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# Thermal Management for Small Sats

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# Importance of thermal analysis

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- Ensuring mission survival
  - Temperatures far outside of acceptable ranges can kill components in a short period
- Extending operational lifespan
  - Even if temperatures are not extreme enough to quickly disable electronics, high temperature variation and long term exposure to extreme temperatures can reduce the lifespan of internal components.

# Importance of thermal analysis-cont'd

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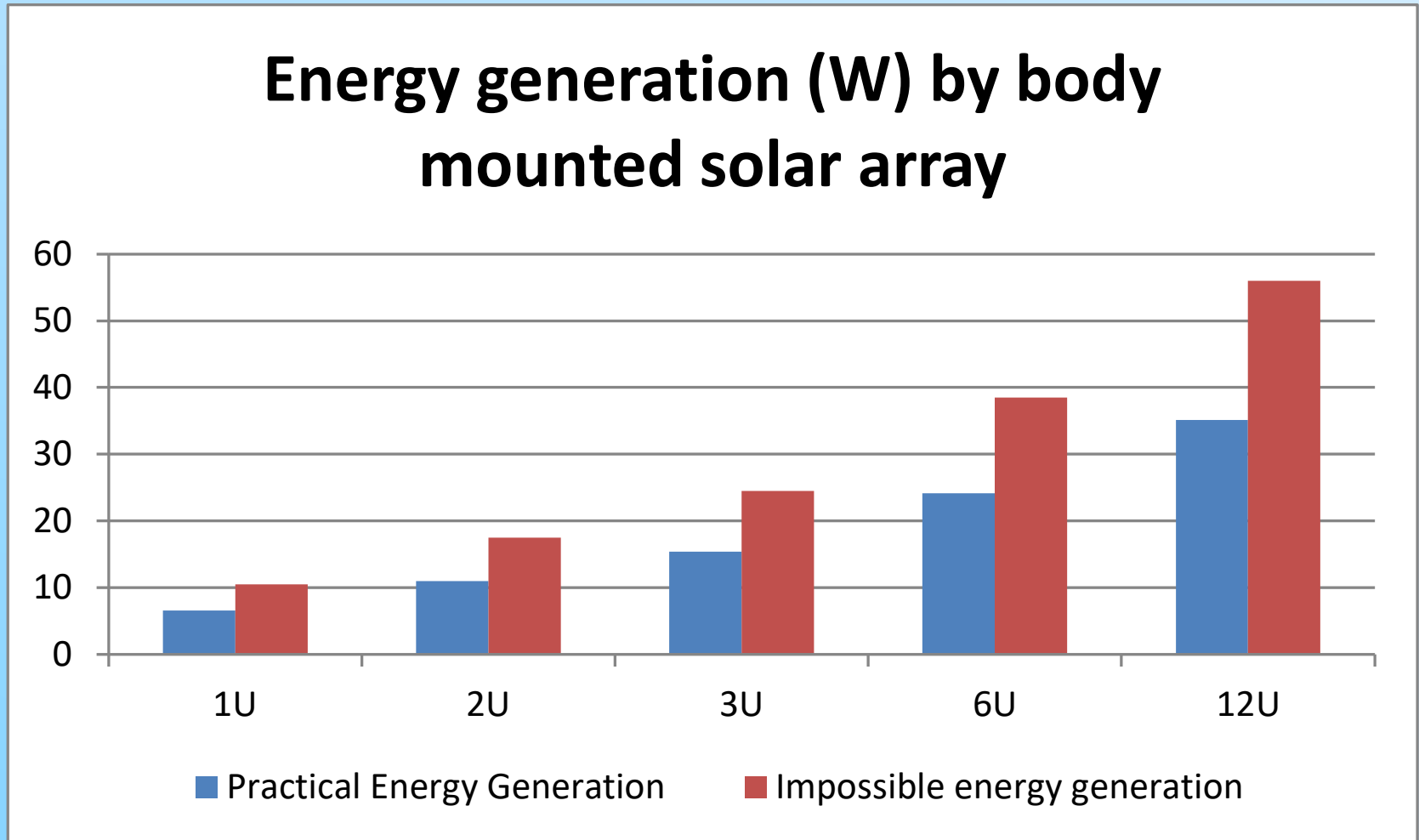
- Generated power is determined by:
  - solar array
  - radiator - **typically missing in thermal analysis for smallsats**
- Electronics is not efficient – up to 50 to 70 % is wasted as heat and must be rejected into space
- Solar arrays
  - body mounted
  - deployable
- Radiators
  - body mounted
  - ~~deployable~~ - **are not practical so far.**

# Body Mounted Solar Array

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- Solar array surface + radiator surface = s/c total surface
- Solar array surface is limited by radiator area
- Assumptions
  - 40% of generated energy is converted to heat and must be rejected into space
  - Energy generation is  $250 \text{ W/m}^2$  of solar array surface
  - Half of radiator surface is facing space, half is facing Earth
  - 20- 30% of remaining s/c surface can't be used as a solar array or radiator
  - Radiator temperature is  $20^\circ\text{C}$

# Body mounted solar array- cont'd



# Deployable solar array

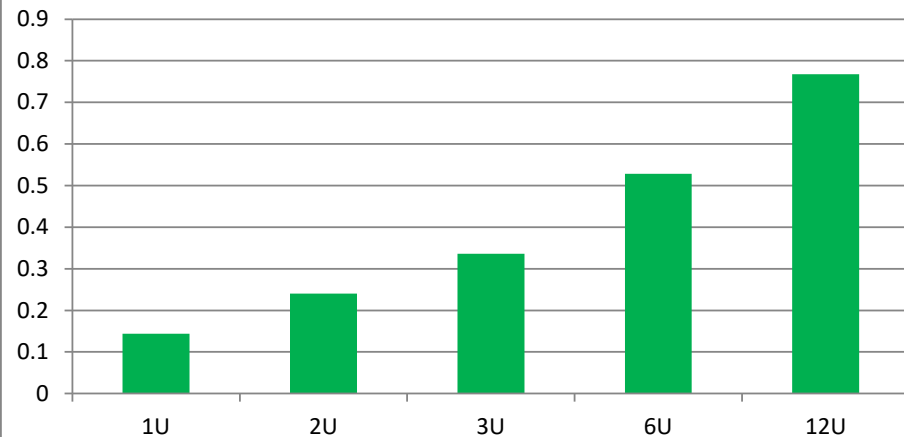
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- Solar array surface – unlimited
- Maximum radiator surface = 70-80% of s/c total surface
- Assumptions – the same
  - 40% of generated energy is converted to heat and must be rejected into space
  - Energy generation is 250 W/m<sup>2</sup> of solar array surface
  - Half of radiator surface is facing space, half is facing Earth
  - Radiator temperature is 20°C

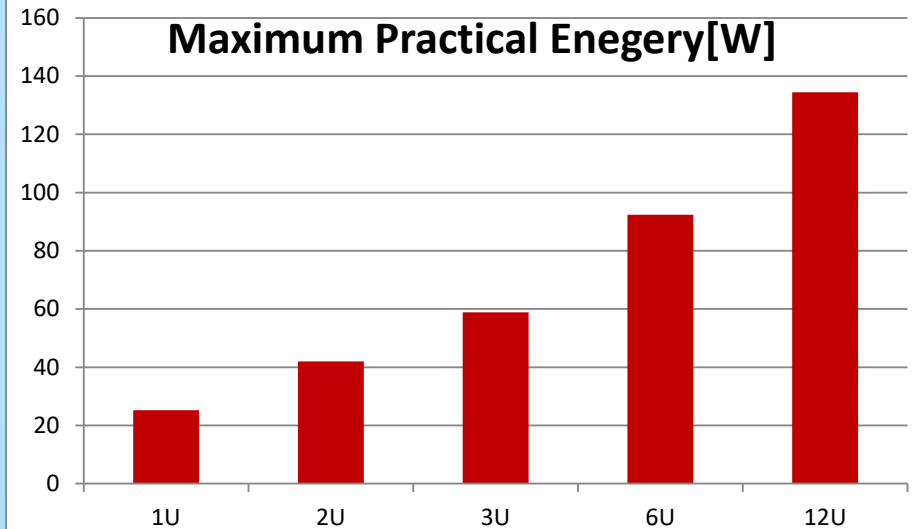
# Deployable solar array- cont'd

## Maximum Practical Energy Generation by Deployable Solar Array

Solar Array Area [m<sup>2</sup>]



Maximum Practical Energy [W]



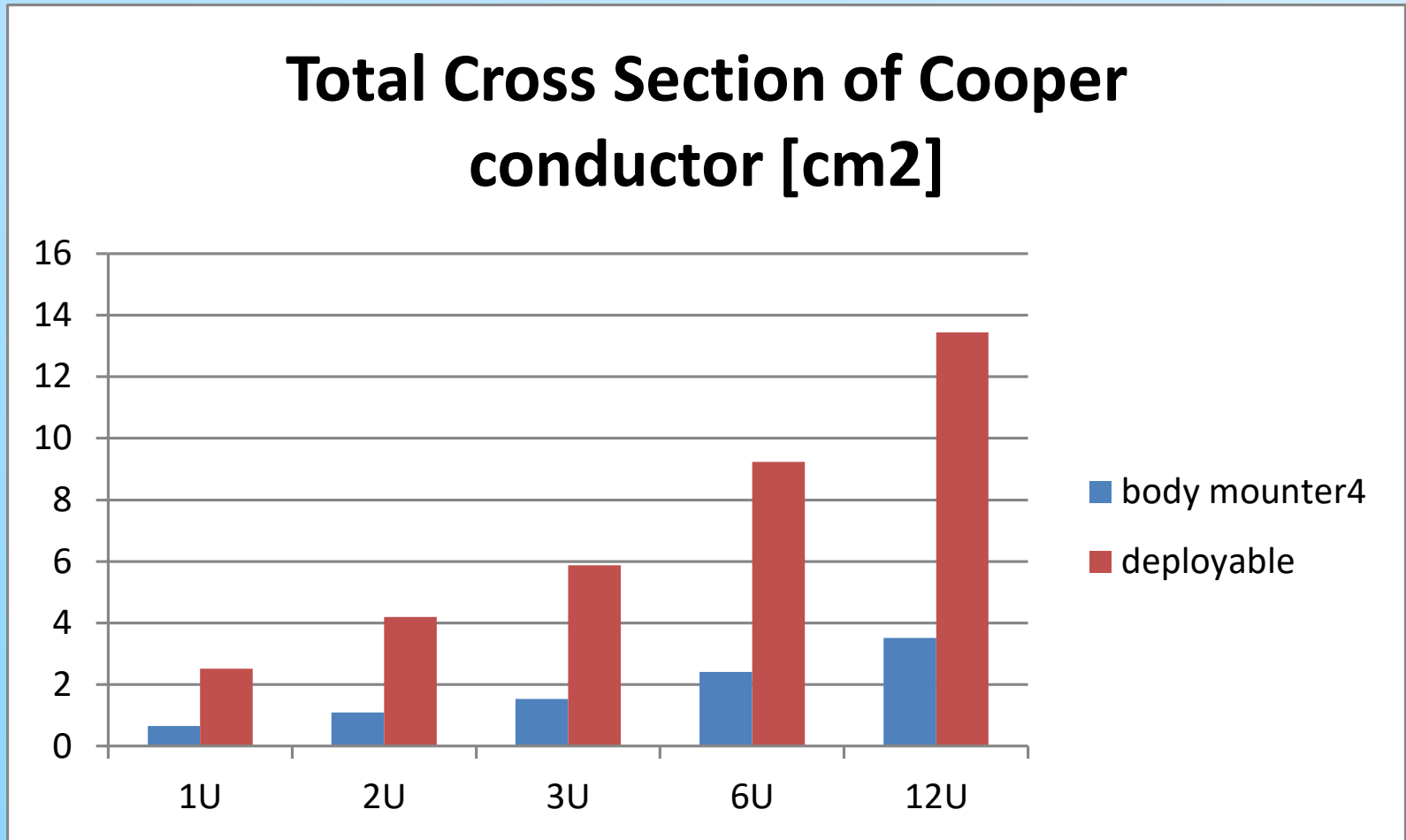
# Transfer of Wasted heat

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- Wasted heat should be transferred from source to s/c surface to be radiated into space.
- Wasted heat is transferred from middle of s/c to closest side/radiator by a copper strip
- Assumptions
  - Length of thermal path from electronics to radiator – 5 cm
  - Conductor – cooper with  $K=200$  w/mK
  - Temperature drop between electronics and radiator is  $10^{\circ}\text{C}$

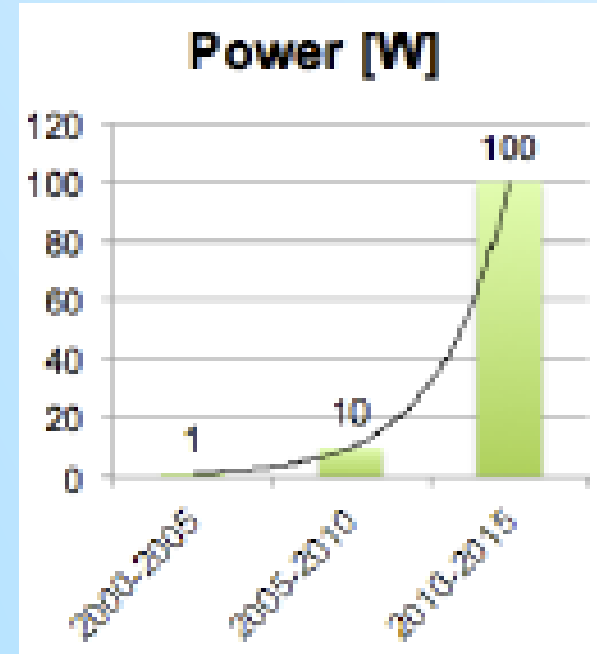


# Transfer of wasted heat- cont'd



# Demand for thermal management

- Earlier years of cubesats - low power consumption
- Rapidly increasing cubesats functionality
- Satellites become more and more power “hungry”
- Lack of thermal management threatens s/c mission success
- Thermal management reduces s/c failure rate => decrease space junk



Platzer, et al, “Smaller Satellites, Smarter Forecasts: GPS-RO Goes mainstream”, 29th Annual AIAA/USU, SSC15-VII-10

# Simple Thermal Management Tool

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- Existing tools require deep knowledge of thermal physics and expensive
- Small companies and universities lack expertise and \$\$
- Solution – Simplified thermal tool for cubesats
- Simple, does not require thermal expertise, inexpensive
- Based on technology proven with multiple spacecraft.
- Customers: small companies, universities, etc.

# Tool Features

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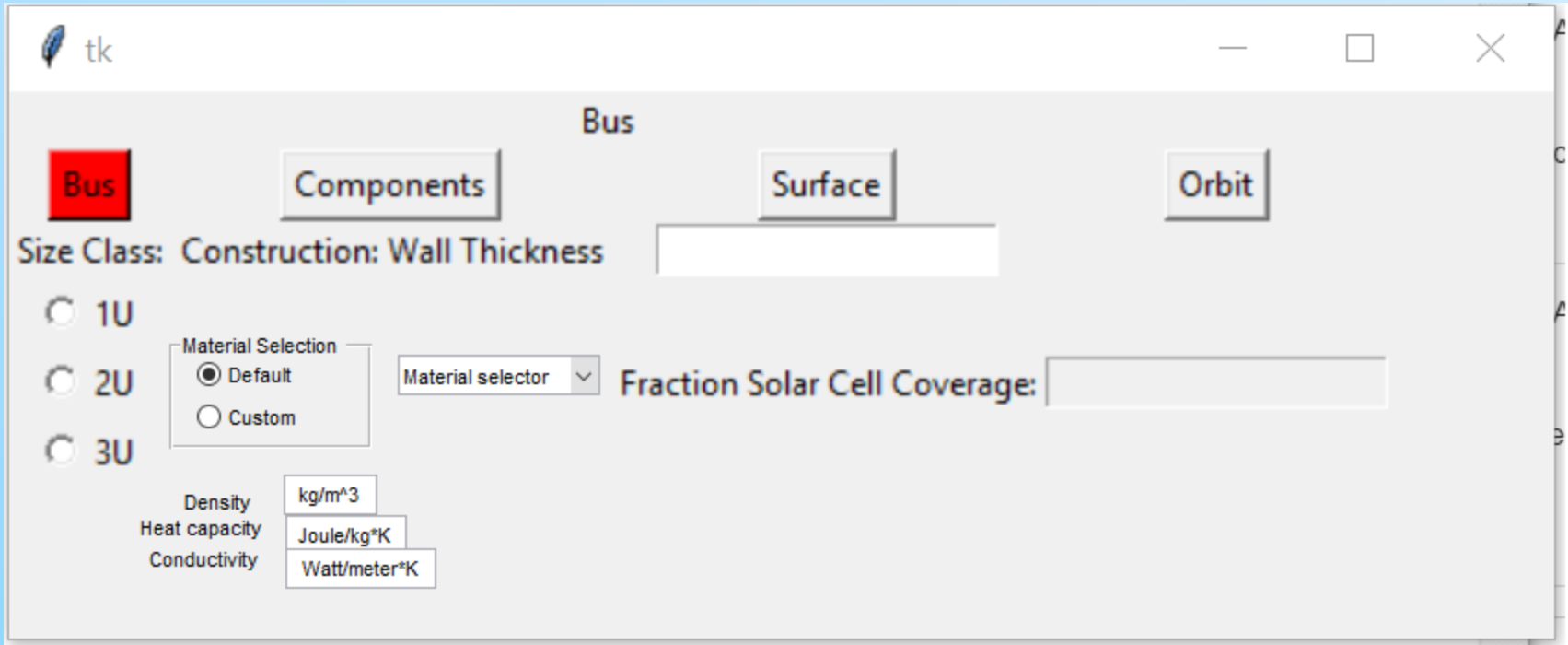
- Minimum required thermal knowledge by
  - Use of pre-built common materials
  - Built-in defaults for thermal and optical properties
  - Pre-built configurations
  - Simplified orbits
- S/c Configuration
  - 1U-3U (Phase 1 development)
  - Pre-built library of components(battery, CPU, etc.)
- Rapid evaluation of s/c thermal performance

# Required input

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- Orbit
  - Traditional Keplerian elements
  - Simplified orbits
- Construction
  - Bus materials
  - Wall thickness
  - Wall mass

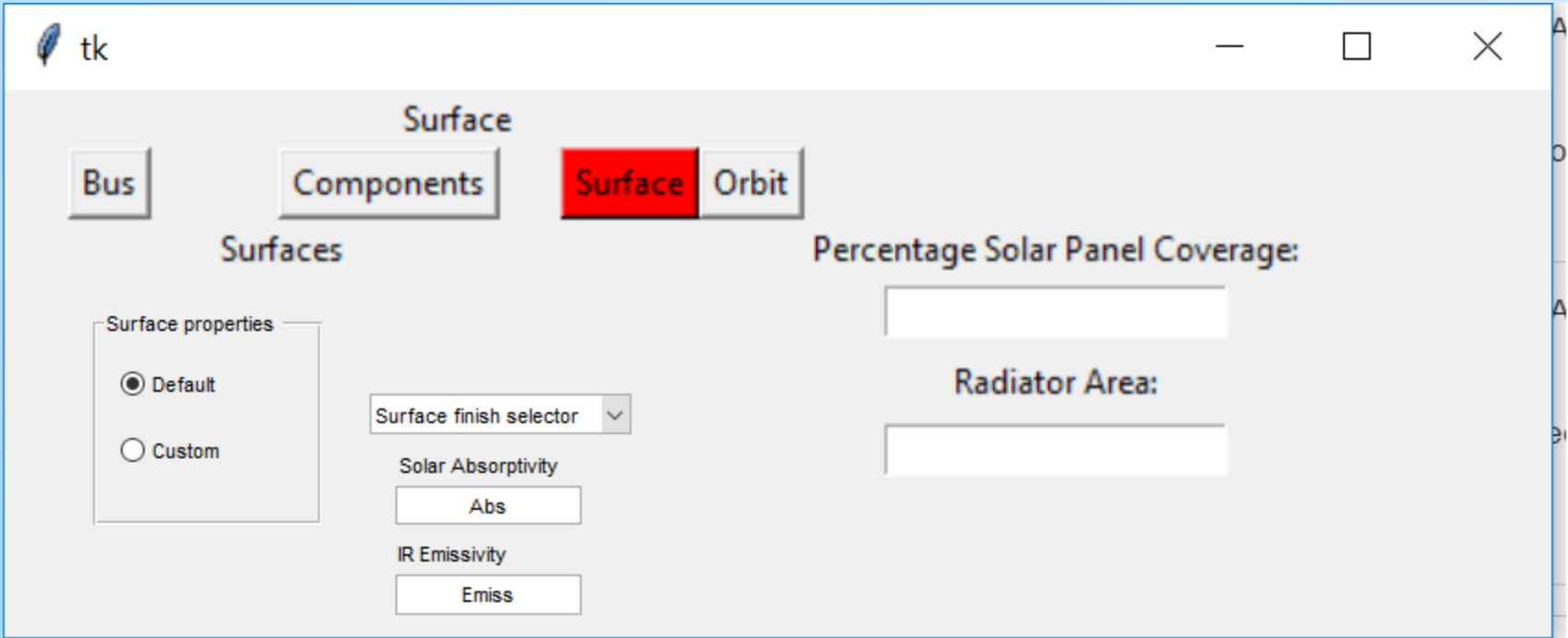
# Input Screen (Example)



The screenshot shows a software window titled 'tk' with a standard Windows-style title bar (minimize, maximize, close buttons). The main content area is titled 'Bus' and contains several interactive elements:

- Four tabs: 'Bus' (highlighted in red), 'Components', 'Surface', and 'Orbit'.
- Labels: 'Size Class:', 'Construction:', and 'Wall Thickness'.
- Radio buttons for '1U', '2U', and '3U'.
- A 'Material Selection' box containing radio buttons for 'Default' (selected) and 'Custom'.
- A 'Material selector' dropdown menu.
- A 'Fraction Solar Cell Coverage:' label followed by an input field.
- Physical property labels: 'Density', 'Heat capacity', and 'Conductivity', each with a corresponding input field.
- Units for the physical properties: 'kg/m<sup>3</sup>' for Density, 'Joule/kg\*K' for Heat capacity, and 'Watt/meter\*K' for Conductivity.

# Input Screen (Example)-cont'd



The screenshot shows a software window titled "tk" with standard window controls. The main content area is titled "Surface" and contains several interactive elements:

- A row of four buttons: "Bus", "Components", "Surface" (highlighted in red), and "Orbit".
- A section titled "Surfaces" containing:
  - A "Surface properties" group box with two radio buttons: "Default" (selected) and "Custom".
  - A "Surface finish selector" dropdown menu.
  - A "Solar Absorptivity" input field with the value "Abs".
  - An "IR Emissivity" input field with the value "Emiss".
- A section titled "Percentage Solar Panel Coverage:" with an empty input field.
- A section titled "Radiator Area:" with an empty input field.

# Input Screen (Example)- sunsynk

tk

Orbit

Bus Components Surface **Orbit**

Simplified Orbit  Full Orbit Determination Start Date: YYYY-MM-DD

Altitude:

Inclination:

Semiparameter:

Eccentricity:

Argument of Periapse:

Right Ascension of the Ascending Node:

tk

Orbit

Bus Components Surface **Orbit**

Simplified Orbit  Full Orbit Determination Start Date: YYYY-MM-DD

Altitude:

Inclination:

Semiparameter:

Eccentricity:

Argument of Periapse:

Right Ascension of the Ascending Node:



# Output

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- Plots
  - Temperatures of all components over the simulation period
- Spreadsheets
- Minimum and maximum temperatures
  - Quick assessment of safe temperature ranges

# Future work

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- More advanced configurations
  - Side by side components
  - Deployables
- Support for more specific hardware
  - Pre-built busses
  - Specific components