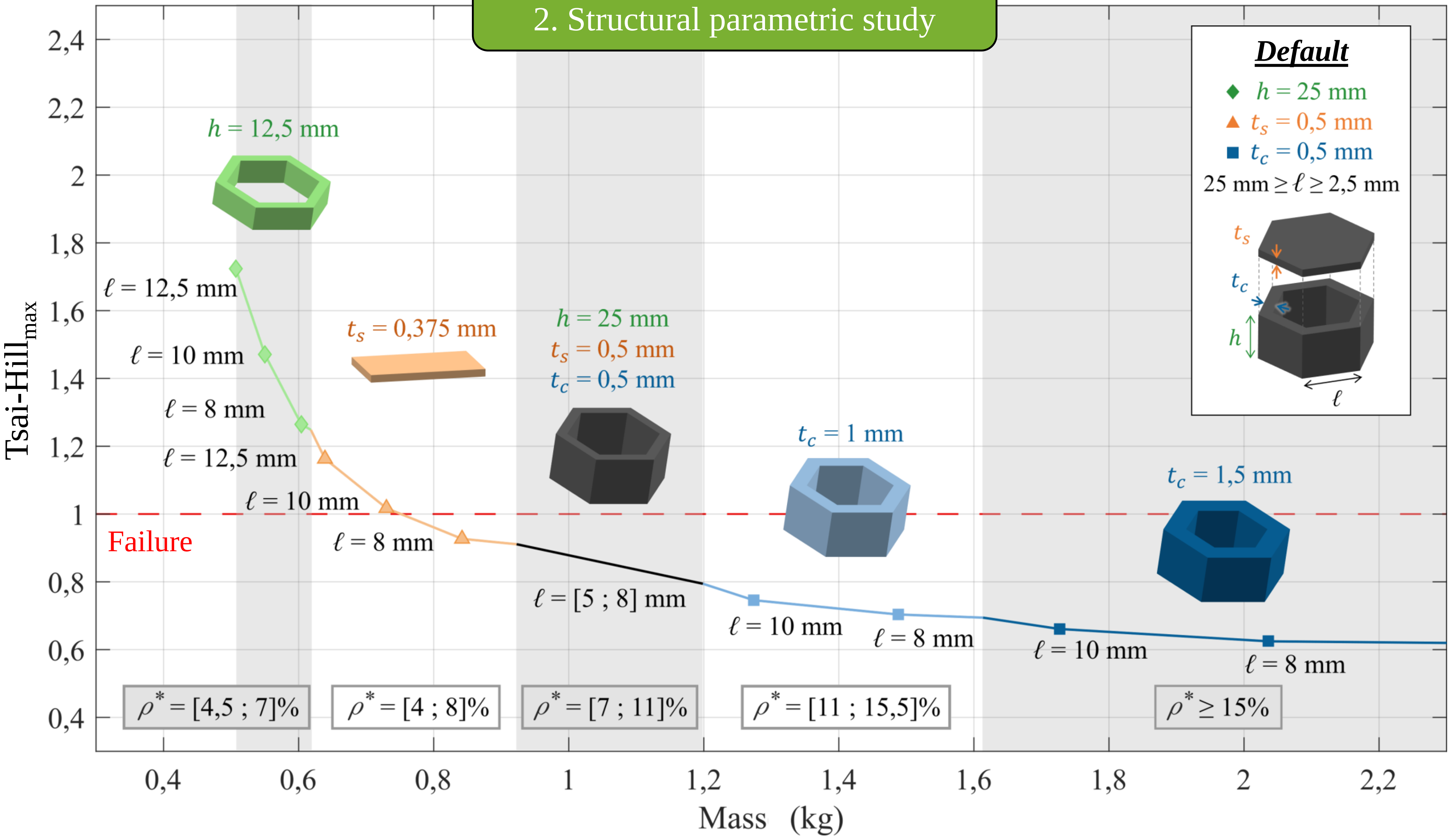
STRONGEST SPECIFIC PANEL MODELED

2. Structural parametric study



STRONGEST SPECIFIC PANEL MODELED

2. Structural parametric study



To **reduce mass** of the sandwich panel forming the base of the lunar rover's frame :

Thermal & Structural

$\boldsymbol{S}$ Regular hexagonal cells

$\boldsymbol{t_c}$ ↘ core's wall thickness

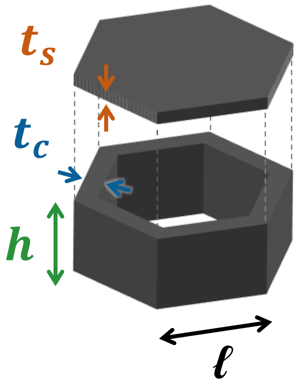
$\boldsymbol{t_s}$ ↘ skin thickness

Thermal

$\boldsymbol{h}$ ↗ panel thickness

$\boldsymbol{\rho^*}$ $4\% < \rho^* < 8\%$

Parameters



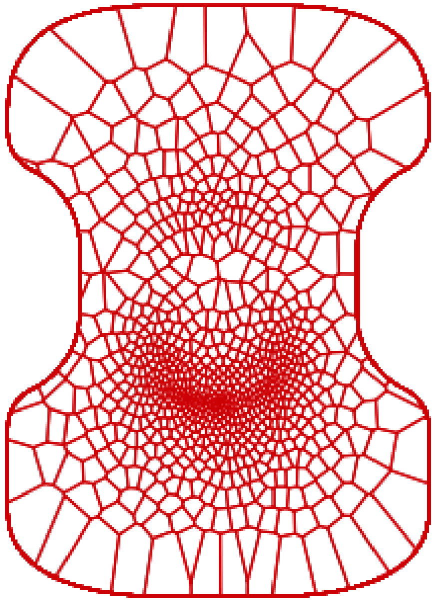
Structural

$\boldsymbol{h}$ ↘ panel thickness

$\boldsymbol{\ell}$ $7 \text{ mm} < \ell < 11 \text{ mm}$

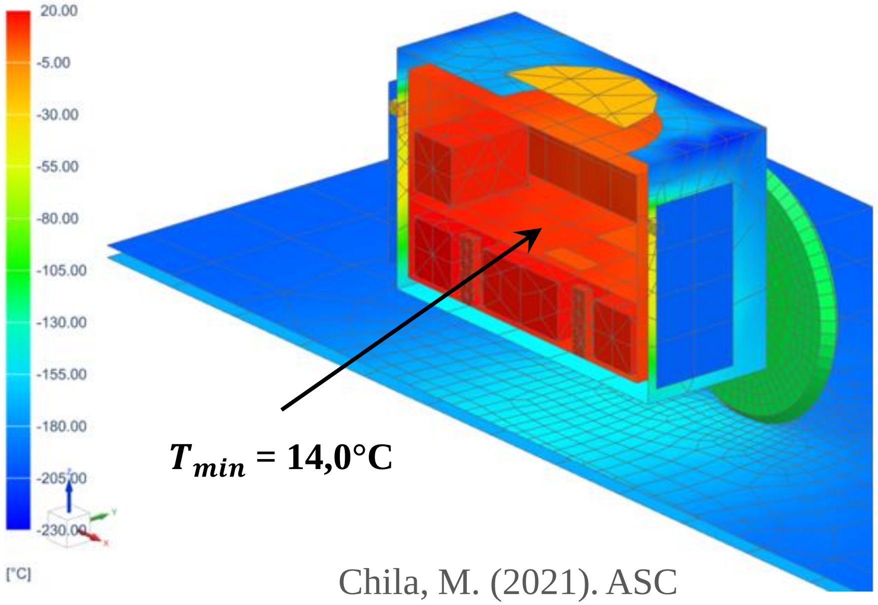
FUTUR WORK

- **Customed** thermoplastic rover structures
- **Optimisation** of the structure for a given loading case
- Study of the **in-plane conduction** impact of rover's structure



Duchesne O. (2021)

PEEK Sandwich Panel Lunar Rover Structure



Chila, M. (2021). ASC

THANK YOU FOR LISTENING