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Thermal Management for Small Sats

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Importance of thermal analysis

- 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.

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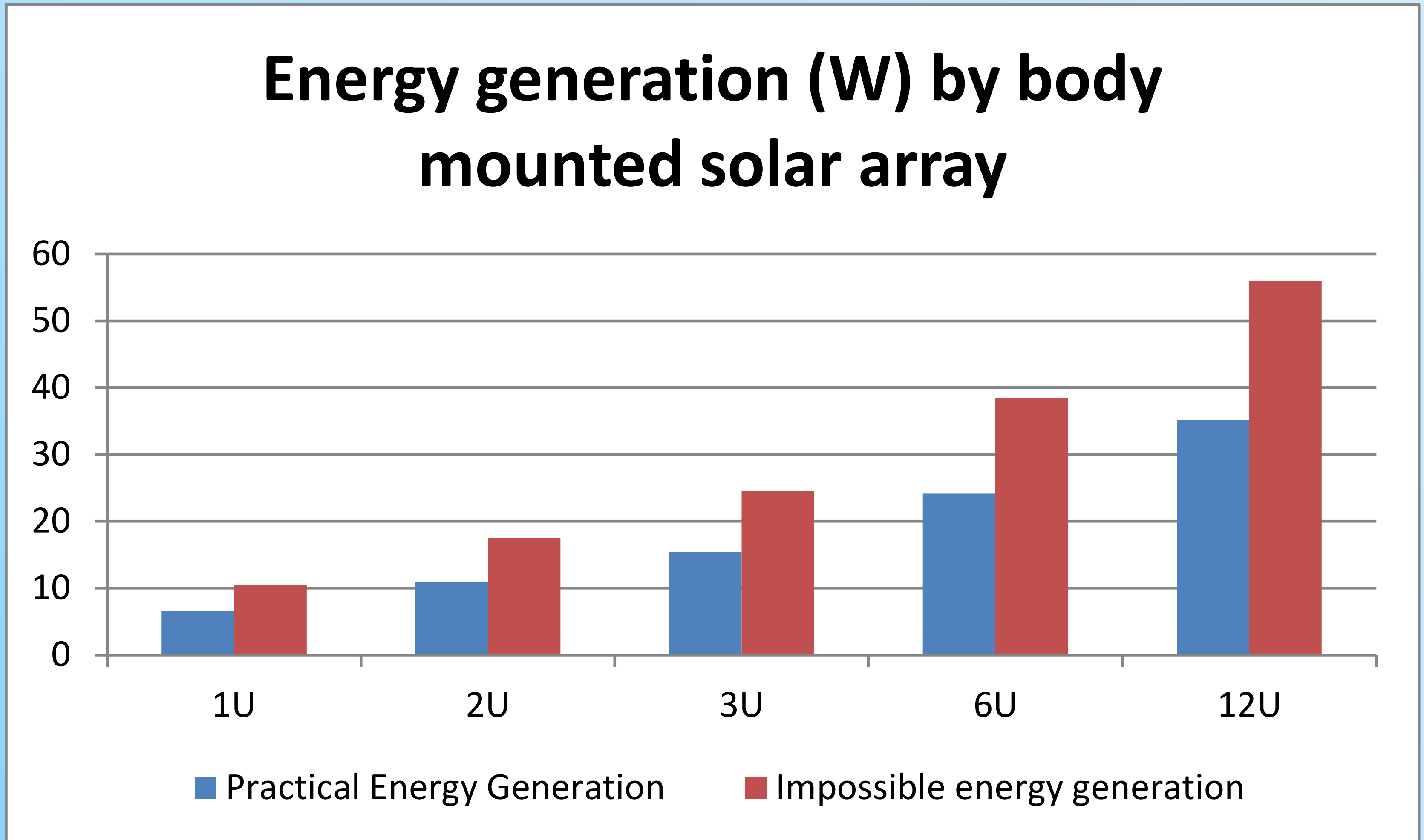
Importance of thermal analysis-cont'd

- 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

- 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 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^{o}C

Body mounted solar array- cont’d

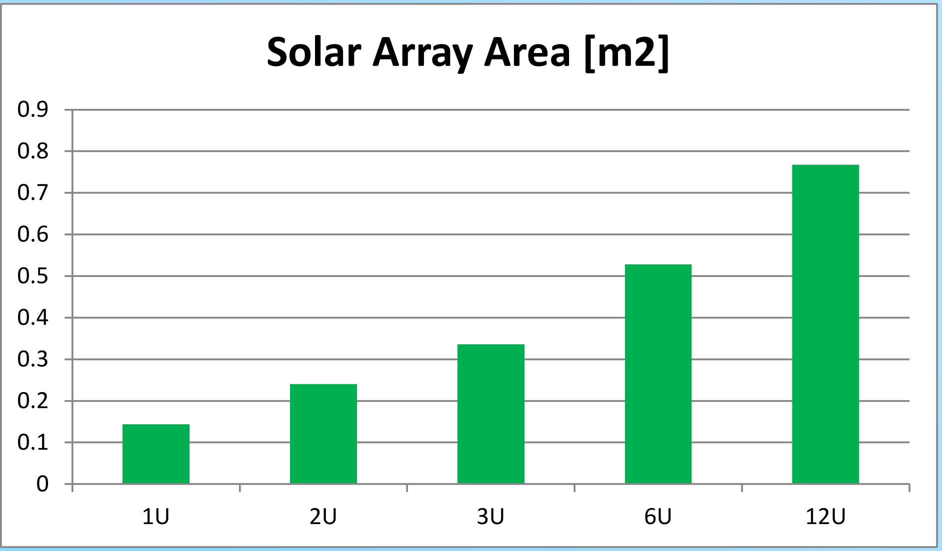


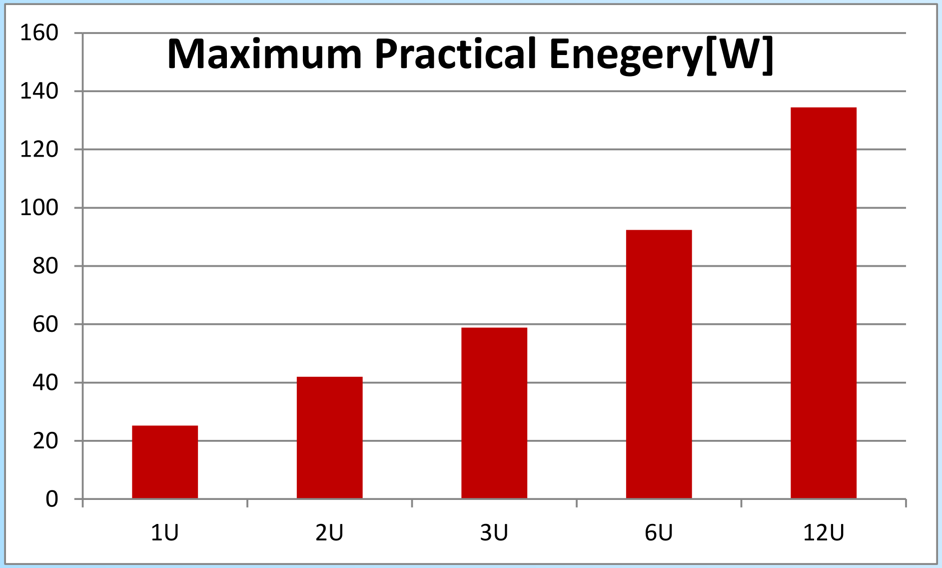
Deployable solar array

- 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^2 of solar array surface
  - Half of radiator surface is facing space, half is facing Earth
  - Radiator temperature is 20^oC

Deployable solar array- cont'd

Maximum Practical Energy Generation by Deployable Solar Array

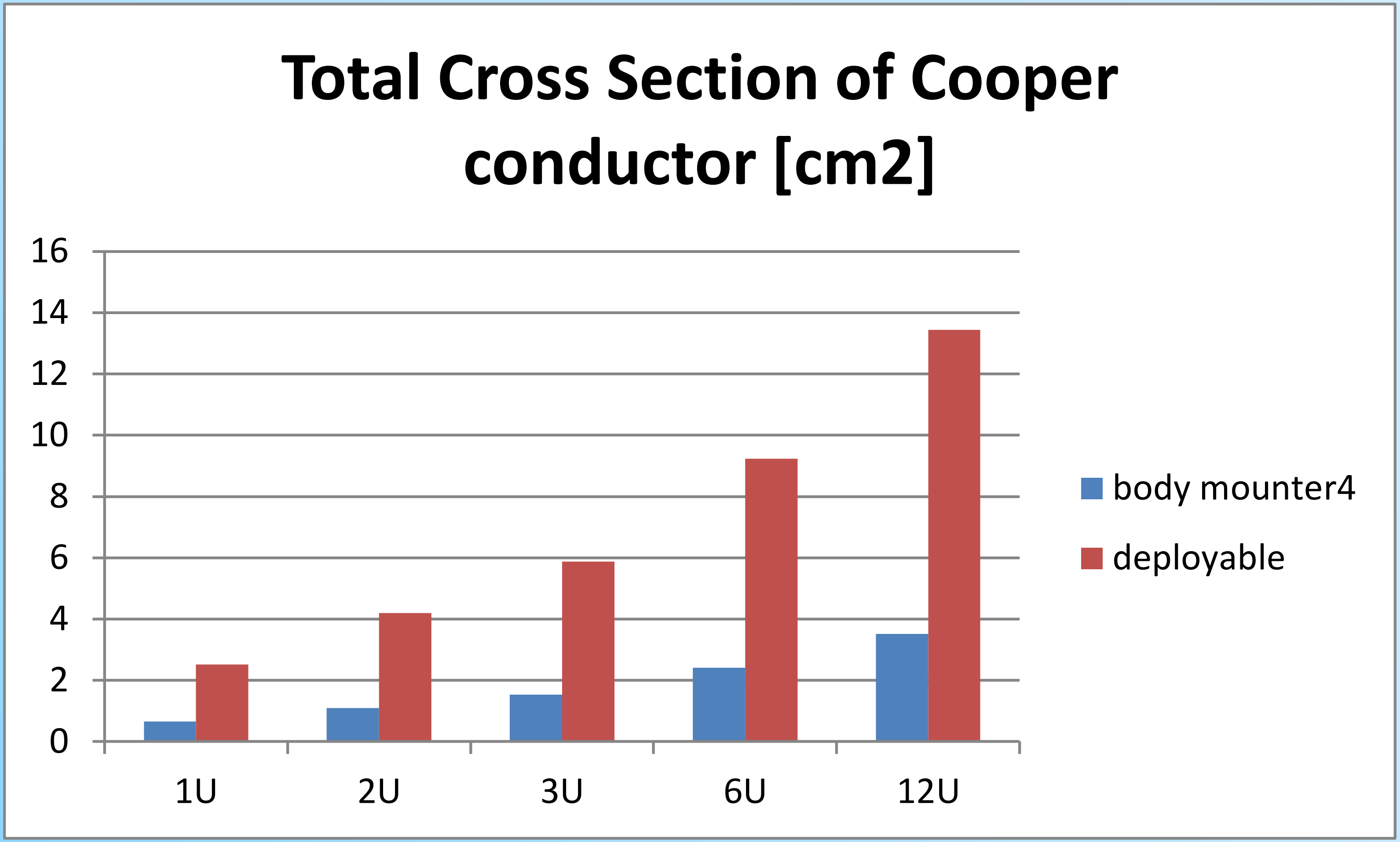




Transfer of Wasted heat

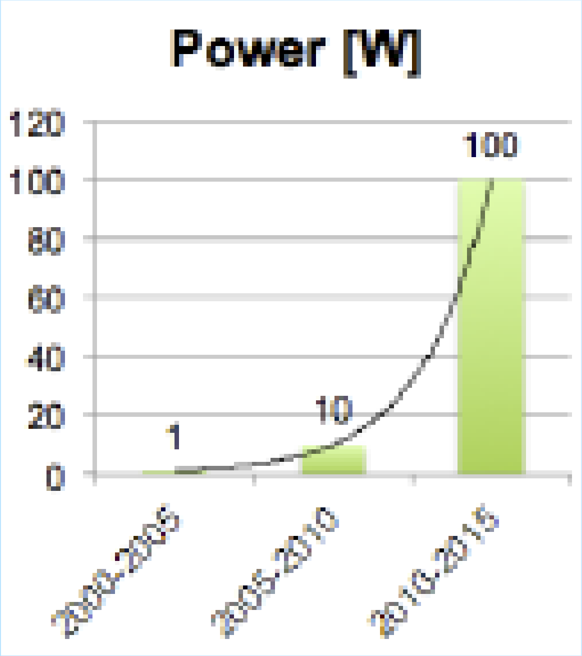
- Wasted heat should be transferred from source to s/c surface to be radiated into space.
- Wasted heat is transferred from middle of s/c to closest side/radiator by a copper strip
- Assumptions
  - Length of thermal path from electronics to radiator – 5 cm
  - Conductor – cooper with K=200 w/mK
  -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

- 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

- 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

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Required input

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

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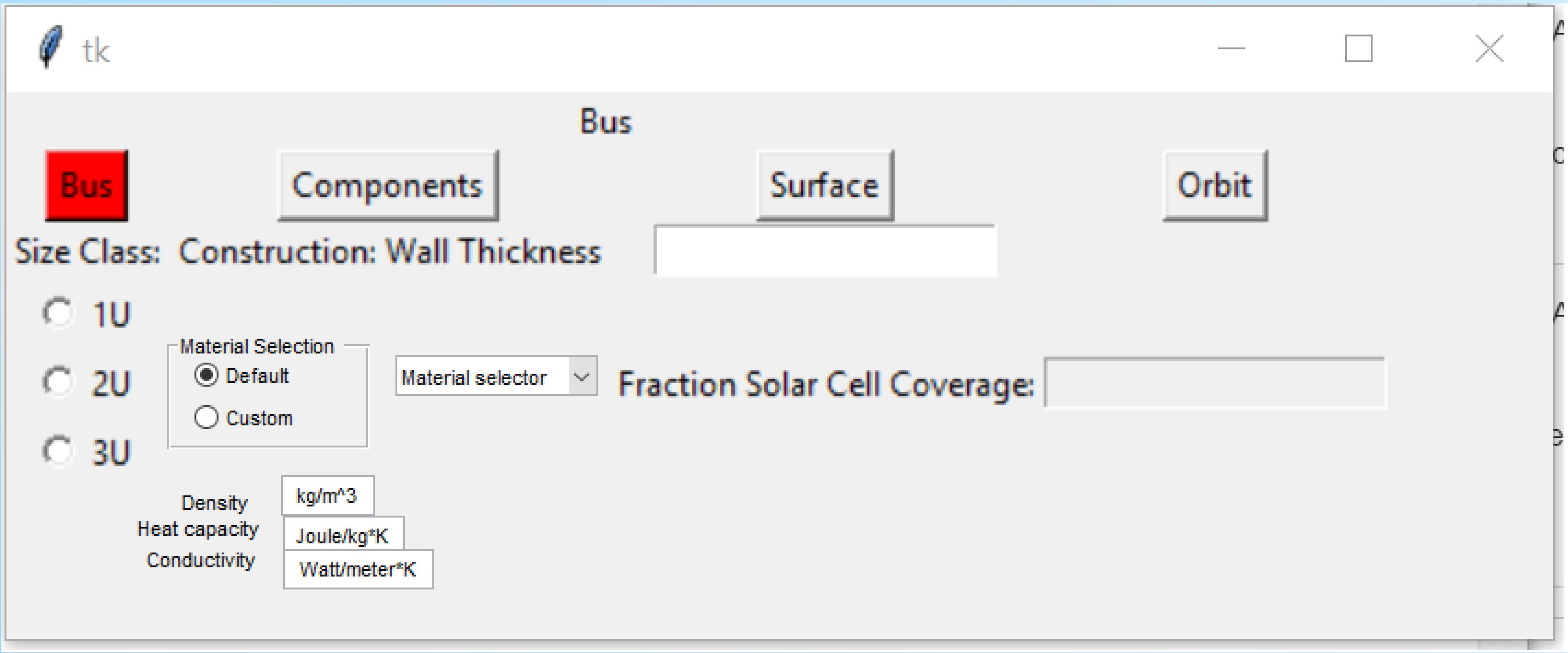
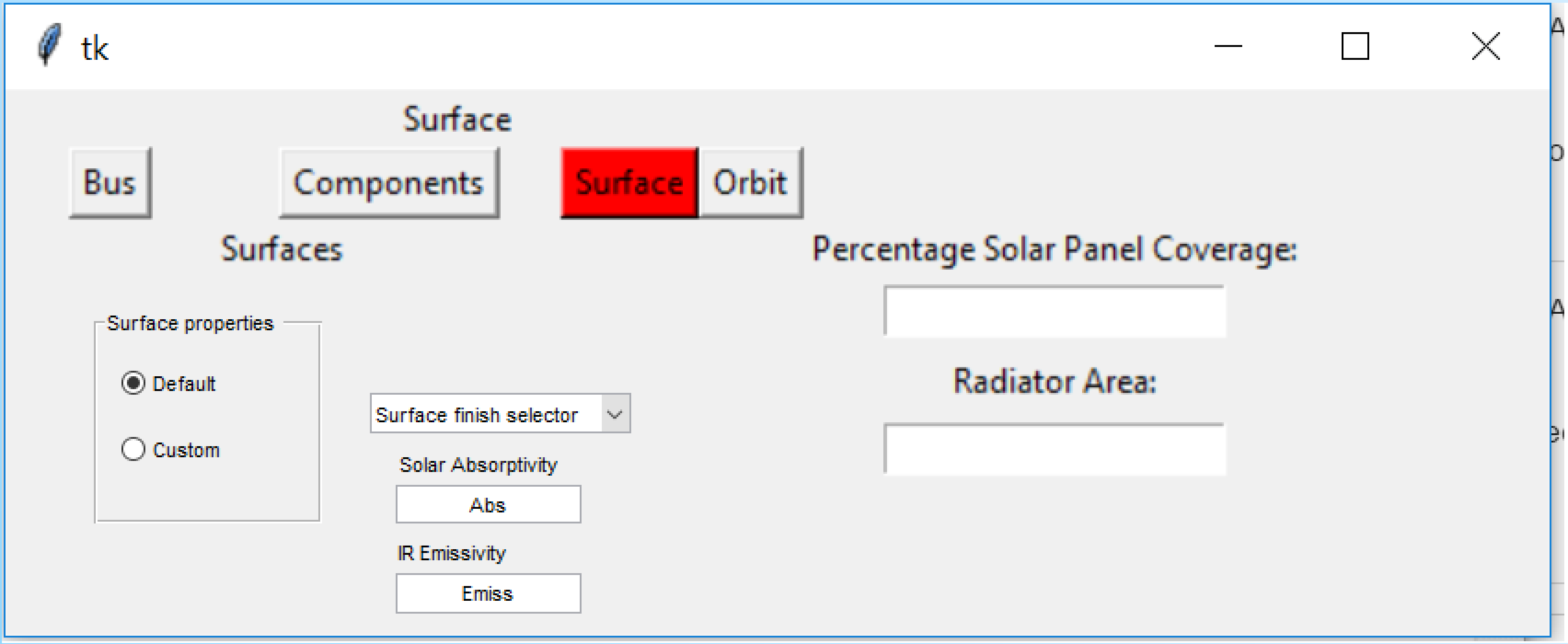
Input Screen (Example)



Input Screen (Example)-cont'd



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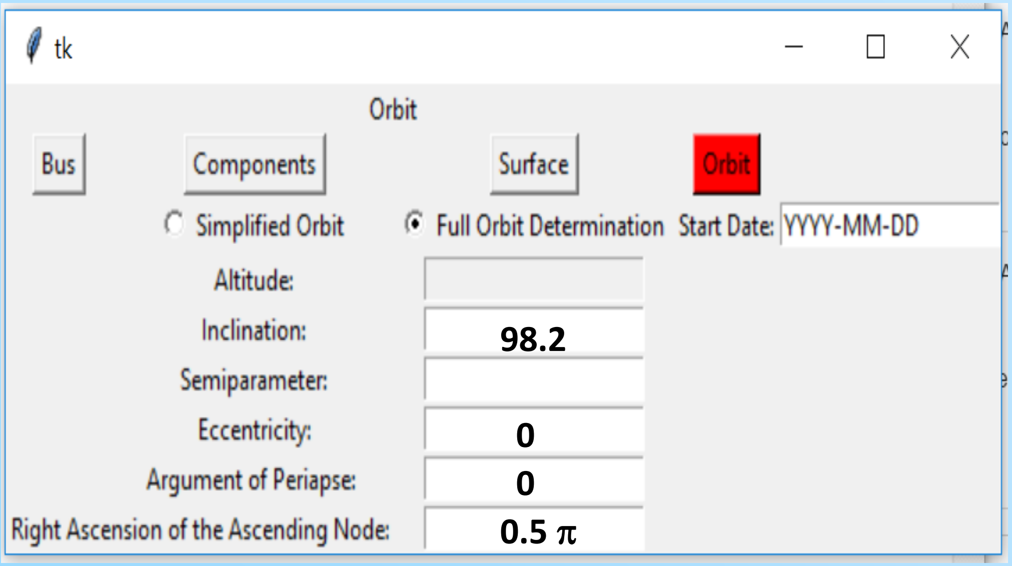
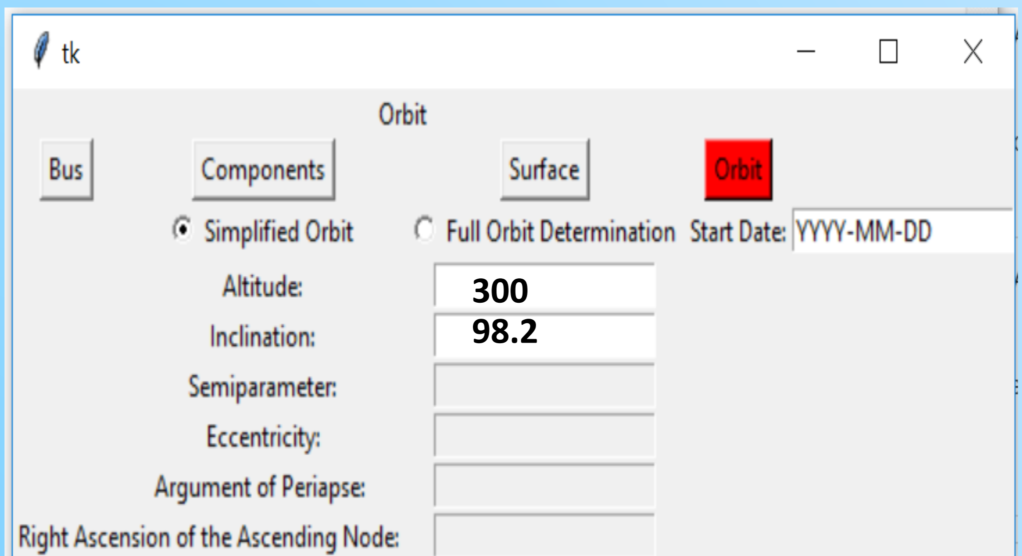
Input Screen (Example)- sunsynk





Output

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

Future work

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