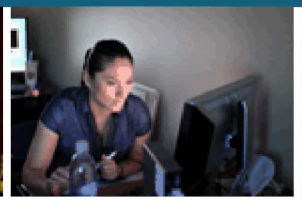
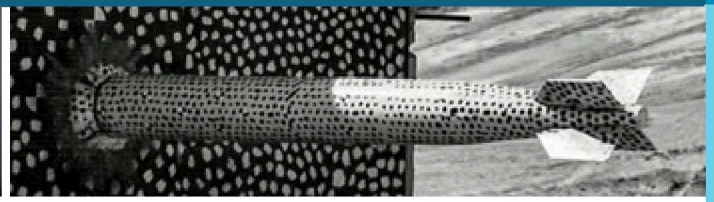
SAND2018-9711PE

A Condensation Model for the Europa Lander





PRESENTED BY

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An overview of Sandia National Laboratories

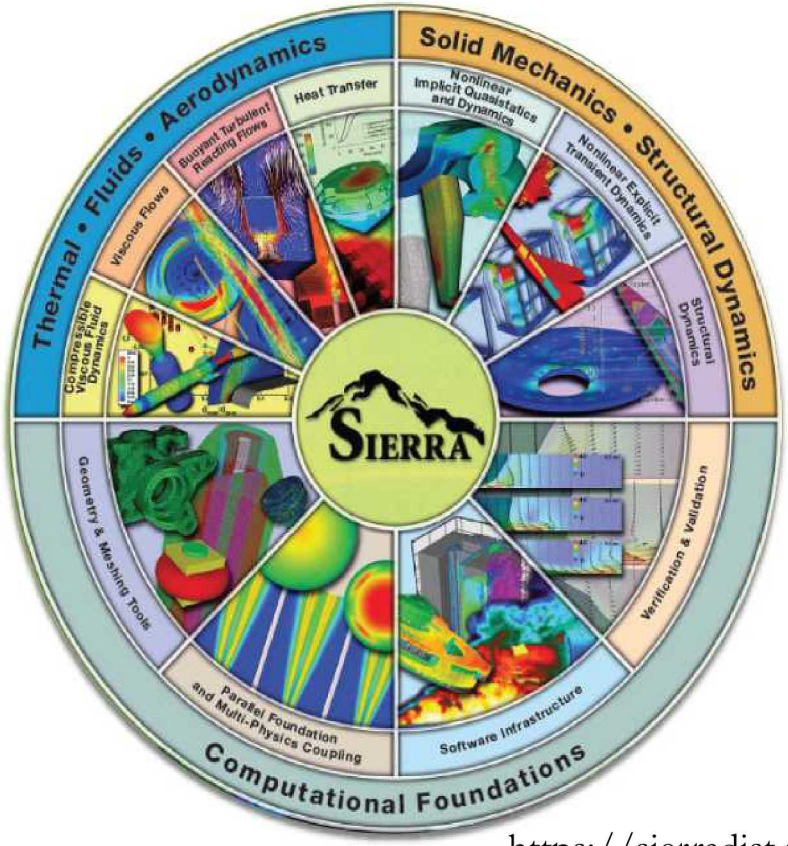
Exceptional Service in the National Interest

- Started with World War II Manhattan Project
- Big focus on national security
- Many areas of simulation: Fire, tires, nuclear weapon storage/transportation, space, wind energy, etc.

Fuego: low Mach fluid mechanics - heat and mass transfer problems (fire simulations)

Aria: coupled physics problems ranging from manufacturing processes to nuclear stockpile surety

Thermal Fluids ToolKit (TFTK): General Chemistry



https://sierradist.sandia.gov/

Jet Propulsion Laboratory's Europa Lander Mission

https://www.jpl.nasa.gov/news/news.php?feature=6737

http://earthsky.org/space/is-europas-ocean-like-earths

Terminal Sterilization Subsystem (TSS)

Need to make sure there are no living things from earth left on the lander before touching down on Europa's surface

In the event of a crash landing:

T>500°C for 0.5 seconds in 10 seconds

probability of extremophiles hitching a ride and surviving the trip? … TBD

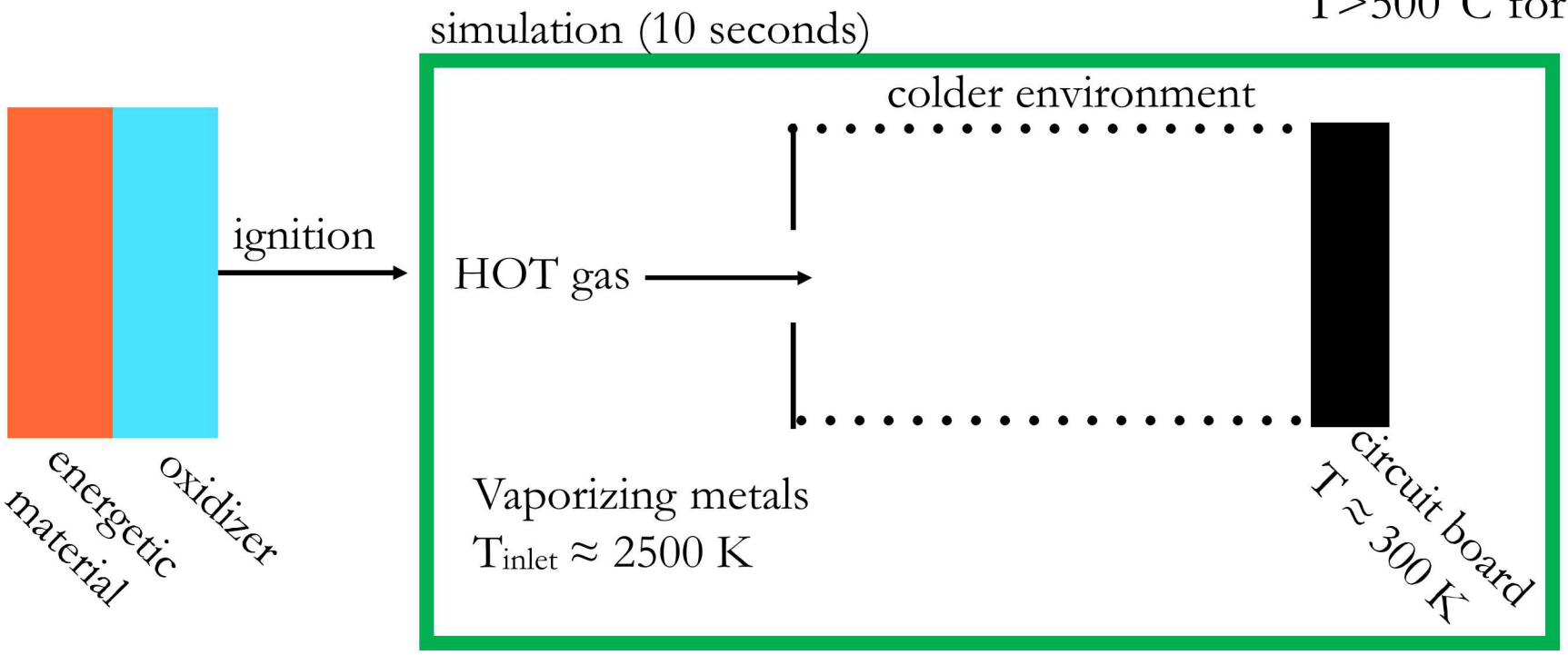
Task

Find the best configuration and materials that result in the most heat transfer to the circuit boards to meet requirements

How to simulate the TSS behavior

Requirement:

T>500°C for 0.5 seconds in 10 seconds



Hot gases entering colder environment -> condensation

Assuming not enough time for evaporation to be significant

Process:

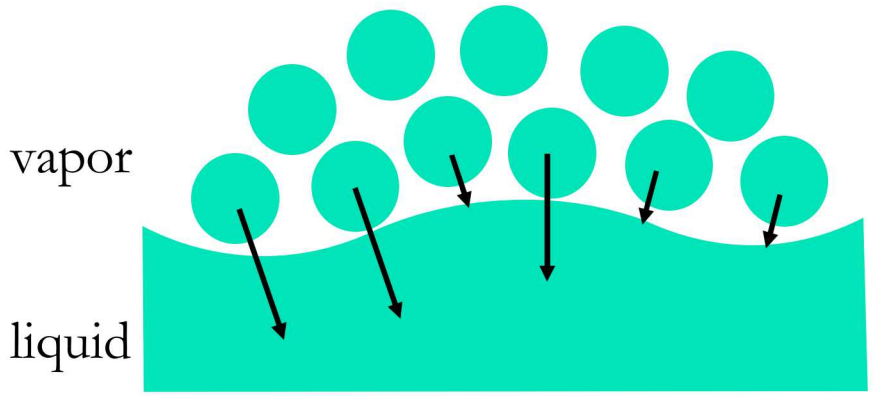
Calculate post-ignition gas composition using equilibrium codes (Tiger) → Run simulation using Fuego → Analyze results:

- Do the simulated temperatures satisfy requirements?
- Do the simulated temperatures and deposition thickness match experimental data?

Picking an appropriate condensation model for the TSS

vapor ⟶ liquid

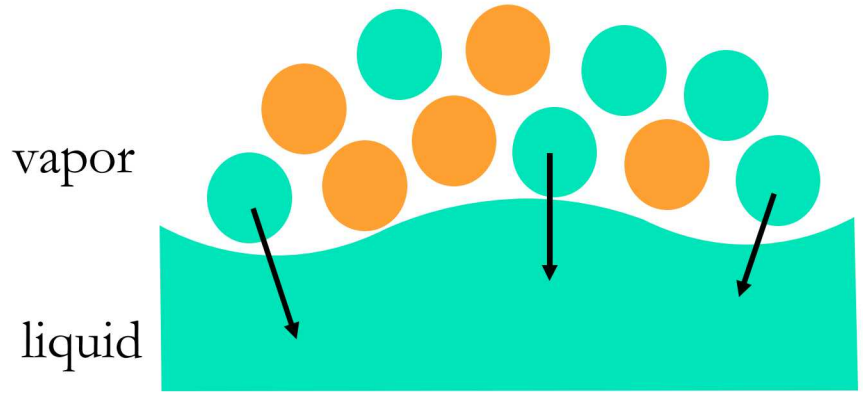
reaction-limited



as soon as a particle condenses, another takes its place

$$\text{efficiency} = \frac{\text{particles condensed}}{\text{particles impacting interface}}$$

diffusion-limited



as soon as a particle reaches the interface, it condenses

important for condensation with impurities/non-condensable gases

condensable component

non-condensable component

Implementing and using a diffusion-limited condensation model for the TSS

Fick's Law $J = -D\nabla\rho$

$$rate = J\frac{A}{V} = \frac{3DM(f_v - f_l)}{r^2 RT}$$

Gas phase fugacity

$$f_v = x_v P$$

Liquid phase fugacity

$$f_l = x_l P_{atm} \exp\left(\frac{L}{R}\left(\frac{1}{T_b} - \frac{1}{T}\right)\right)$$

Raoult's Law determines equilibrium

$$f_l = x_l H$$

$$f_l = x_l 10^{A - \frac{B}{C+T}}$$

Process:

Calculate post-ignition gas composition using equilibrium codes (Tiger) → Calculate D using cantera for this composition → Run simulation with condensation model using Fuego → Analyze results

Future work

Still need to add condensation to the actual simulations:

- Is the model behaving as expected?

- Does it improve simulation results compared to the experimental data?

Other model improvements:

- Want better resolution of concentrations inside boundary layer…mass transfer correlations