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.

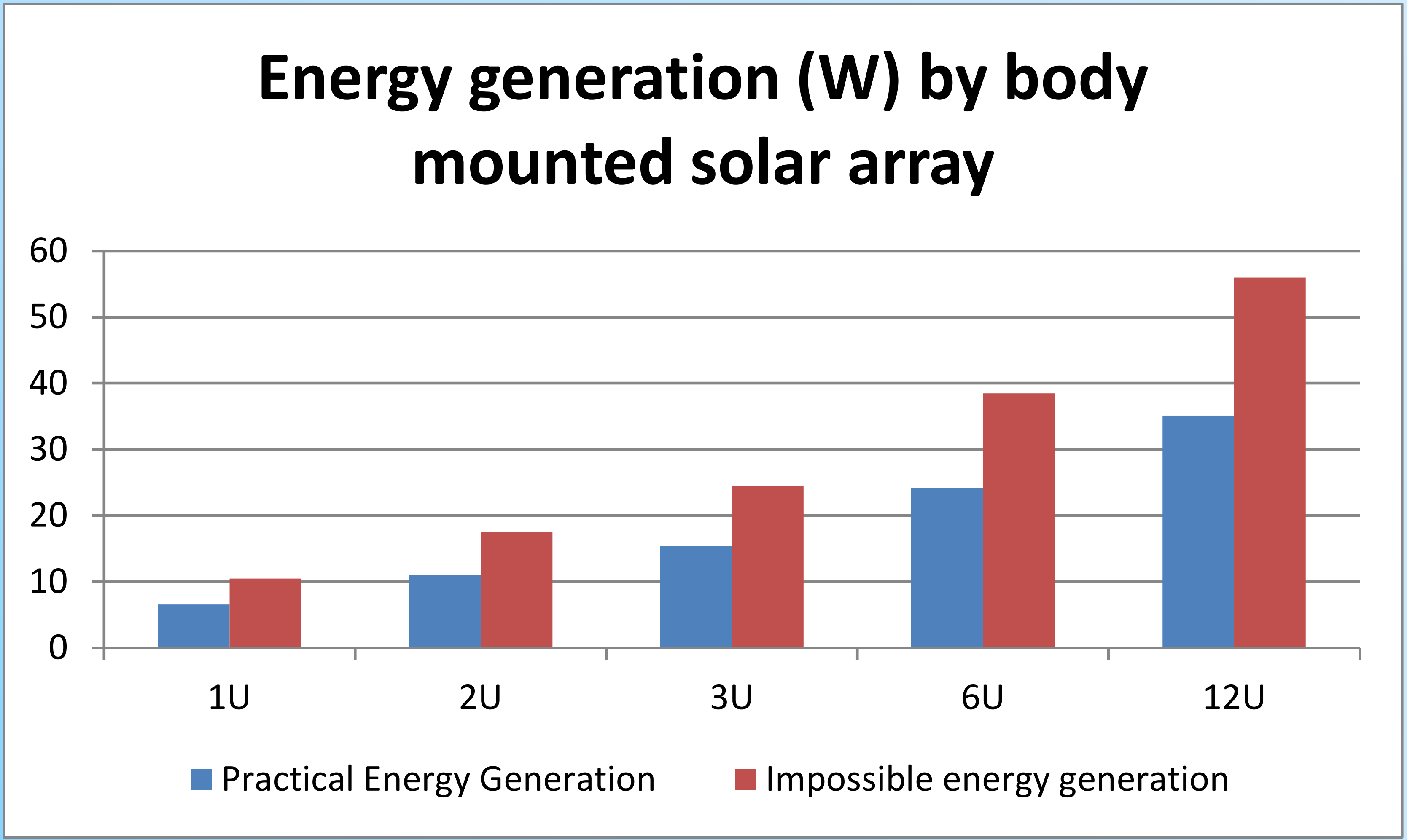
Importance of thermal analysis-cont'd

- 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^oC

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

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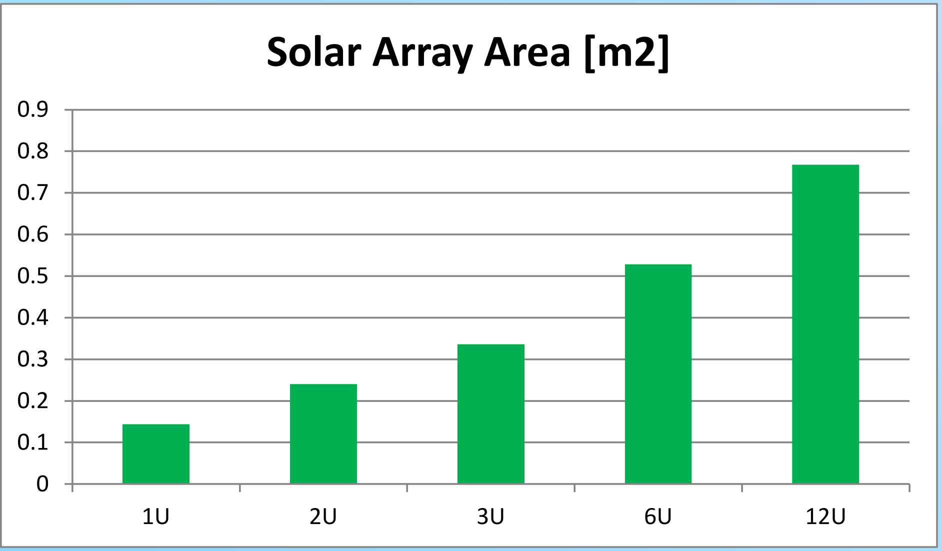
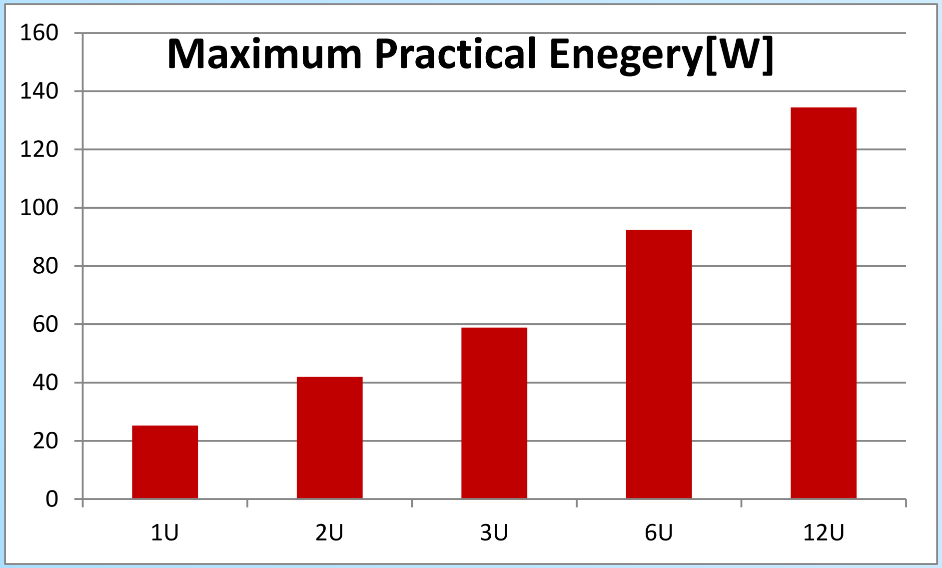
Deployable solar array- cont'd

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

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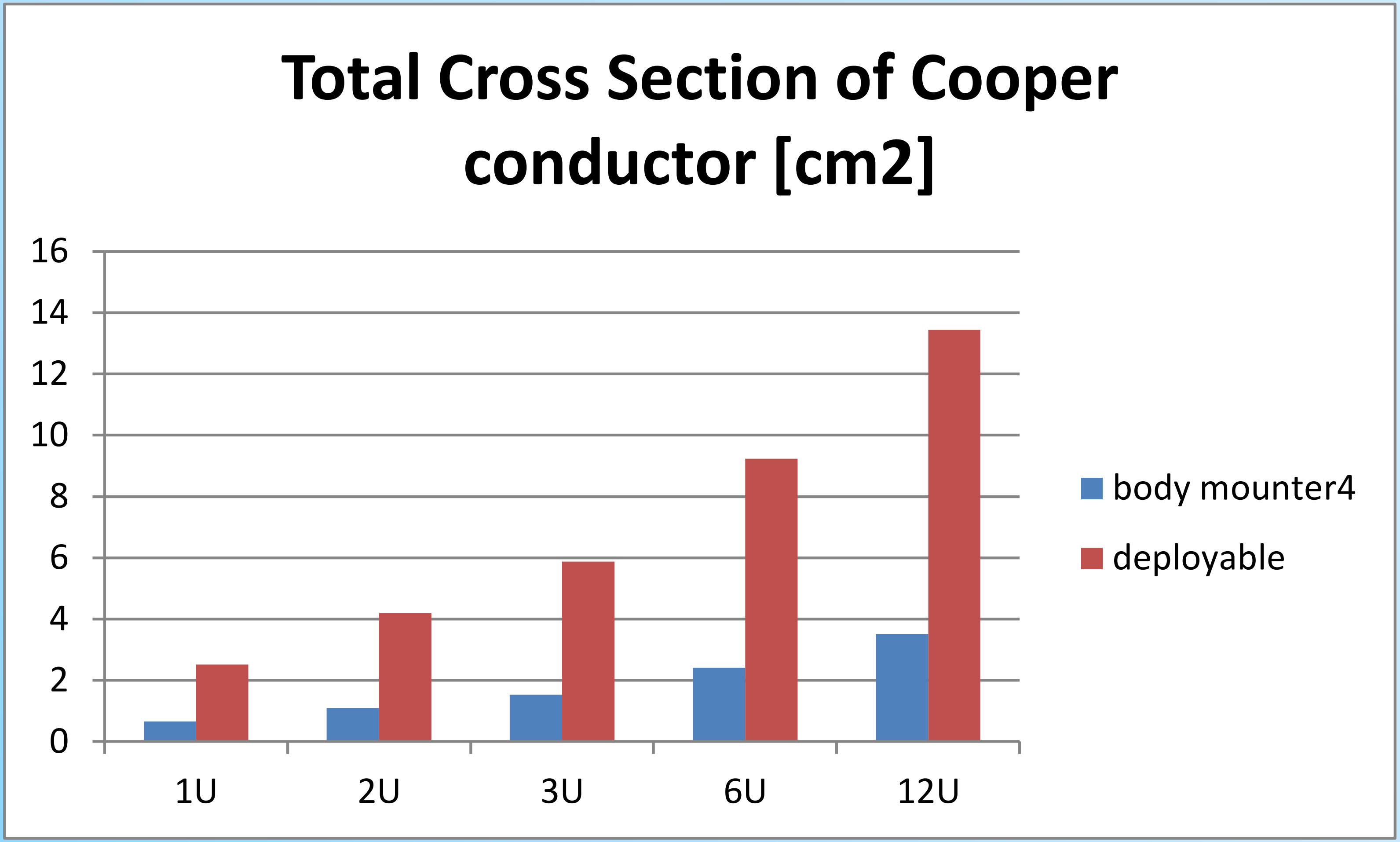
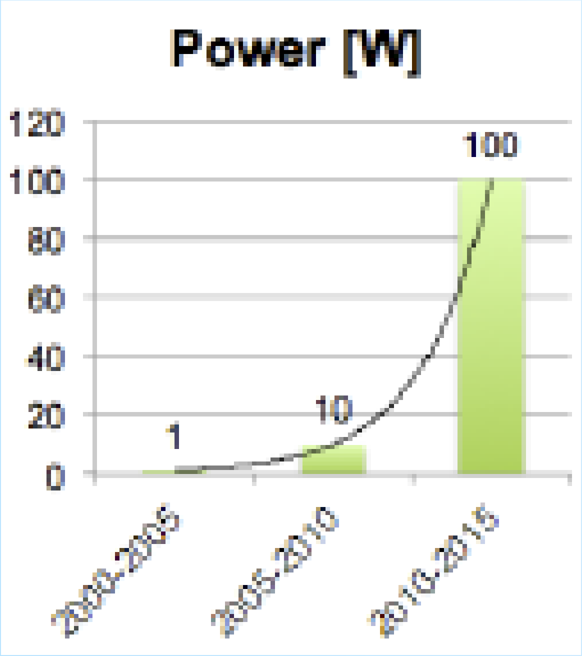
Transfer of wasted heat- cont'd



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

Required input

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

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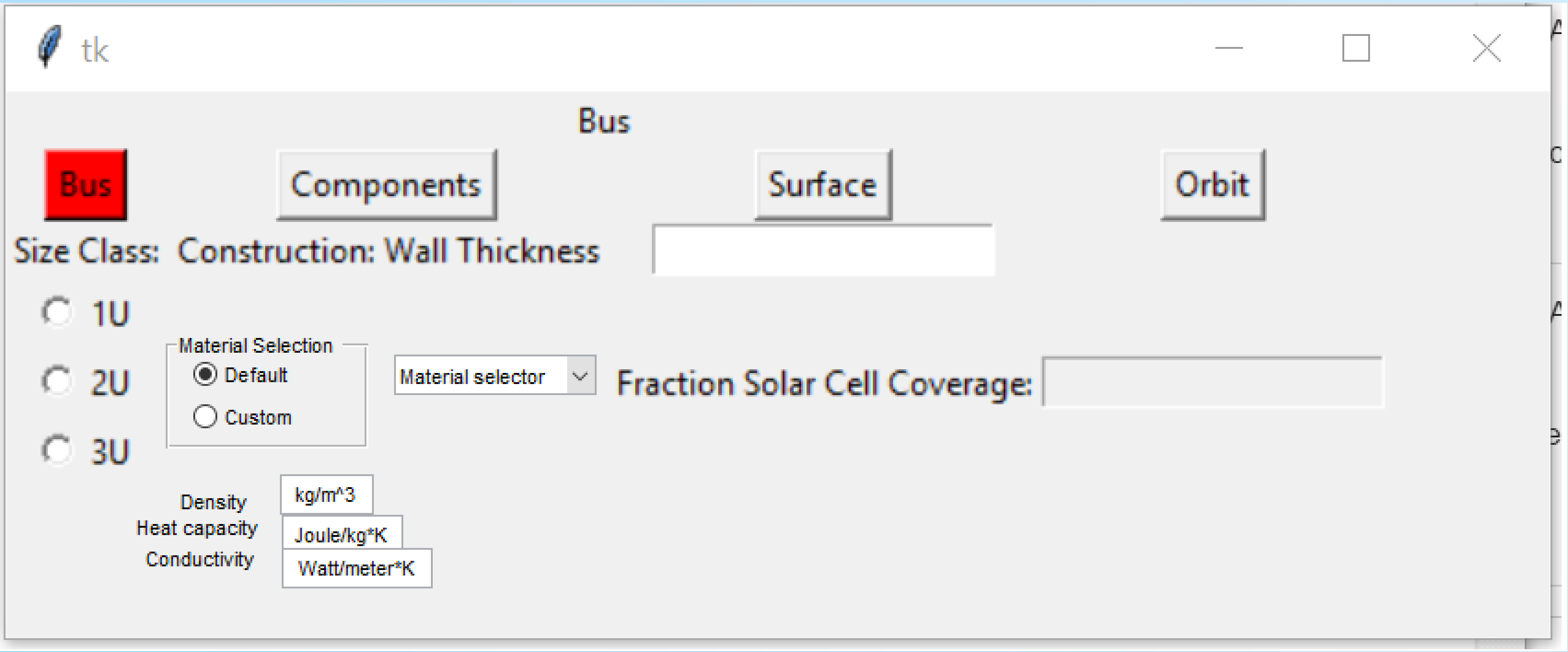
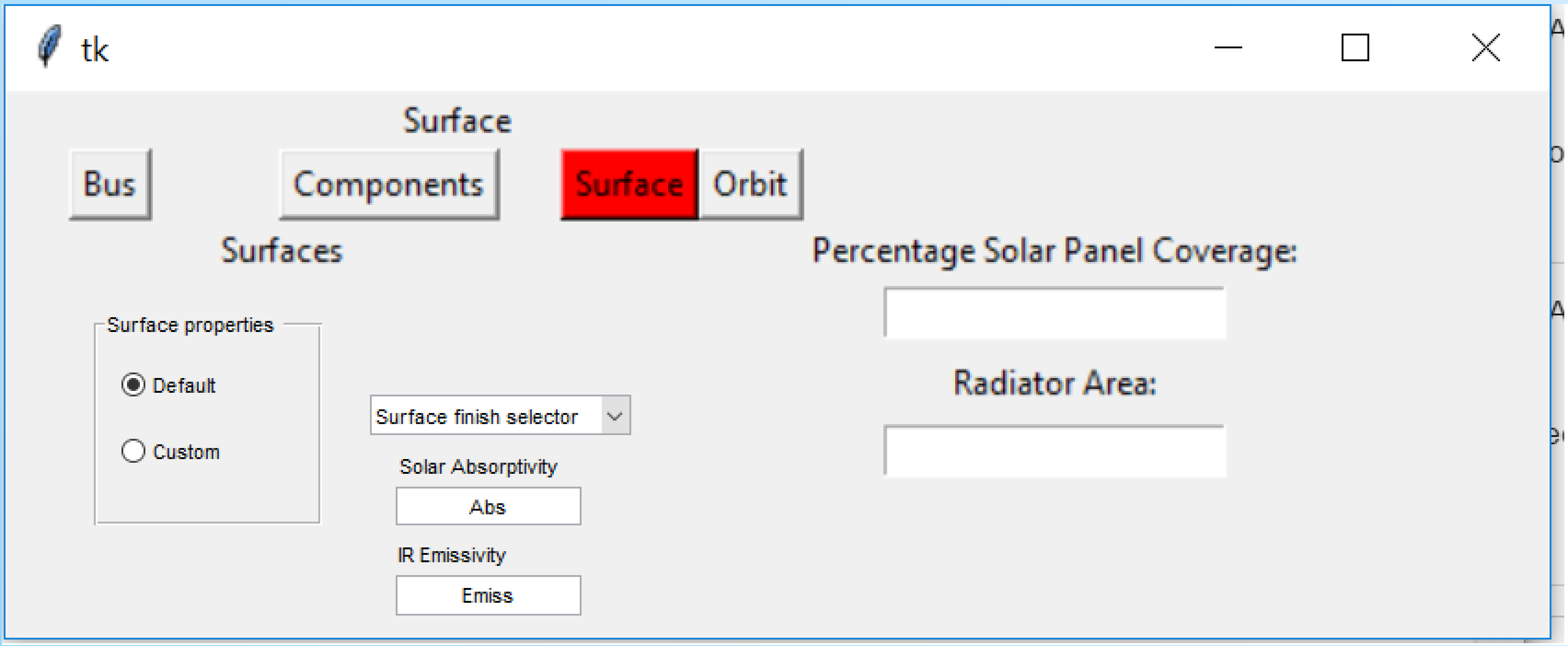
Input Screen (Example)



Input Screen (Example)-cont’d



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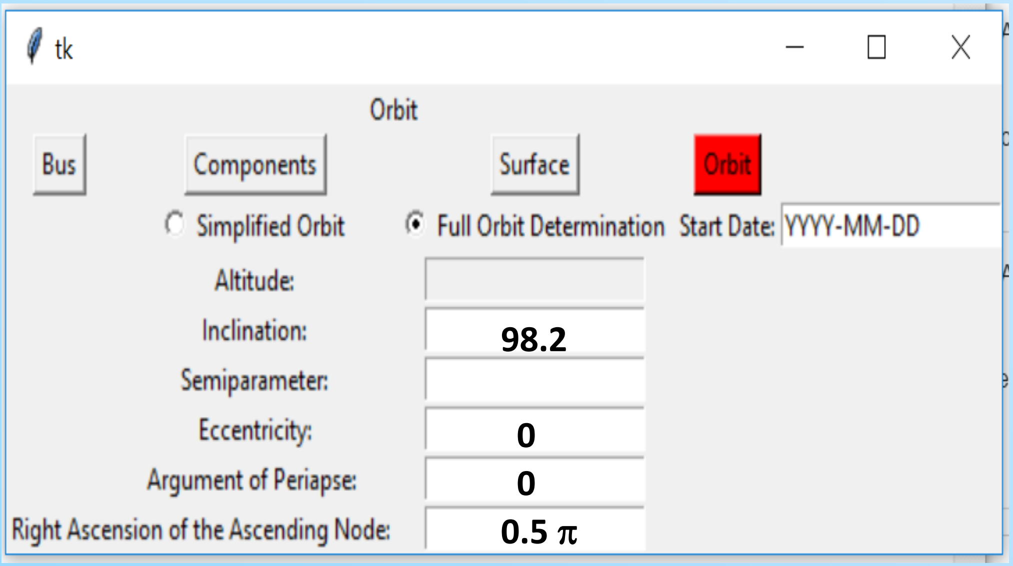
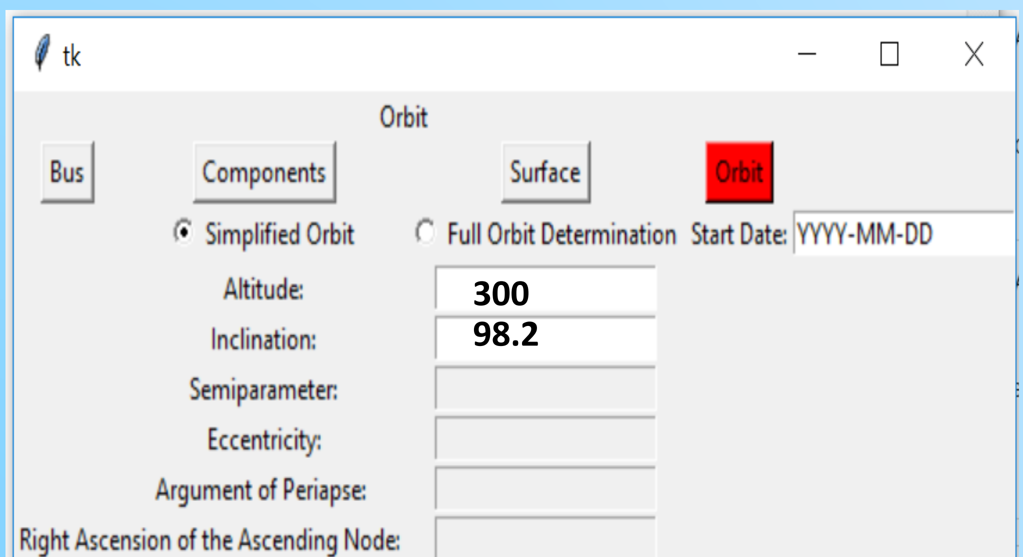
Input Screen (Example)- sunsynk





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