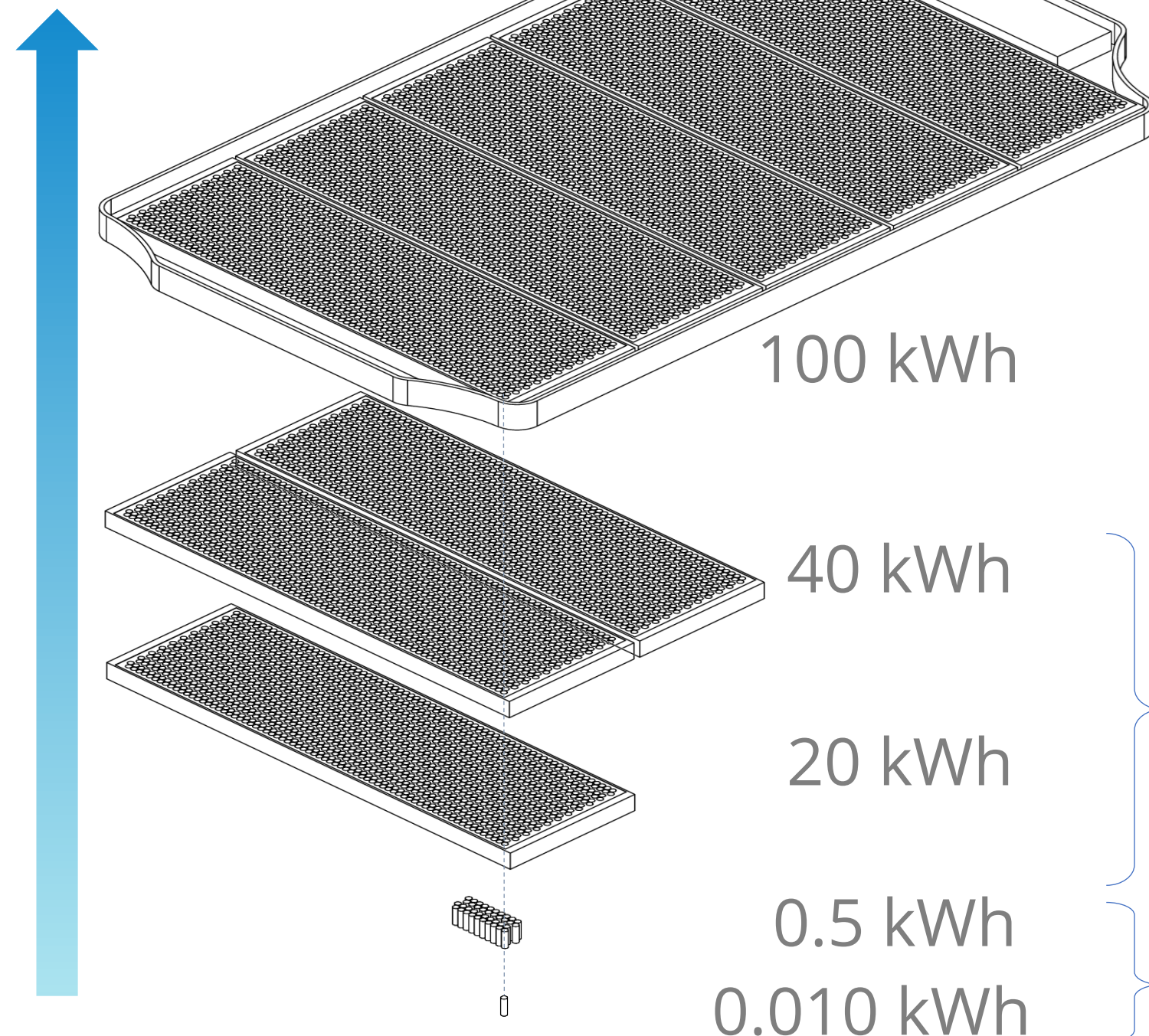


Early Thermal Runaway Detection Using Advanced Sensors in Scaled EV Packs

Best representation of application-level behavior



Low-cost testing

- Experimental thermal runaway (TR) studies on larger systems are limited due to practical limitations (e.g. testing capabilities, budget, etc.) but are needed to validate application-level effectiveness
- Large-scale tests can capture additional complexities presented at the pack-level. For early detection, this means understanding the effect of application-level design factors (i.e., cell configurations, headspace/ dilution volumes, thermal gradients, etc.)
- Intermediate-scale tests can help balance these competing factors.

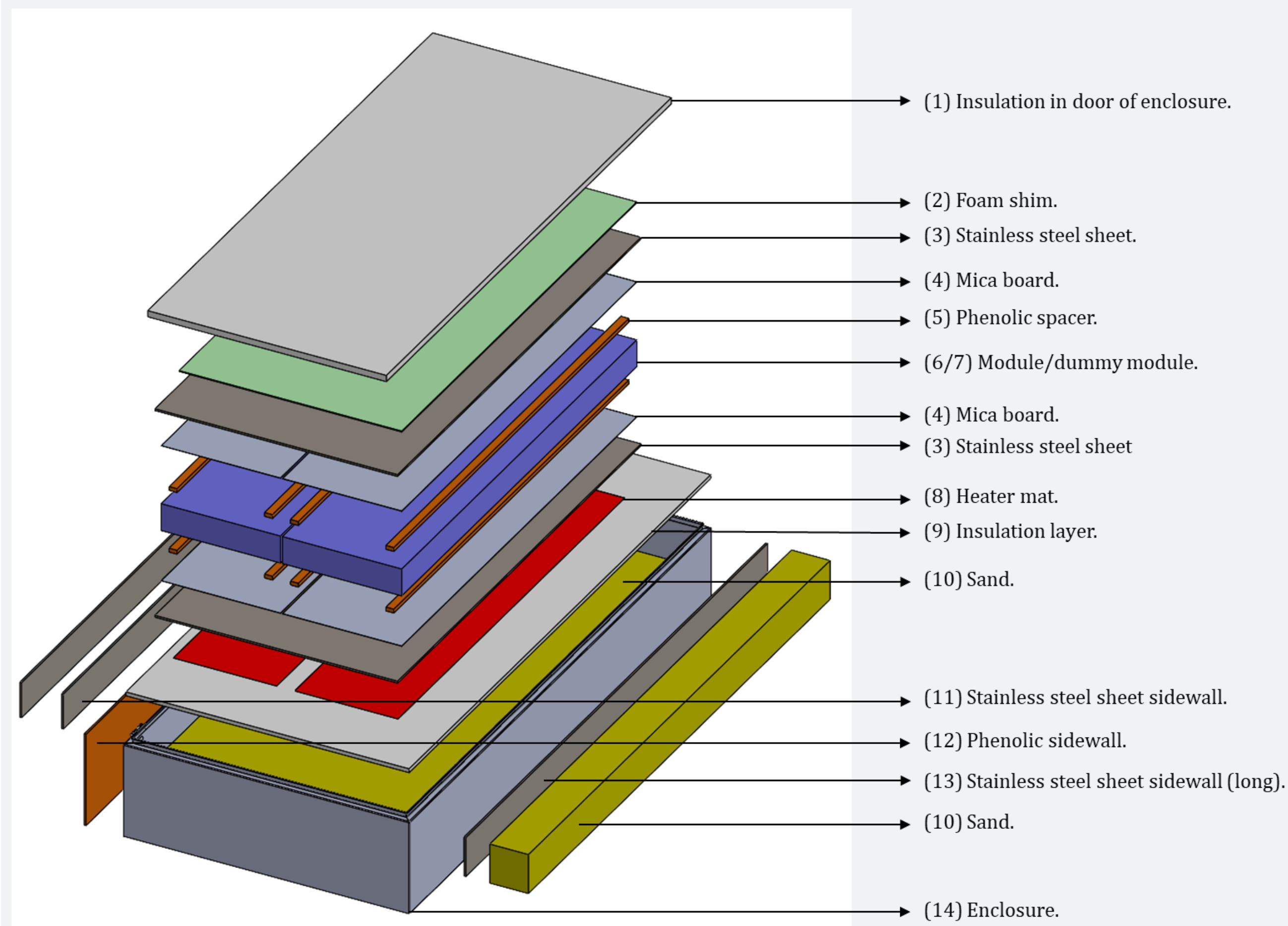
THIS STUDY:

- Two overheating tests of scaled EV packs with one and two 22.6 kWh Tesla Model S Plaid modules, triggered by a cartridge heater attached to 1-2 cells
- Our goal is to evaluate early detection capability of gas sensors and HV EIS

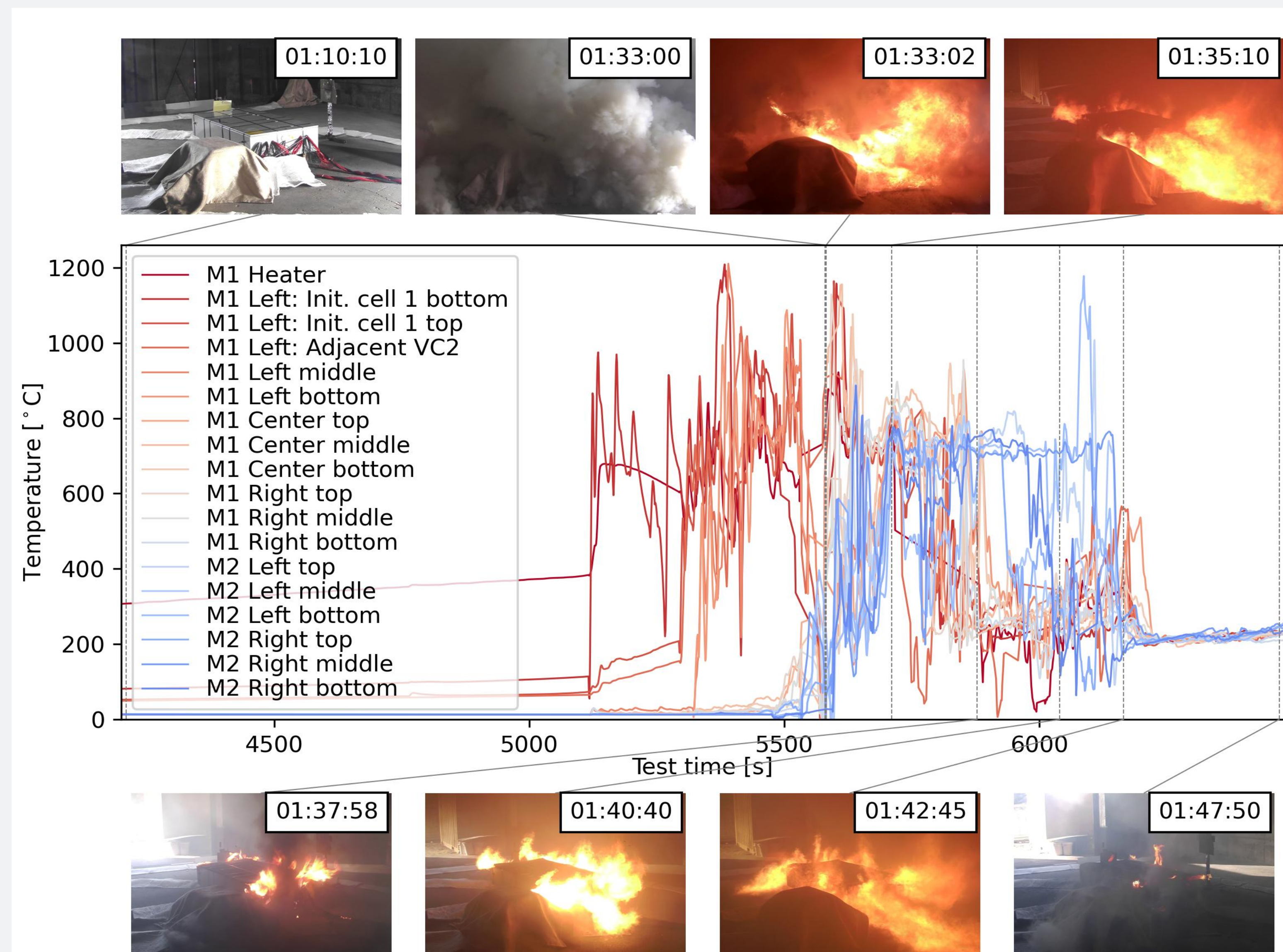
Most advanced diagnostic sensor testing

[Torres-Castro et al \(2024\)](#), [Li et al \(2024\)](#), [Cai et al \(2021\)](#), [Mateev et al \(2019\)](#)

SCALED PACK ASSEMBLY



THERMAL RUNAWAY PROPAGATION



GAS SENSORS ARE MOST PROMISING FOR EARLY TR DETECTION

Results suggest that implementing these sensors can provide enough time to...

- ✓ Alert emergency responders
- ✓ Evacuate passengers
- ✓ Mitigate or prevent fire propagation (e.g., adjacent EVs, buildings, etc.)
- ✓ Deploy intervention strategies (e.g., active cooling, emergency discharge)

These sensors show promise, but other real-world considerations still need to be evaluated including accuracy, long-term reliability, placement, and costs.

Most advanced warning

Least advanced warning

Sensor	Target signal	Detection time (w.r.t. cell TR)	Detection temperature
Sensiron SEK-SPS30	PM	65 mins	84°C
Telaire T6713	CO ₂	26 mins	142°C
Winsen MQ-138	VOC, Formaldehyde (HCHO), H ₂ , acetone, alcohol	18 mins	162°C
SGX Sensortech SGX-HF-10-MOD	HF	7 mins	207°C
SGX Sensortech TRDU5	CO	7 mins	205°C
	NH ₃	7 mins	205°C
	H ₂	4 mins	228°C
Renesas/ INL SGAS711	Flammable gases (e.g., VOCs, H ₂)	2 mins	232°C
HV EIS	Impedance	-2 mins	351°C
Li-ion Tamer	Elyte. solvent vapors	-9 mins	463°C

Before onset of cell self-heating

Before cell TR

After cell TR