Thermal Engineering for space

Science and Technology Facilities Council

RAL Space

RAL Space

- Based at the Rutherford Appleton Laboratory in Oxfordshire
- Approximately 330 staff

“We are the UK’s national laboratory to advance the exploration of space and the environment, for the benefit of all.”

Explore inside our labs on our virtual 360 tour: https://www.ralspace.stfc.ac.uk/Virtual%20Tour/RALSpaceV1/index.aspx

Credit: STFC RAL Space

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What do we do?

- **Design and Build -** Space hardware
- **Science and Research -** Astronomy, Solar Physics, Climate, Earth observation
- **Technology Development -** Optics, Thermal, Electronics, Spectroscopy
- **Data/Information -** Curation, Analysis, Dissemination
- **Facilities -** Ground Stations, Precision machining, Calibration, Environmental Testing
- **Economic Impact -** Spin-out, Outreach, Training

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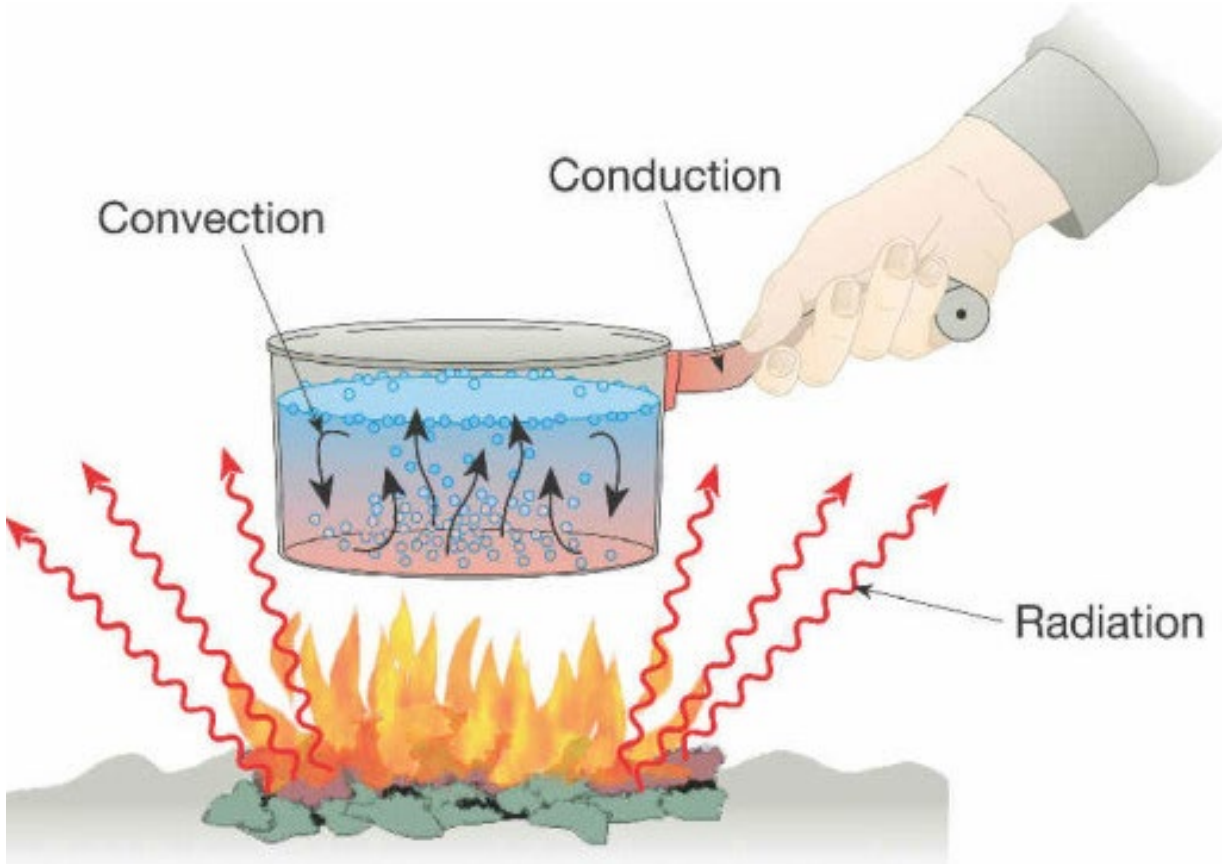
Top left: Chilbolton Observatory 25m radio dish.
Top right: space weather.
Bottom: Space test chamber. Credit: STFC RAL Space

What is thermal engineering and how does it apply to space?

Animation: https://youtu.be/ESSbVgWOJ8s

Modes of Heat Transfer

- **Conduction**: the transfer of heat via direct contact
- **Convection**: the transfer of heat through a fluid (liquid or gas) caused by molecular motion
- **Radiation**: the transfer of heat via electromagnetic radiation



Thermal engineering is the study and understanding of heat transfer and controlling these processes to manage the **temperature** of the equipment we design, ensuring it stays within safe operating limits.

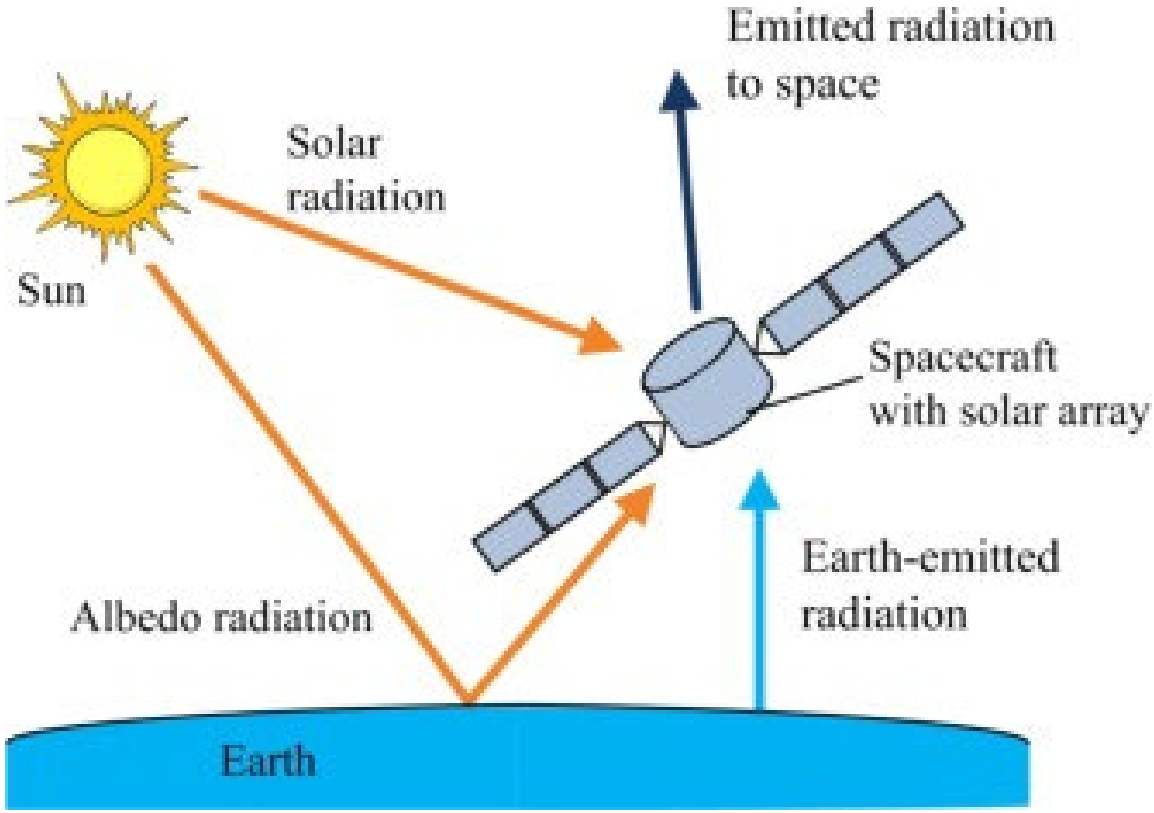
Why is this important for space?

- Reliable, long-term performance of most spacecraft components requires them to operate within thermal ranges
  - We can't replace items once they're in space!
- We need to ensure that these temperature requirements are met for **all components during all mission phases**
- Thermal engineers are therefore involved in the design of nearly every onboard system

Component	Operating Temperature Range (°C)	Survival Temperature Range (°C)
Electronics	0 to 50	-20 to 70
Batteries	0 to 15	-10 to 25
IR detectors	-269 to -173	-269 to 35
Solar panels	-150 to 110	-200 to 130
Momentum wheels	0 to 40	-20 to 50
Fuel	15 to 40	5 to 50

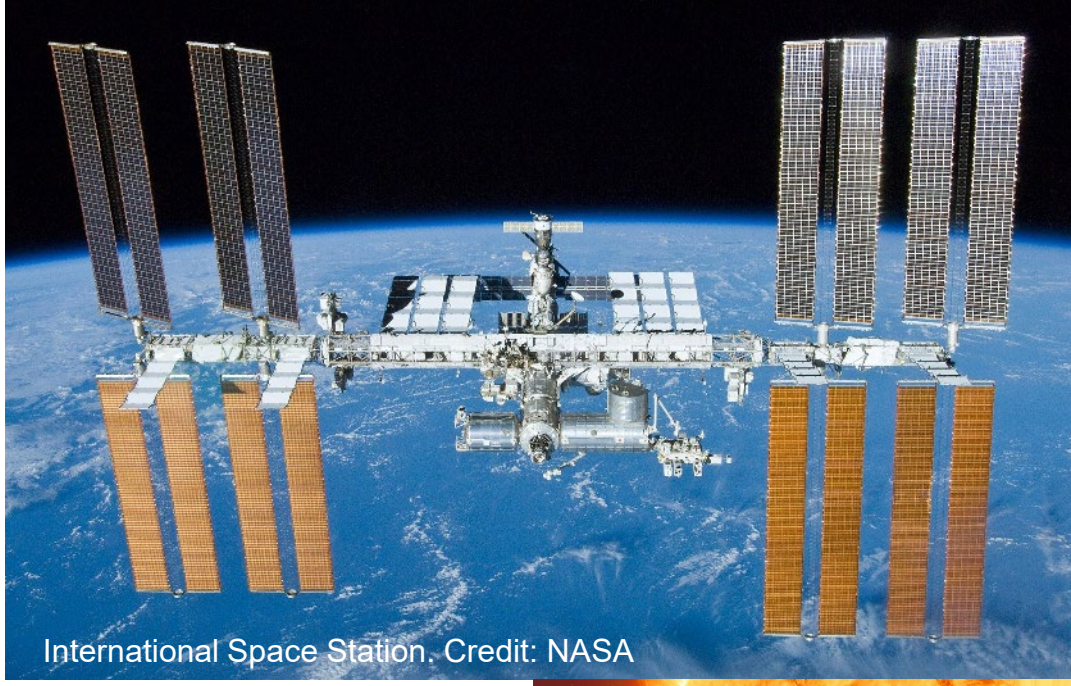
Why is this difficult?

- There is no atmosphere in space so radiation is the dominant heat transfer mode between a spacecraft and its surroundings
- The thermal environment is very extreme and variable
  - Very cold background at about -270°C
  - Intense solar radiation in direct sunlight, which disappears when the spacecraft enters the Earth's shadow
- We need to balance the extremes of hot and cold to keep the spacecraft temperature somewhere in the middle

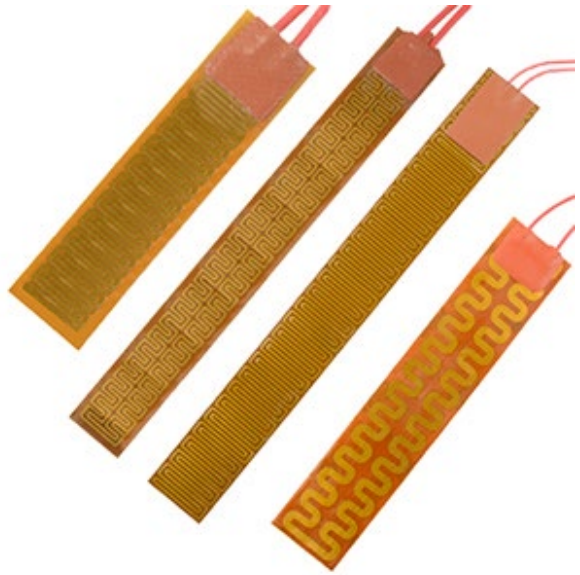


How do we do it?

- Combination of **passive** (unpowered) supplemented by **active** (powered) thermal control
- Passive
  - Radiators to transmit heat to deep space and prevent overheating
  - Insulation to limit heat absorption from the environment (or stop heat escaping)
  - Specialised coatings to absorb or reflect sunlight
- Active
  - Heater control systems (to stop sensitive components from freezing)
  - Cryogenic cooler systems
- Thermal engineers prefer passive control because of limited power availability and it's more reliable



International Space Station. Credit: NASA



Kapton heaters are small (few cm across) flexible and resilient, suitable for efficient heat transfer in spacecraft.

Solar Orbiter. Credit: ESA

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Passive Thermal Control

Polar bears have transparent fur with black skin underneath to absorb as much sunlight as possible while trapping the heat

Fennec foxes have large ears that act as natural radiators, to maximise surface area for heat removal and stay cool

How do we insulate in space?

- We use a special type of material called **Multi-Layer Insulation (MLI)**
- MLI is made up of lots of very thin layers of foil separated by a spacer material
- The foil is shiny, to limit radiative heat transfer, and the spacer material stops heat from conducting between layers
  - And remember, there's no air in space so no convection between the layers!
- Pretty much every spacecraft uses MLI in some way – we have our own MLI manufacturing facility at RAL Space
- We made novel cryogenic MLI for the Mid-Infrared Instrument onboard the Webb Telescope, to ensure it stays at 7K (-266°C) for its highly sensitive IR detectors

MLI sample. Credit: STFC RAL Space

MIRI covered in MLI blankets. Credit: STFC RAL Space

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MLI experiment


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Video demonstration: https://youtu.be/dqbY2_vL3RI
So first off Multi-Layer Insulation can be a bit of a mouthful
so we tend to shorten it to MLI.

Materials

Tin foil

3 ice cubes

Netting (from a pack of oranges/fruit)

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Materials

Single Layer Insulation

Multi Layer Insulation

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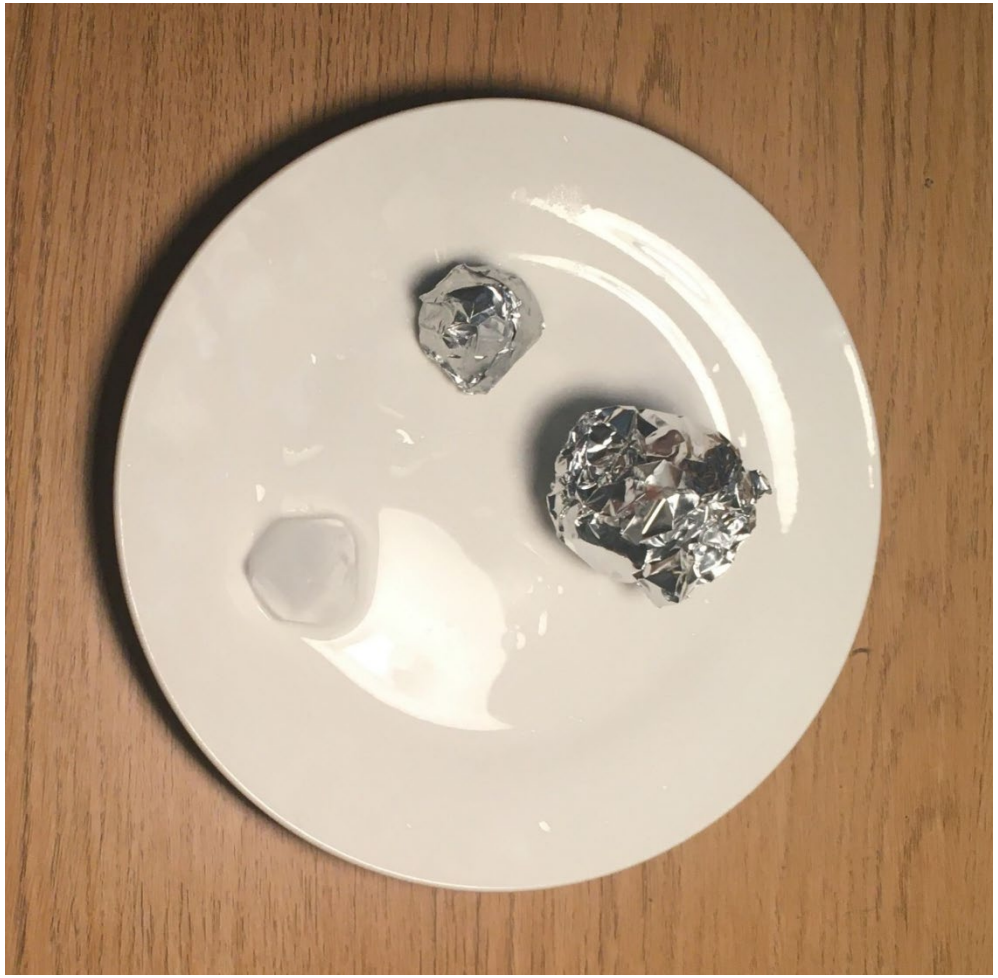
Before and after



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Meet our MLI Technicians

Read and watch our technicians' career profiles to find out what they do day-to-day and why they enjoy it, and how they got into their jobs – there are a variety of routes into the space sector.

Celine:
https://www.ralspace.stfc.ac.uk/Pages/Celine-Elledge.aspx

Reuben:
https://www.ralspace.stfc.ac.uk/Pages/Reuben-Chesterman.aspx

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Thank you

If you have any questions, get in touch via our social media channels or email ralspaceenquiries@stfc.ac.uk

Acknowledgements

Declan Jonckers

Sam Tustain

Haider Razzaq

Vicky Stowell

Dylan Feore

Vicky Hall

Celine Elledge

Reuben Chesterman

Poppy Holford