Multi-layer insulation modeling

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Introducing multi-layer insulation

Multi-layer insulation (MLI) is a type of thermal insulation commonly used in spacecraft and other applications where it is necessary to maintain a stable temperature within a structure.

Photo Credit : John Rossie of AerospaceEd.org

MLI blankets consist of:

- Alternating layers of highly reflecting material.
- Low conductivity spacer material or insulator.

In Simcenter 3D Space Systems Thermal, you can model multi layer insulation or MLI in different ways.

Modeling MLI layer explicitly

To model each layer explicitly, you:

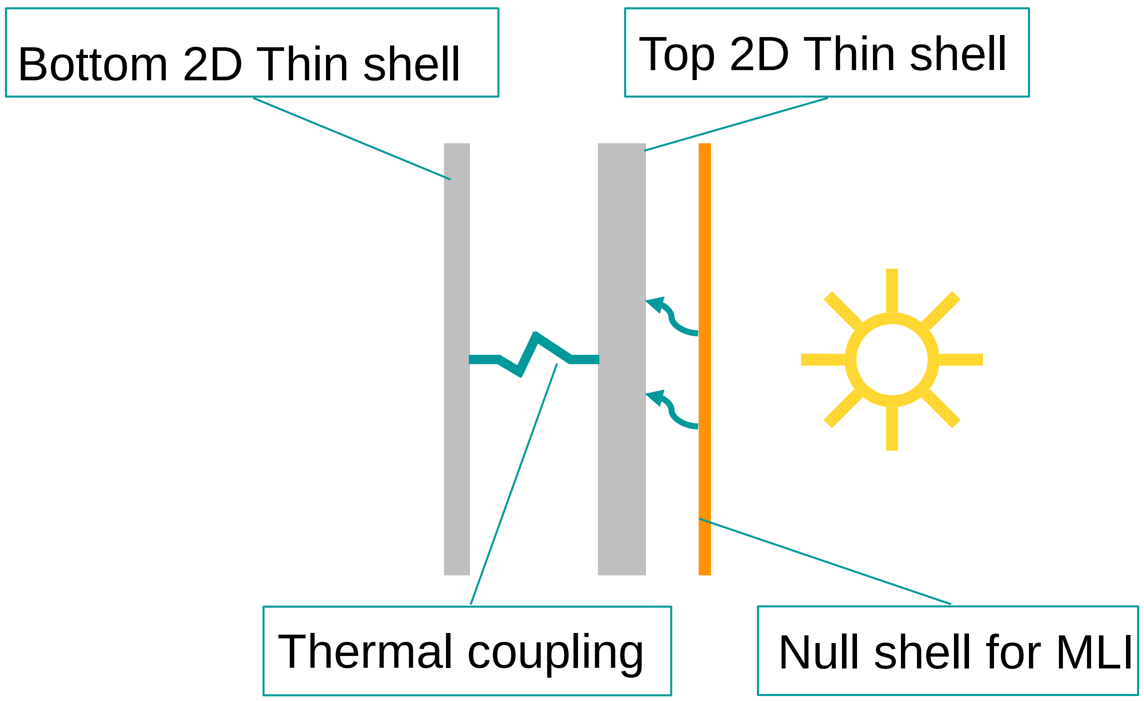
- Create top and bottom facesheets of a honeycomb panel as separate 2D thin shells.
- Create a null shell for MLI with defined top and bottom thermo-optical properties.
- Define **Thermal Coupling** between 2D thin shells.
- Define **Thermal Coupling-Radiation** between the top facesheet and MLI using the specified effective emissivity.

Pros:

- MLI and facesheets are explicitly modeled and are available in post-processing.

Cons:

- A separate sheet for MLI needs to be created.
- An additional thermal coupling between MLI and 2D thin shell needs to be defined.



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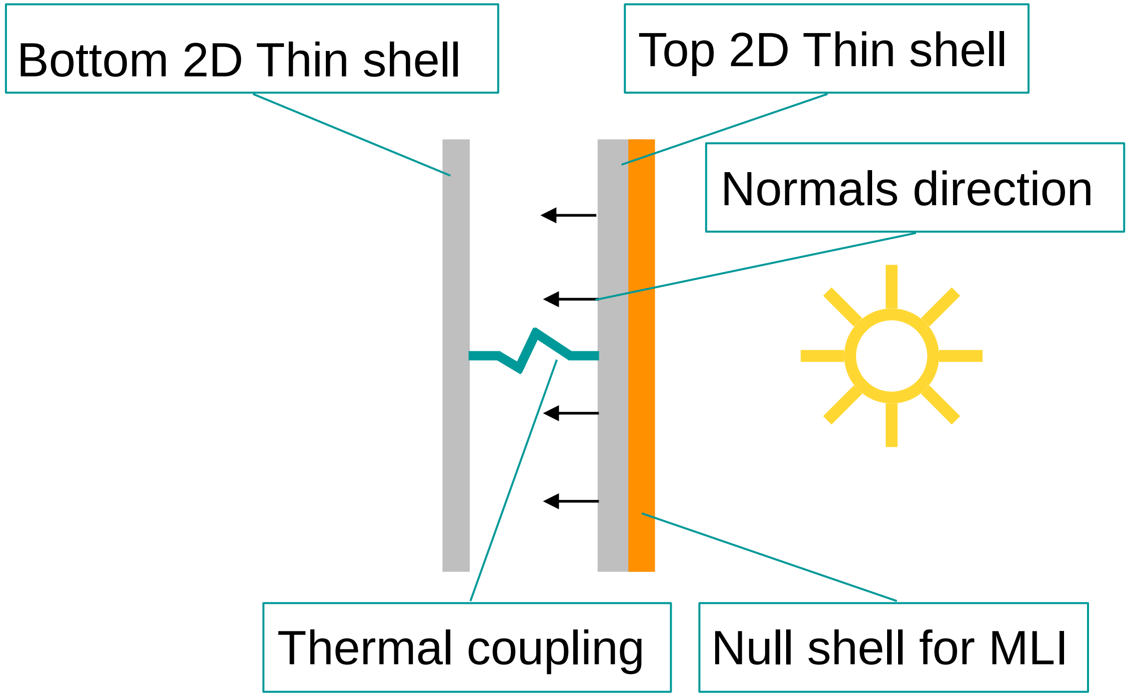
Modeling MLI using two-layer shells

To model MLI using two-layer shells, you:

- Create top and bottom facesheets as separate 2D thin shells.
- For the top 2D thin shell, use the **Create Top and Bottom as Two-Layer Shells** option to create a thermal resistance between the top and bottom of the shell element.
- Reverse the top 2D thin shell element normals to point inside the panel.
- Define **Thermal Coupling** between 2D thin shells.



Pros:
- No need to create additional shells or layers.

Cons:
- Verify the element normals.
- Display results on bottom location, or on top and bottom locations with **Backface Culling**.

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Modeling MLI using multi-layer shell

To model MLI using multi-layer shell, you:

- Create **Multi-Layer Shell Non-Uniform** for part or all of stack.
- Use the **Coupling to Layer above** option to specify the coupling magnitude. Optionally, you can create a thermal coupling separately.

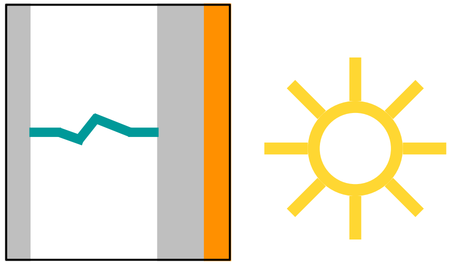
Pros:

- All layers are defined in a single shell.
- Can capture full stack or just top facesheet and MLI.

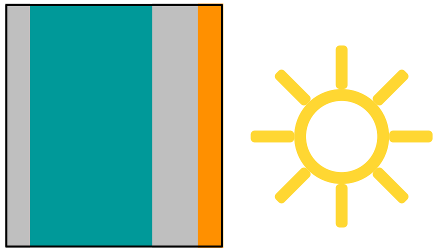
Cons:

- All layers, including MLI thickness and null material properties need to be defined.
- In post processing, you can view layer going from bottom (Ply 1) to top (Ply N).

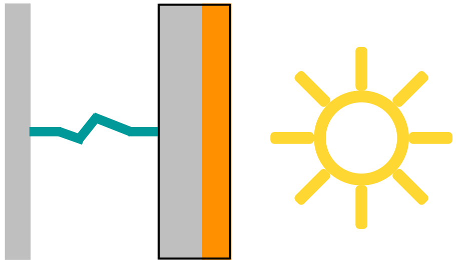
Honeycomb as thermal coupling



Honeycomb as a layer



Top facesheet and MLI only



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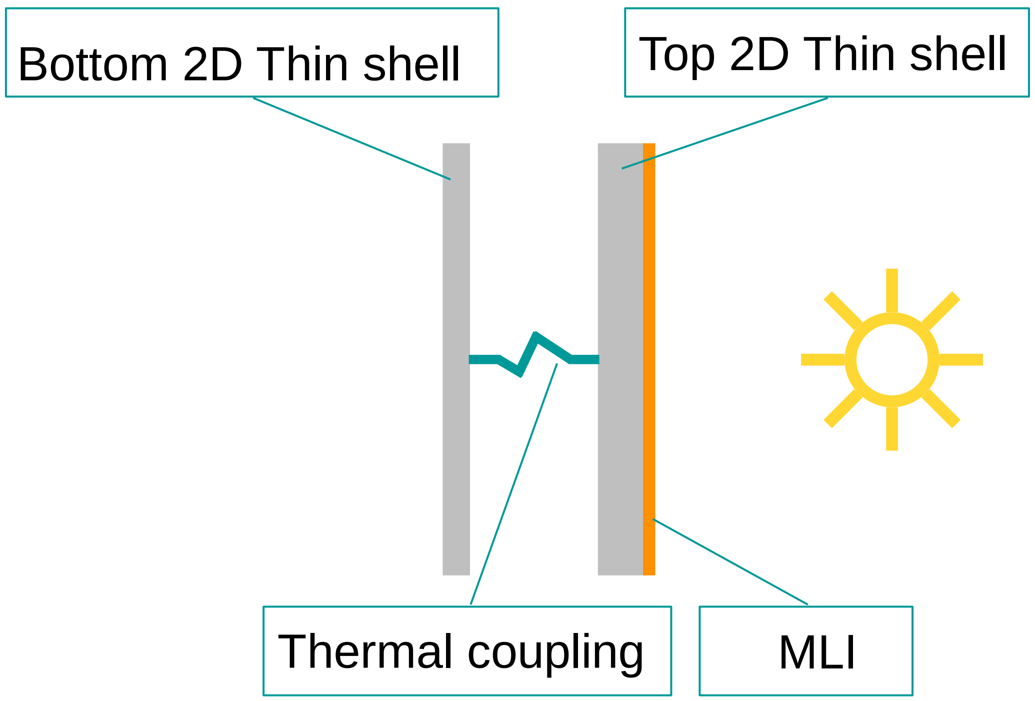
Modeling MLI using effective thermo-optical properties

To model MLI using thermo-optical properties, you:

- Create top and bottom facesheets as separate 2D thin shells.
- Define thermo-optical properties, such as emissivity and absorptivity, for MLI on the top facesheet.
- Define **Thermal Coupling** between 2D thin shells.

Pros:
- No need to create additional shells or layers.

Cons:
- Need to compute effective properties.
- Shows less accurate results.



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Comparing results

Modeling approach	Tmin (MLI)	Tmax (MLI)	Tmin (Top FS)	Tmax (Top FS)	Tmin (Bottom FS)	Tmax (Bottom FS)
Explicit MLI	57.714	58.175	91.041	99.724	91.071	100.496
Two-layer shells	57.713	58.173	91.04	99.722	91.07	100.494
Multi-layer shell	57.714	58.175	91.041	99.724	91.071	100.496
Effective TO properties			89.84	98.525	89.87	99.297