Modeling and Application of Thermochromic Variable Emissivity Materials

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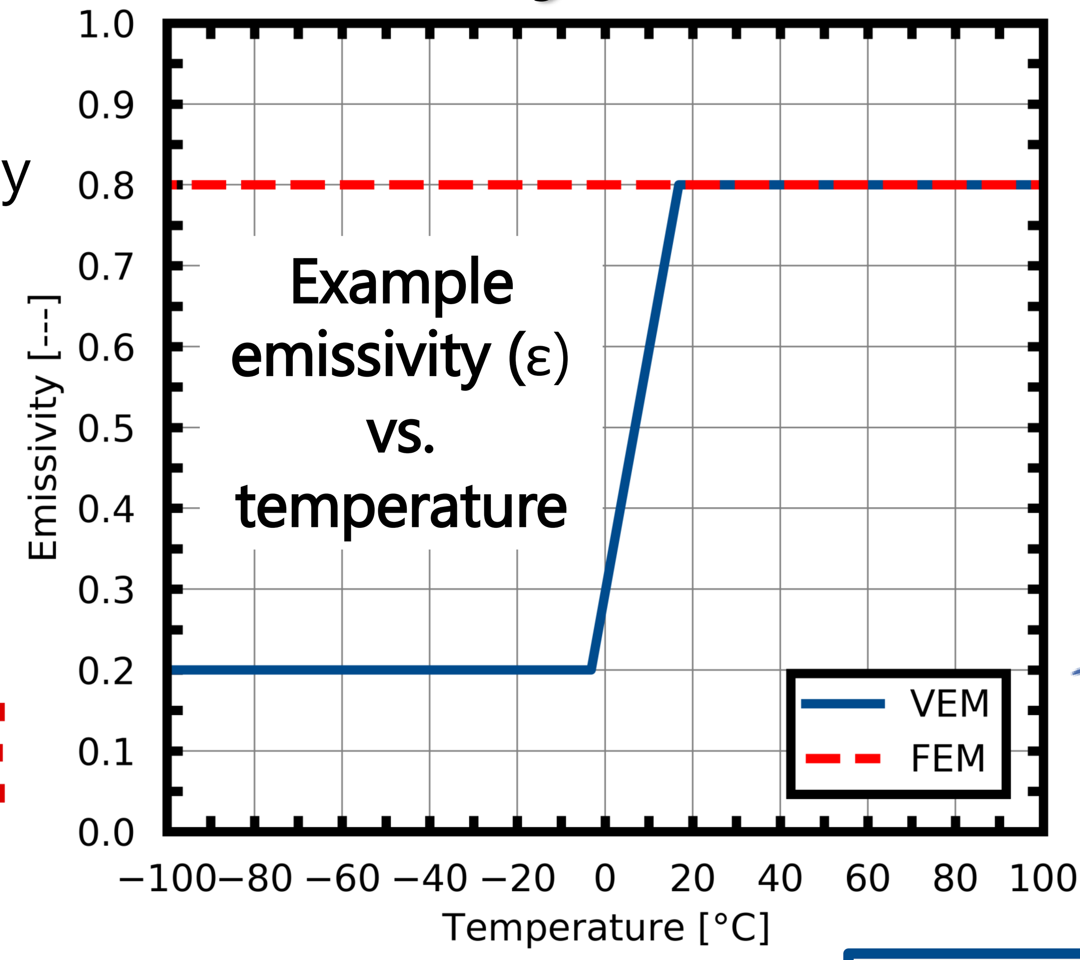
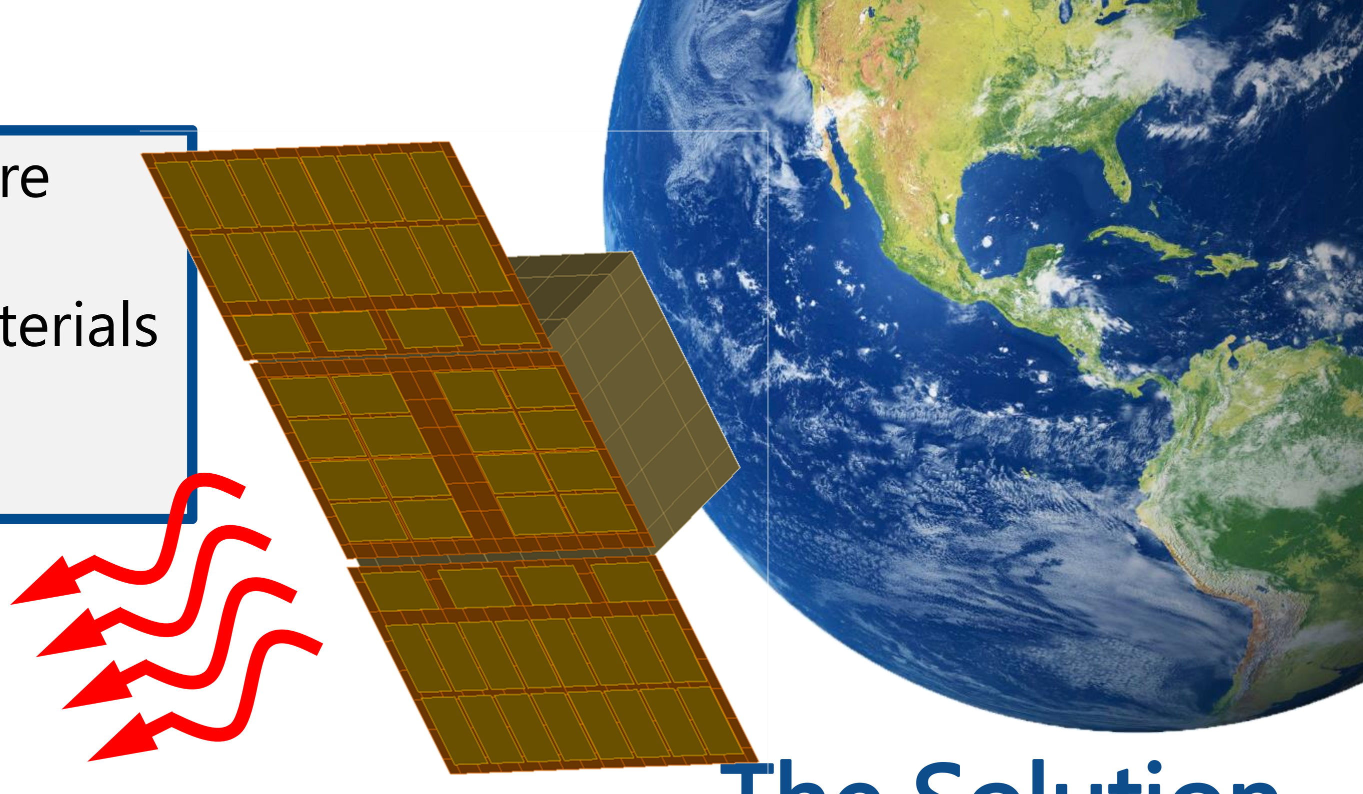


The Problem

- Spacecraft (S/C) radiators are sized for hot conditions
- Existing fixed emissivity materials (FEM) let S/C get too cold without heaters



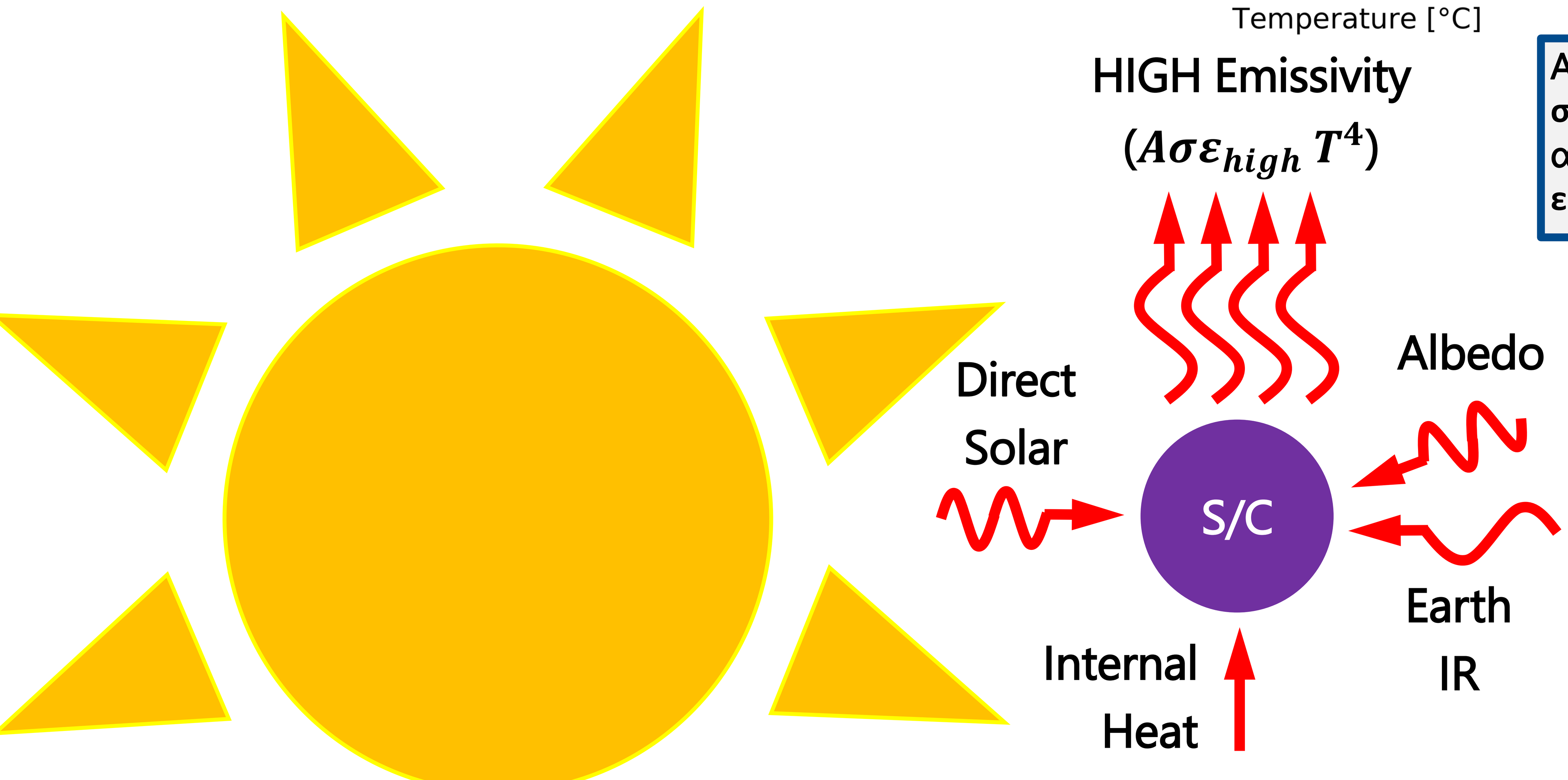
The Solution

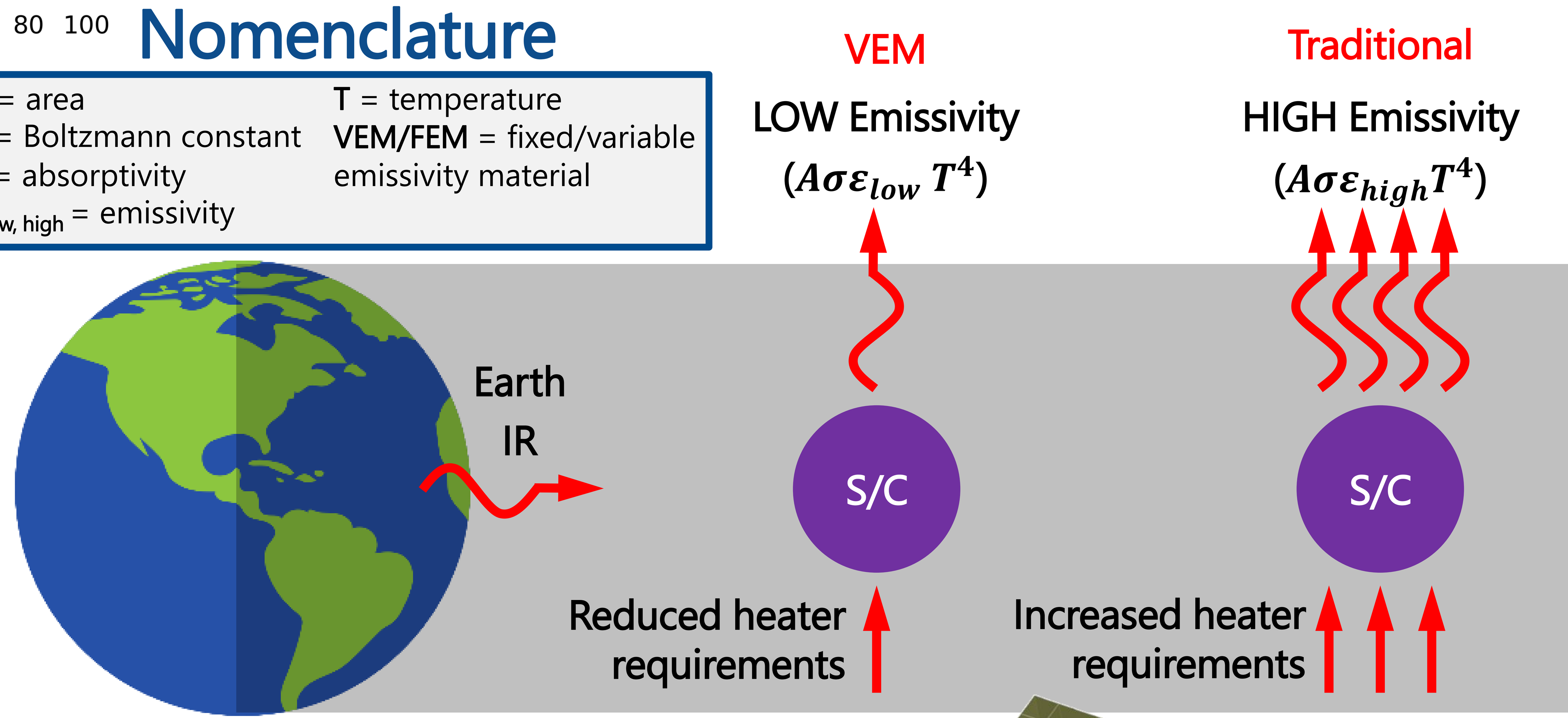
Thermochromic Variable Emissivity Materials (VEMs)

- IR emissivity (ε) passively changes in response to temperature
- Holy grail of S/C thermal for past 30+ yrs

Nomenclature

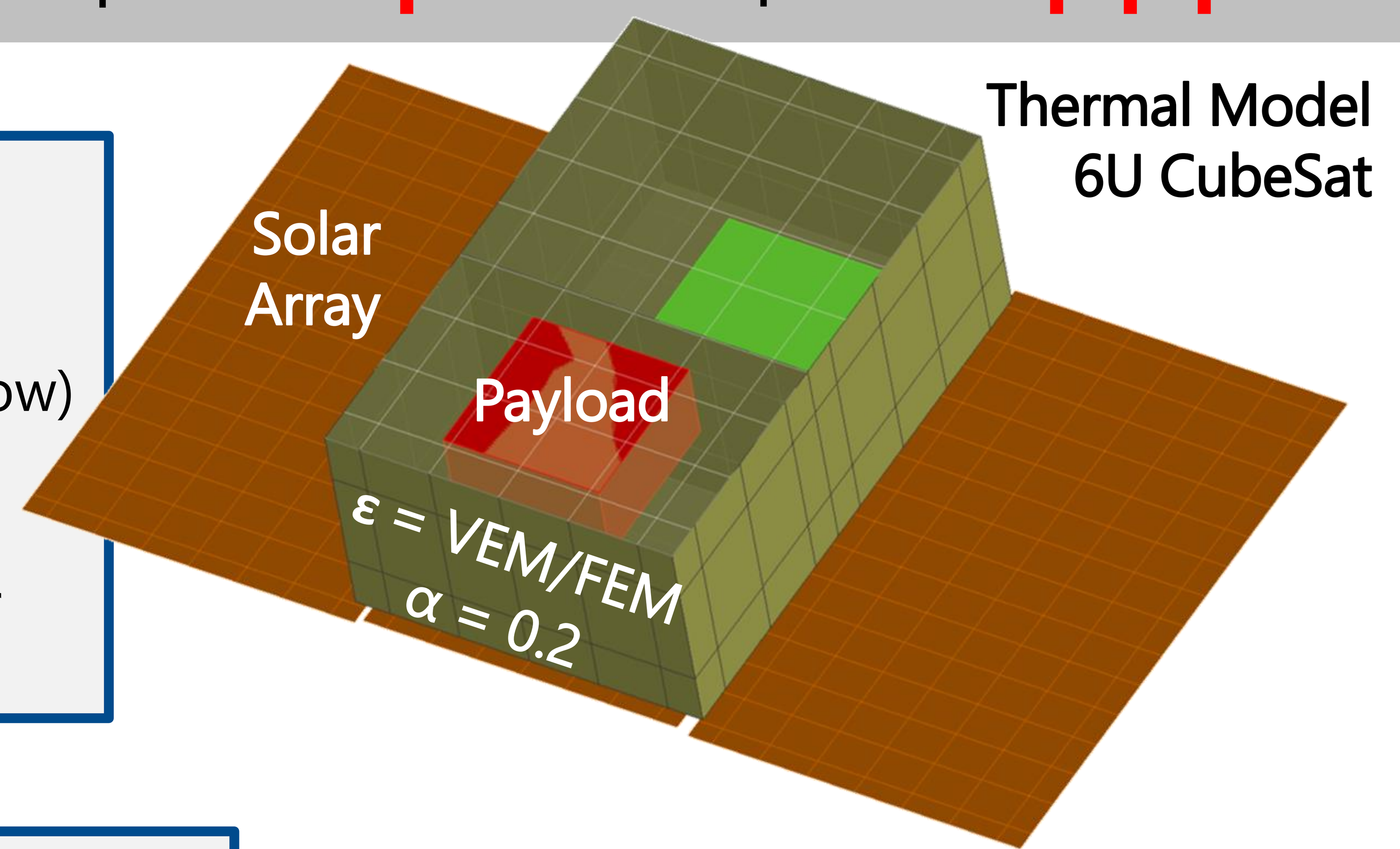
A = area
σ = Boltzmann constant
α = absorptivity
$\varepsilon_{low,\,high}$ = emissivity
T = temperature
VEM/FEM = fixed/variable emissivity material





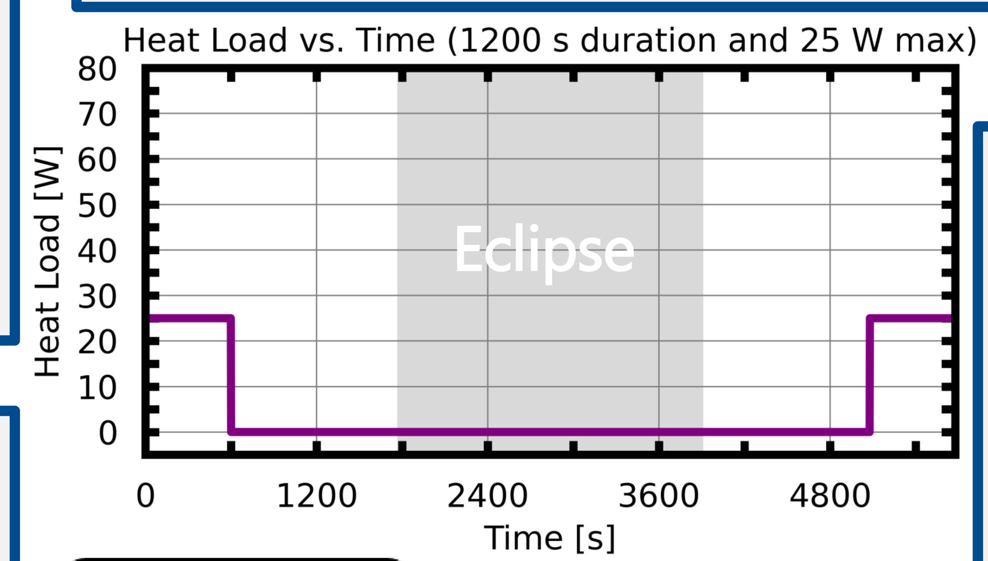
VEM Application

- 6U CubeSat
- 500 km, β = 0°, circular orbit, sun-pointing solar array
- Payload (P/L) Heat Load: Off and 25W max (operational)
- Range of operational durations/duty-cycles (example below)
  - Payload protected with 10W heater (-3°C on; 0°C off)
- Exterior surfaces coated with either FEM or VEM radiators
  - VEM is 5 surfaces; FEM is 3 surfaces (to reduce heater energy requirements)

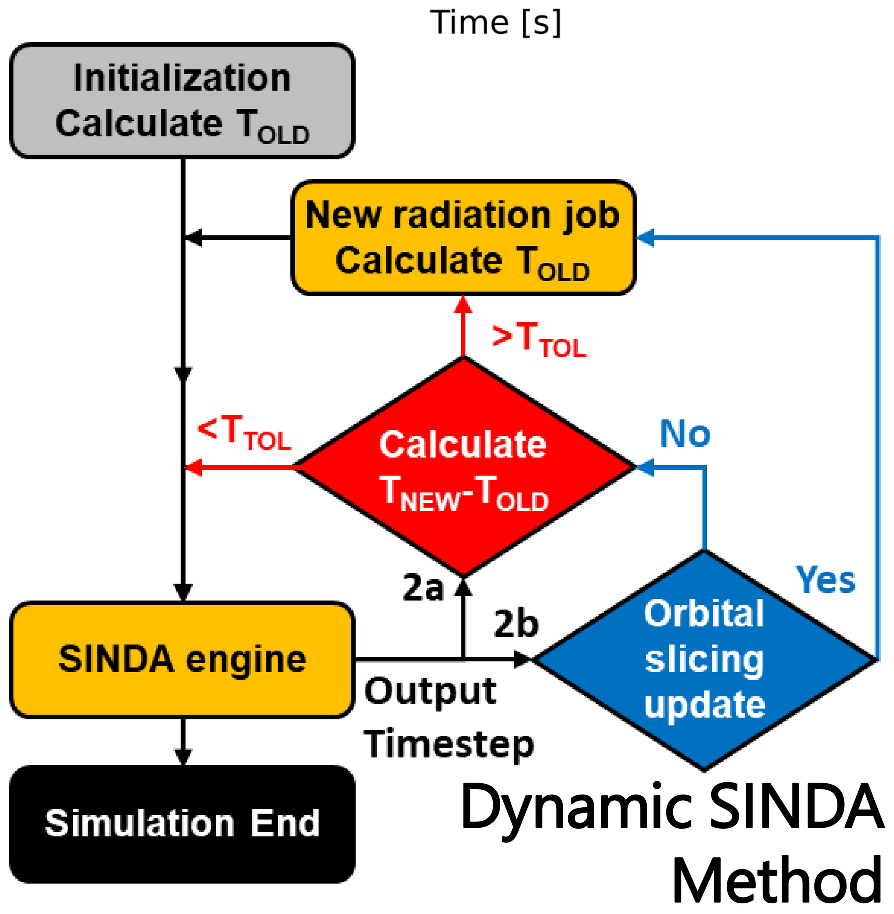


Modeling VEMs

- Traditional thermal modeling tools (Thermal Desktop®) assume fixed optical properties (ε = constant).
- Three methods developed to handle VEMs
  - Radiation conductor
  - Radiation Database
  - Dynamic SINDA (see below)



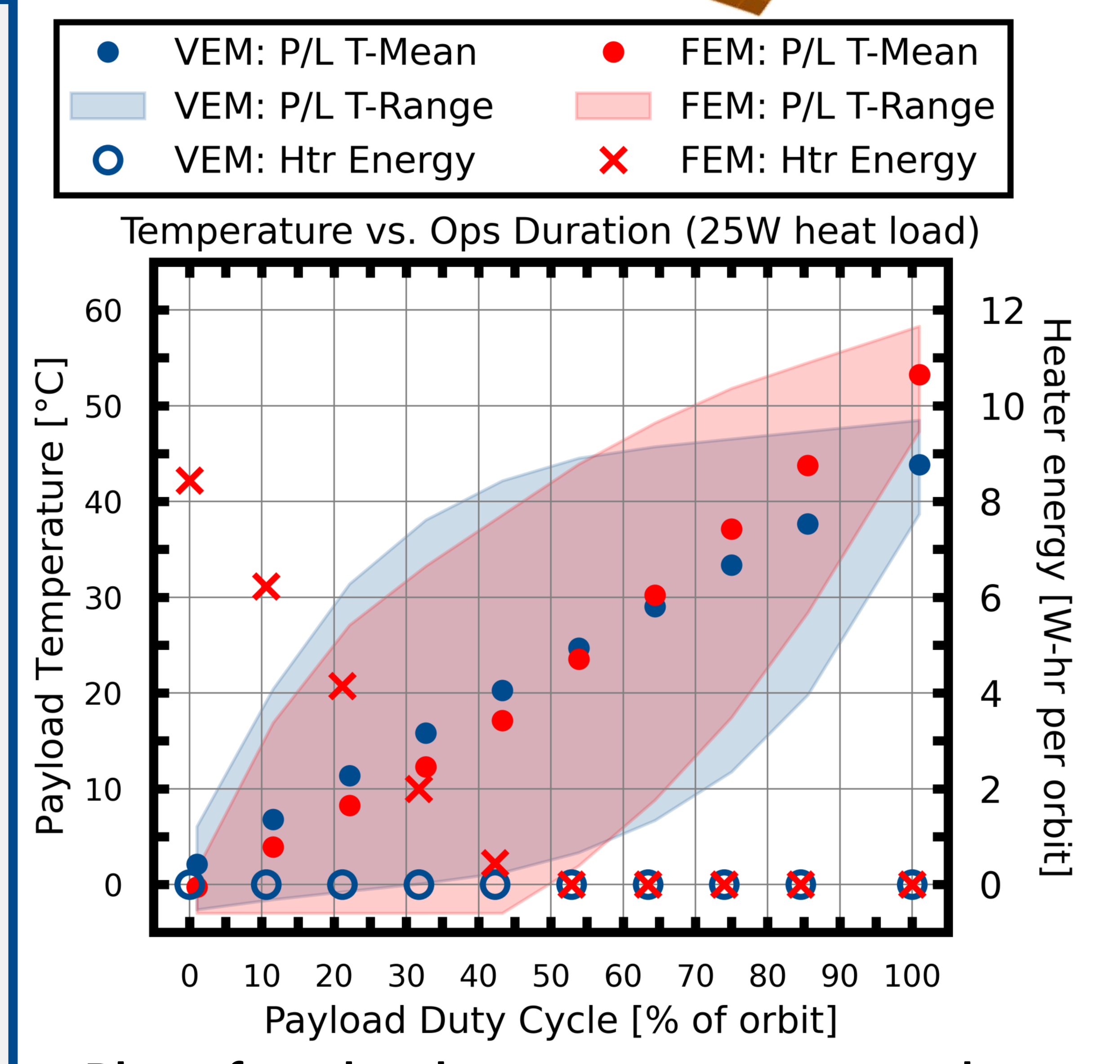
- Dynamic SINDA
  - Leverages Dynamic SINDA (a connection between SINDA and Thermal Desktop)
  - Temperature-dependent optical property
  - Periodically pause current SINDA solution, update radiation jobs (e.g., Radk and Heating Rates), then resume
  - The most versatile method and can be applied to nearly all situations but can be computationally expensive
  - Orbital slicing used to reduce expense



Dynamic SINDA Method

Results

- CubeSat design for ~50% duty cycle
- VEMs provide significant reduction in required heater energy at low duty cycles (e.g. 10%)
  - 6 W-hr per orbit (constant) vs. 0 W-hr per orbit (VEM)
- VEMs allow for increased duty cycles.
- Thermochromic VEM advantages
  - Simple, no-moving parts
  - Scalable and robust
  - Little size, mass, depth
  - Simple AI&T
  - Reduced/elimination of heater power demand



Plot of payload temperature versus duty cycle for VEM/FEM designs

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