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Investigating Environmental Impacts of Particle Emissions from a High-Temperature Falling Particle Receiver

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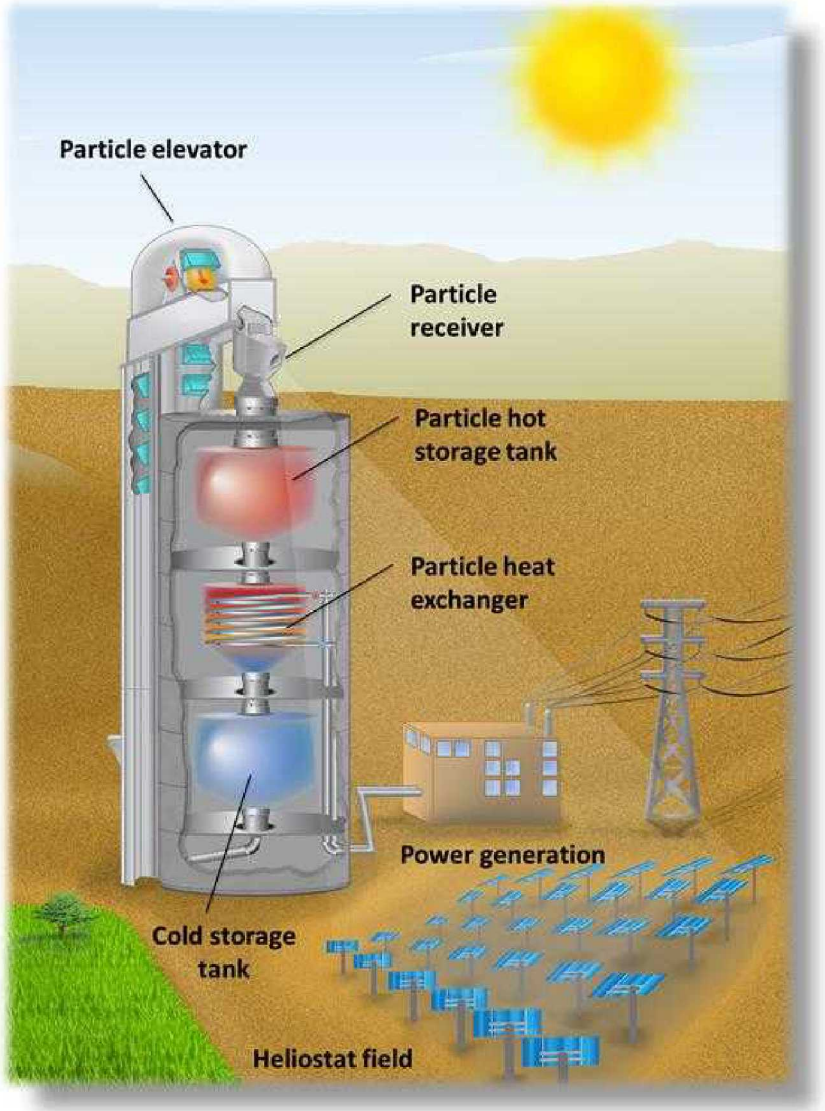
Overview

- Introduction and Objectives
- Testing for Particle Emissions
- Modeling of Particle Emissions and Environmental Impacts
- Conclusions

Introduction

- High-temperature particle receivers are being pursued to provide heat for sCO2 Brayton cycles

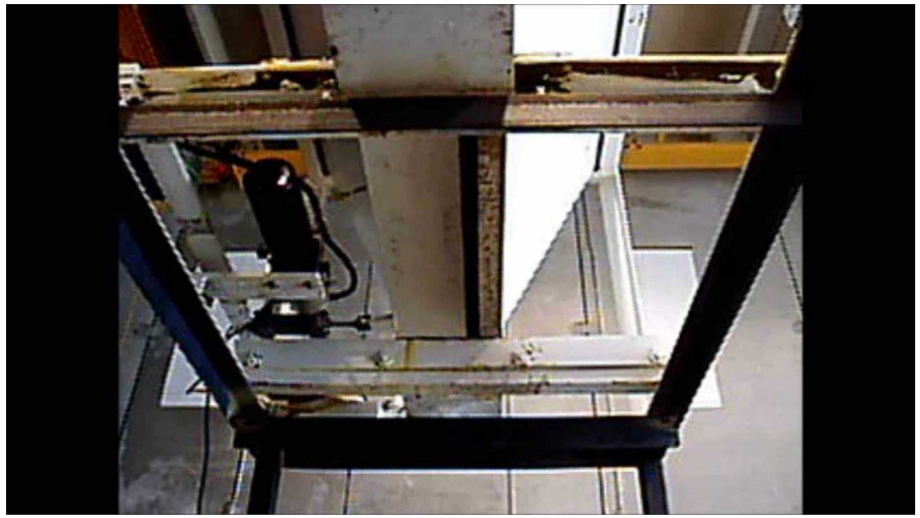


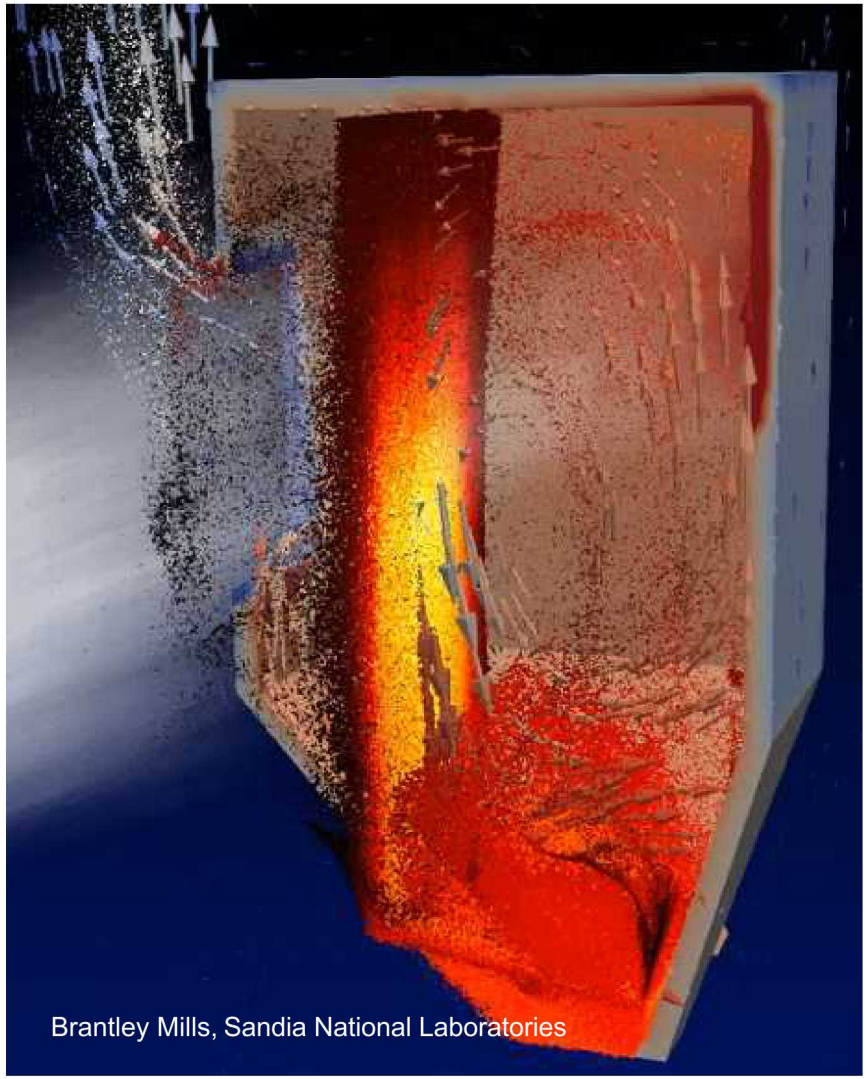
Value Proposition

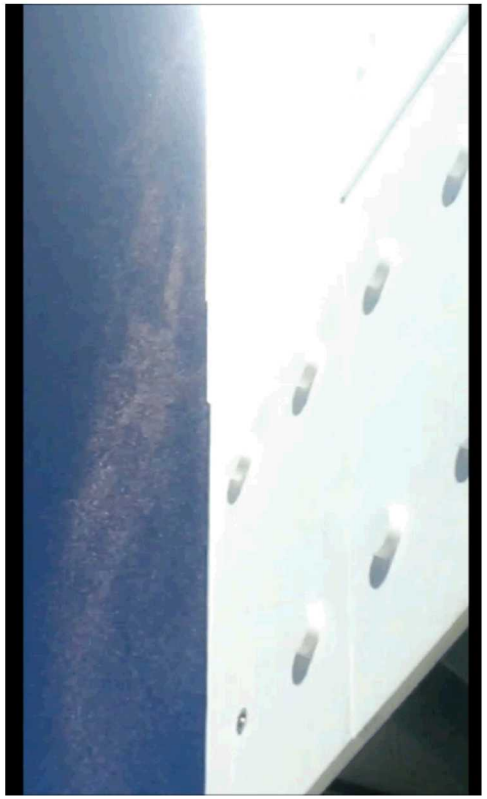
- Proposed particle receiver system has significant advantages over current state-of-the-art CSP systems
  - Sub-zero to over ~1000 °C operating temperatures
  - No freezing and need for expensive trace heating
  - Use of inert, non-corrosive, inexpensive materials
  - Direct storage (no need for additional heat exchanger)
  - Direct heating of particles (no flux limitations on tubes; immediate temperature response)

Problem Statement

- Particles fall through a cavity receiver
- Particles can escape from the open aperture of a falling particle receiver
  - Inhalation/pollution hazard
  - Loss of particle inventory







Nov. 2, 2015
3/8” slot – free fall
280 micron ACCUCAST ID50
10-15 mph south wind
500 – 1000 suns

Project Objectives

- Perform tests to characterize particle losses emitted from the aperture of a high-temperature particle receiver
- Develop models of particle emissions and exposure
- Compare to inhalation and pollution metrics (OSHA, 15 mg/m^3; EPA, 12 $\mu g/m^3$)

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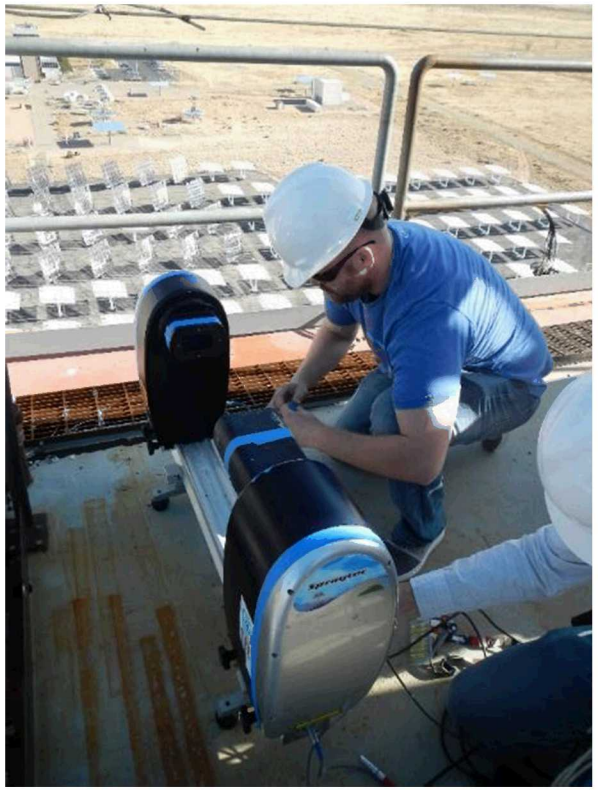
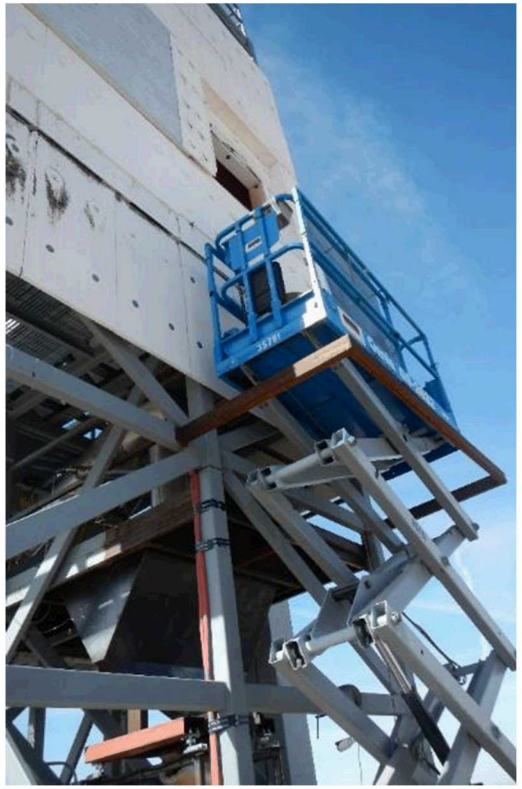
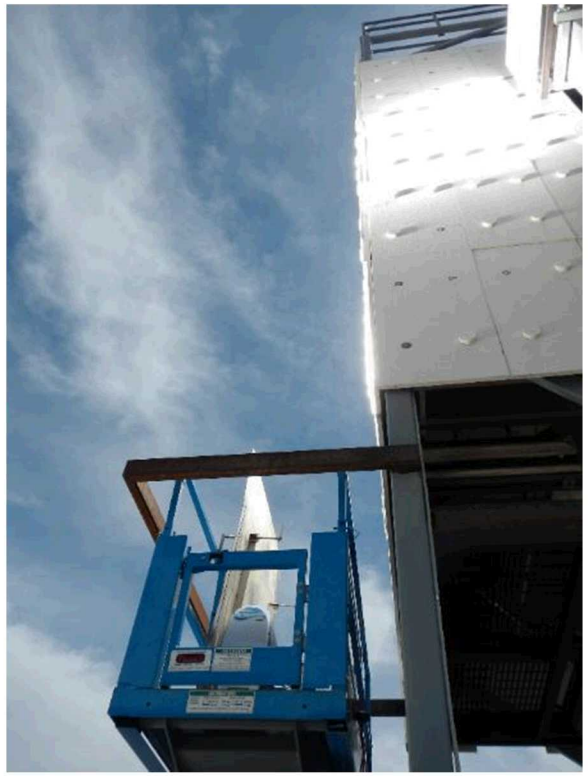
Large Particle Sampling

Malvern Spraytec particle analyzer used to evaluate large particles (tens to hundreds of microns)
April 5, 2018, Sandia National Laboratories

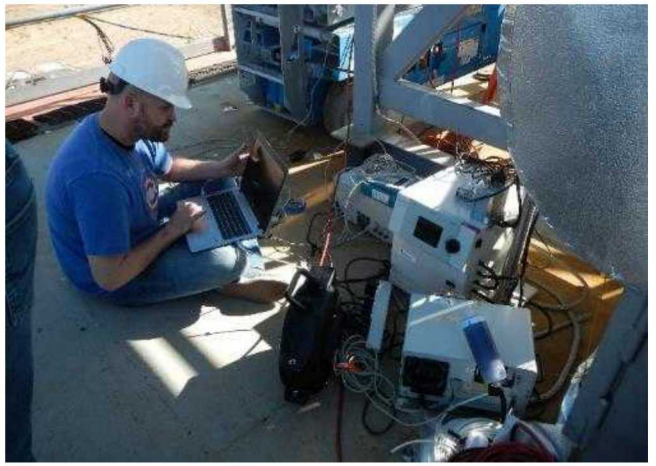






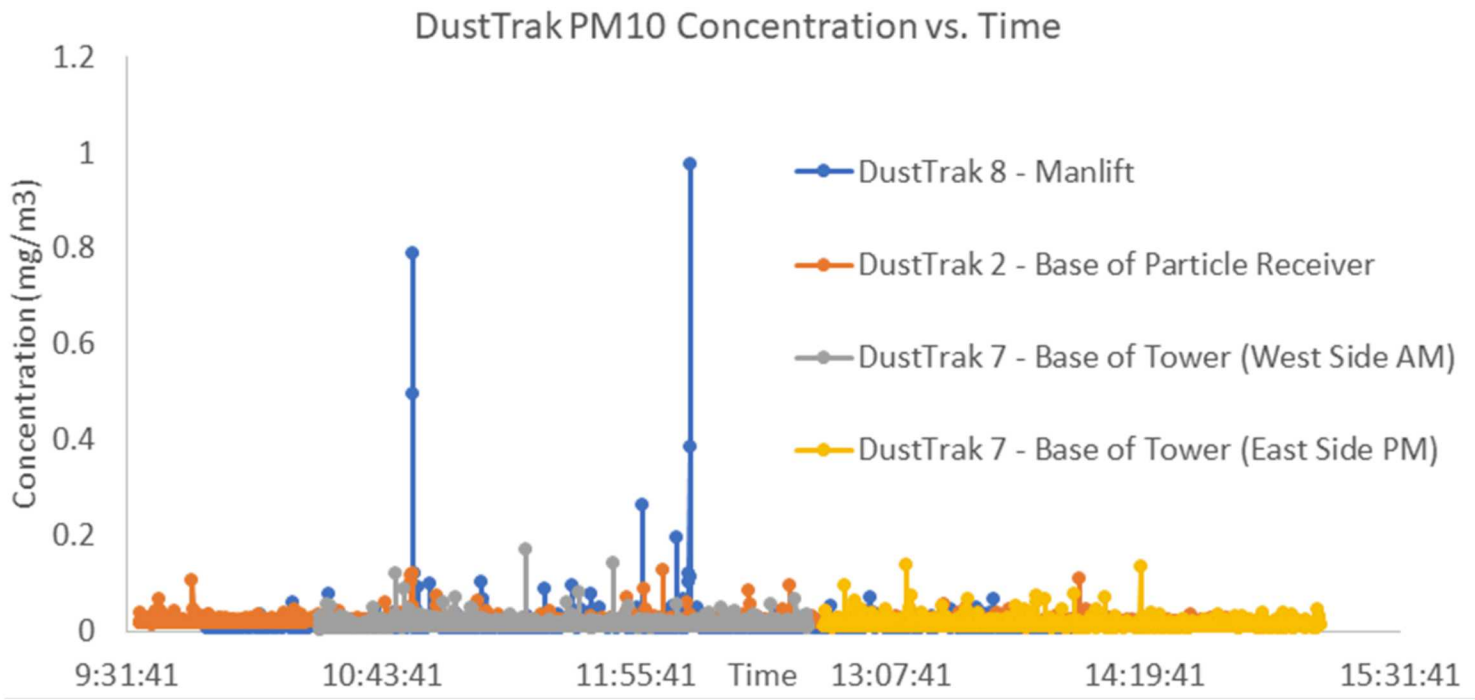
Small Particle Sampling

Used traditional air samplers to evaluate small particle emissions (submicron to micron) at the base and top of the tower



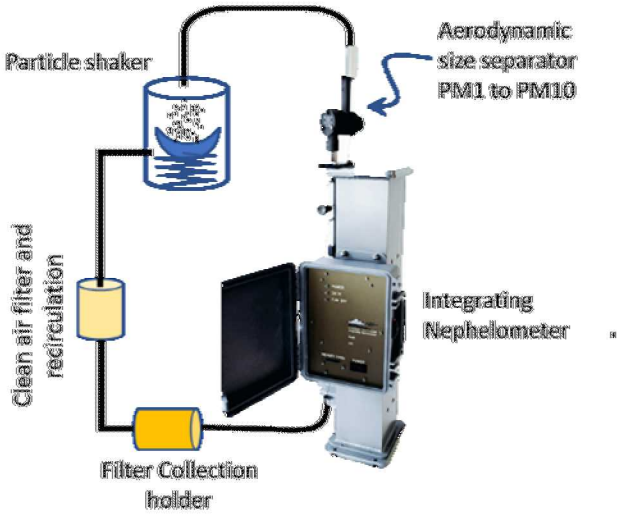
Air Monitoring Results

- Results showed PM10 emissions much lower than OSHA standard (15 mg/m^3)
- Peak particle emissions corresponded to start-up activities
  - Indigenous dust being shaken off equipment?

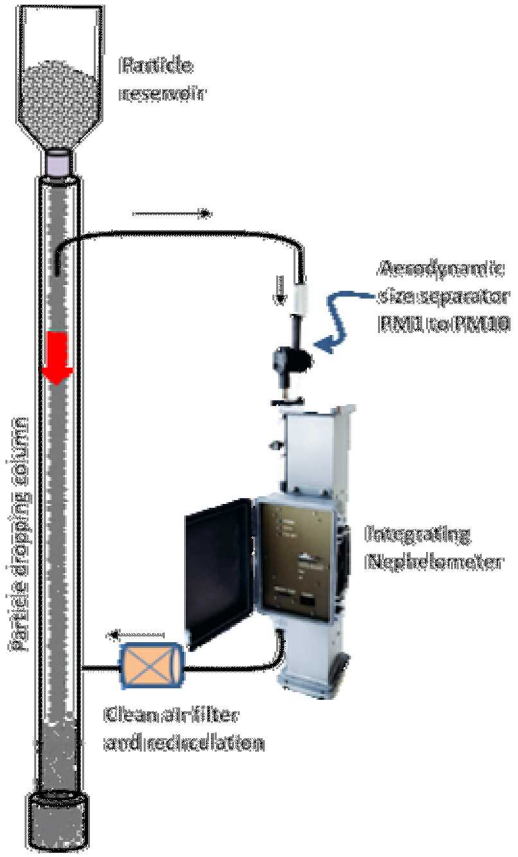


Lab-Scale Particle Fines Generation

- AirPhoton bench-scale testing of small particle generation



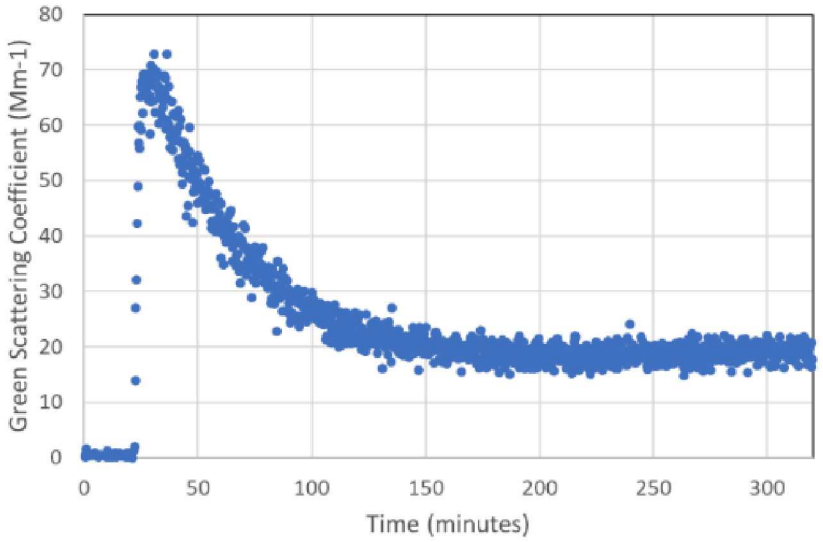
Particle shaker

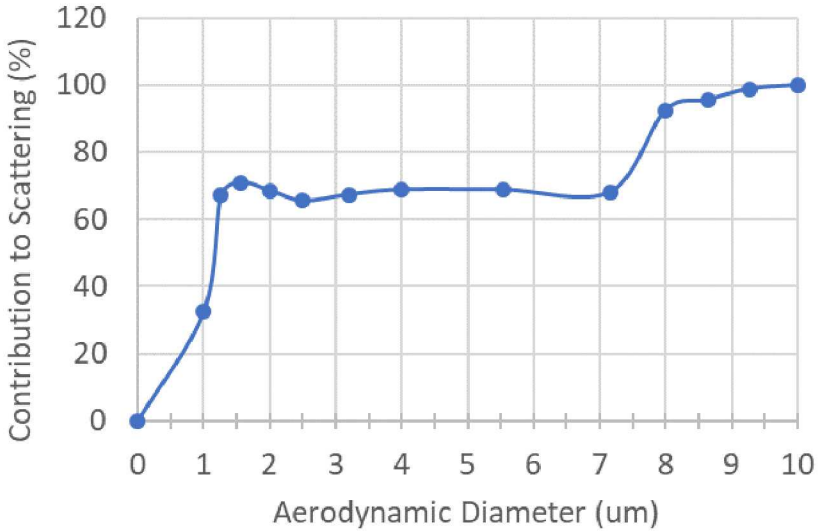


Dropping column

Particle Fines Generation

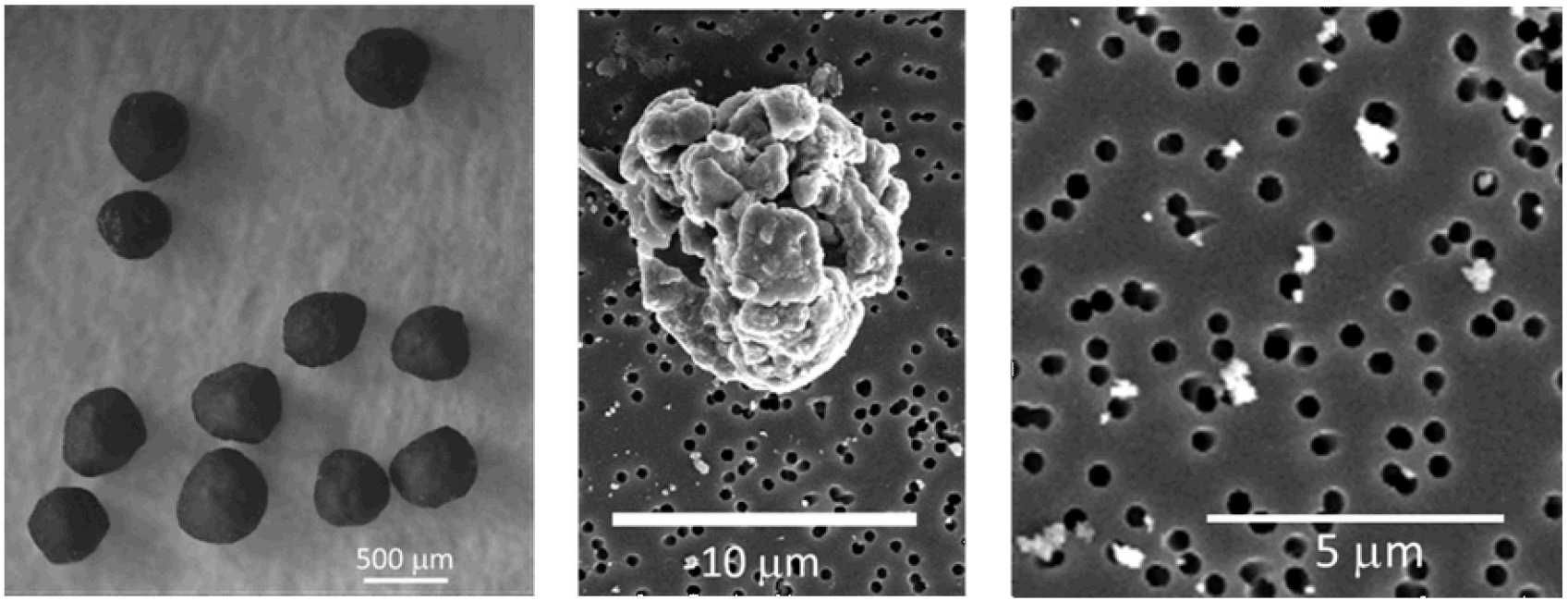
- Continuous production of small particles (~4 days of continuous shaking)
- Small particles produced
  - < ~1 micron (deagglomeration of pre-existing particles)
  - ~8 – 10 microns (mechanical fracture/abrasion during particle collisions)
  - Small particle generation rate ~$1x10^{-5}$ % of original mass





Particle Fines Characterization

- Optical microscopy (left) showing CARBO HSP parent particles and SEM images (center and right)



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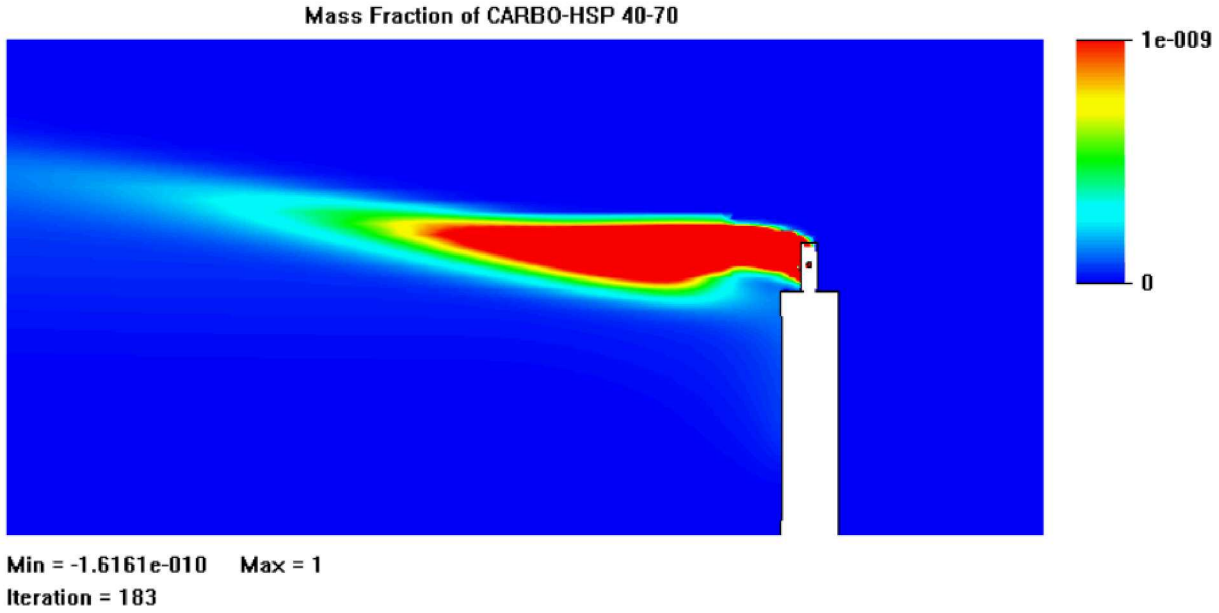
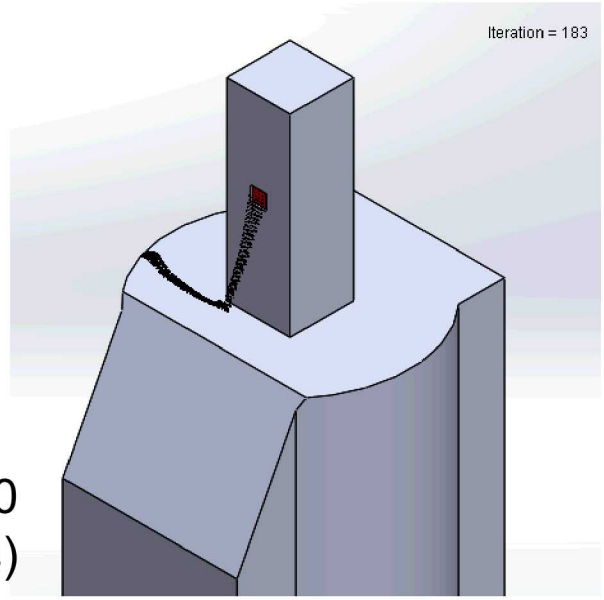
Particle Emission & Dispersion Modeling



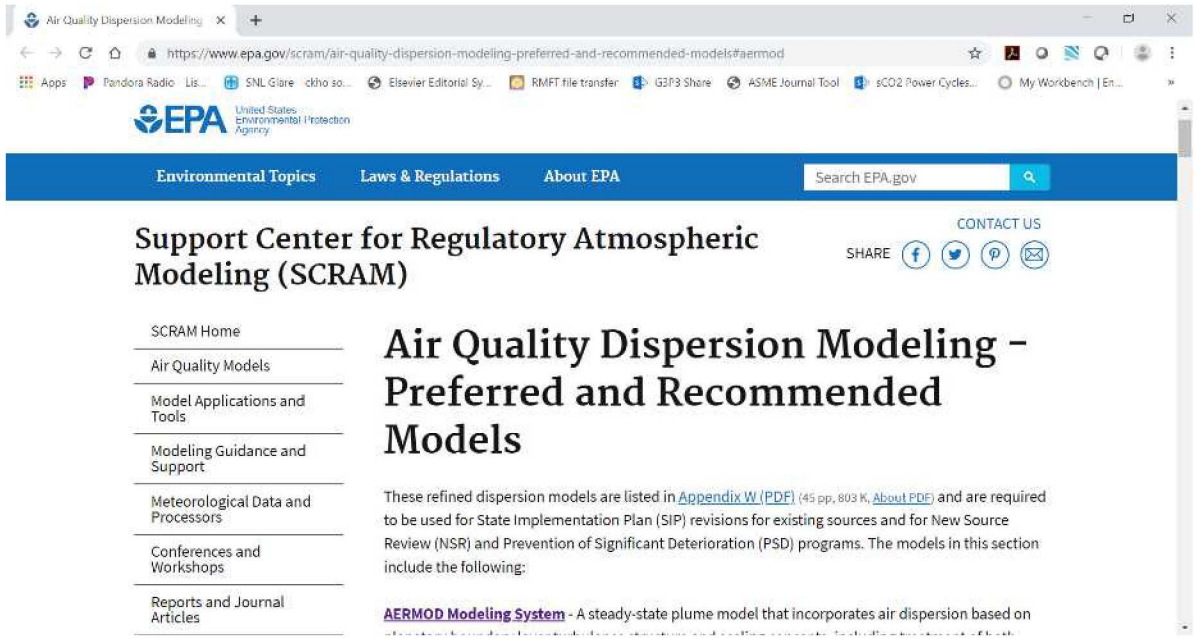
Simulation of small particle (~1-10 micron) concentrations with 2 m/s wind



Simulation of large particle (~350 microns)

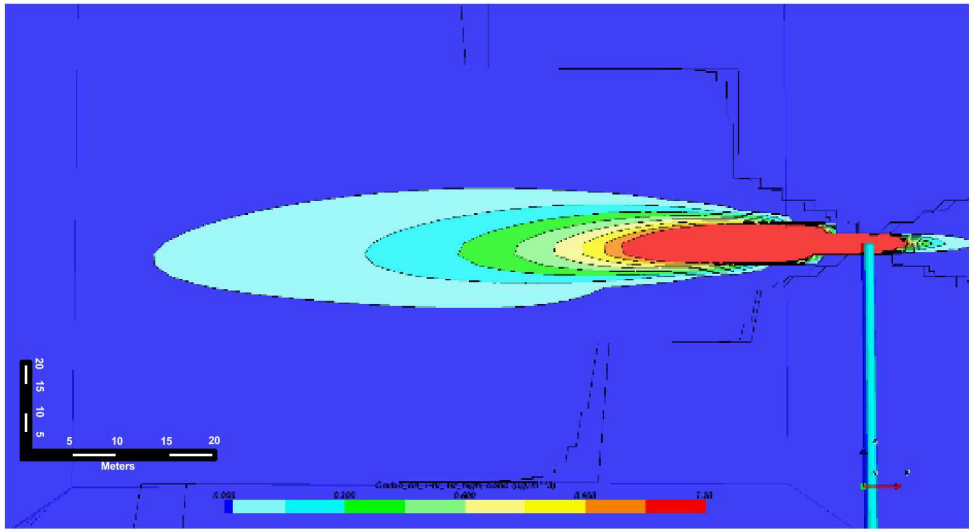
AERMOD – EPA Plume Dispersion Model

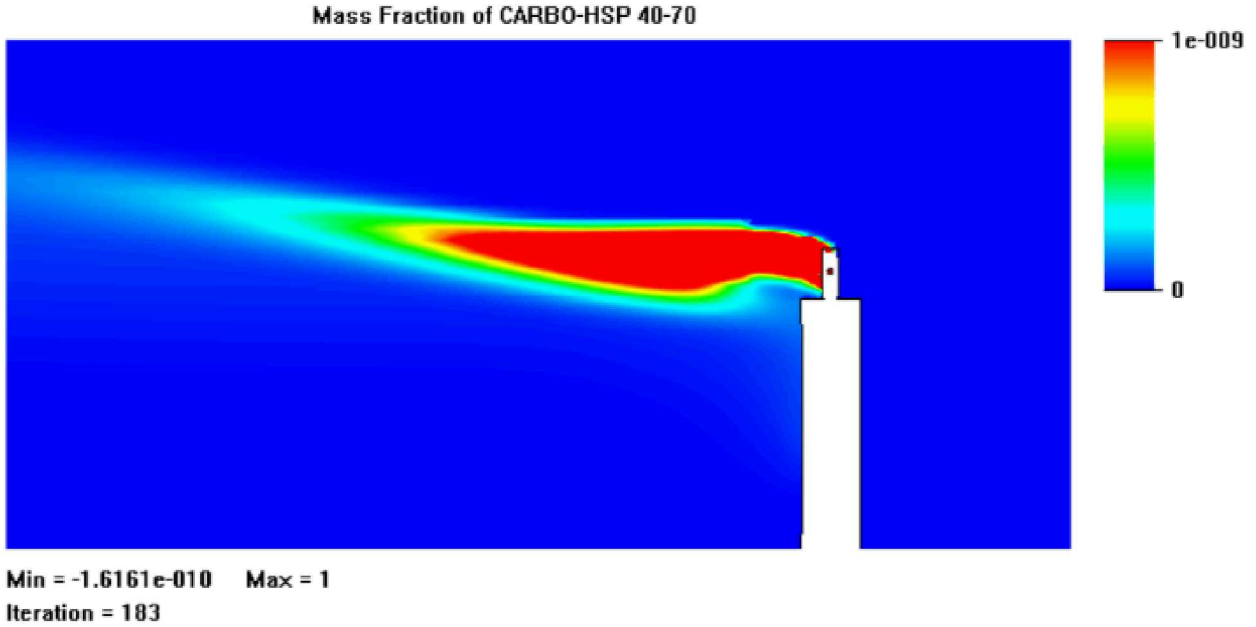
- EPA-recommended plume modeling software
  - Models steady-state dispersion and deposition of six common air pollutants, including particles
  - Used to assess National Ambient Air Quality Standards (NAAQS)



AERMOD – EPA Plume Dispersion Model

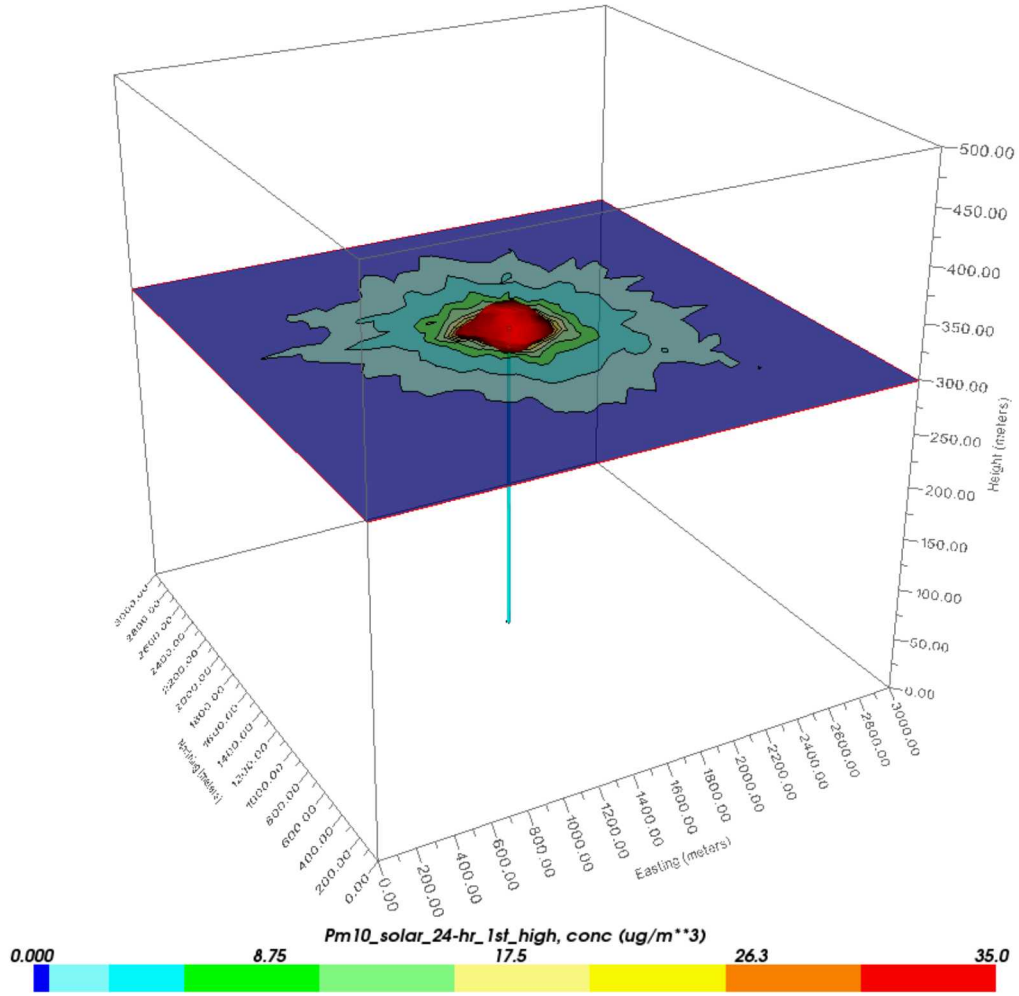
- Benchmarking against CFD model
  - 2 m/s west wind
  - Small particle emission (1e-5%) from 1m^2 aperture at 220’





AERMOD – Modeling of Particle Emissions

- Commercial scale (100 MW_e) particle-based CSP system
  - Assumes hourly meteorological conditions in Albuquerque
  - 285 m tower height, aperture diameter = 23 m, particle temperature = 700 C
  - Assumes particle mass flow of 2,000 kg/s through receiver with 1.4e-5% small-particle loss (PM10) based on lab testing



AERMOD Plume Modeling Results ()

- 100 MW_e Particle-Based CSP System

Modeled Parameter			Model Results ($\mu g/m^3$)	NMAAQS [4,5] ($\mu g/m^3$)	Result?
PM-2.5	Annual	Ground	0.006	12	PASS
		Plume	4.479		---
	24-hr	Ground	0.034	35	PASS
		Plume	117.2		---
PM-10	Annual	Ground	0.006	150	PASS
		Plume	4.544		---
	24-hr	Ground	0.043	150	PASS
		Plume	145.8		---
TSP	Annual	Ground	0.012	12	PASS
		Plume	9.024		---
	24-hr	Ground	0.160	35	PASS
		Plume	290.4		---

Conclusions

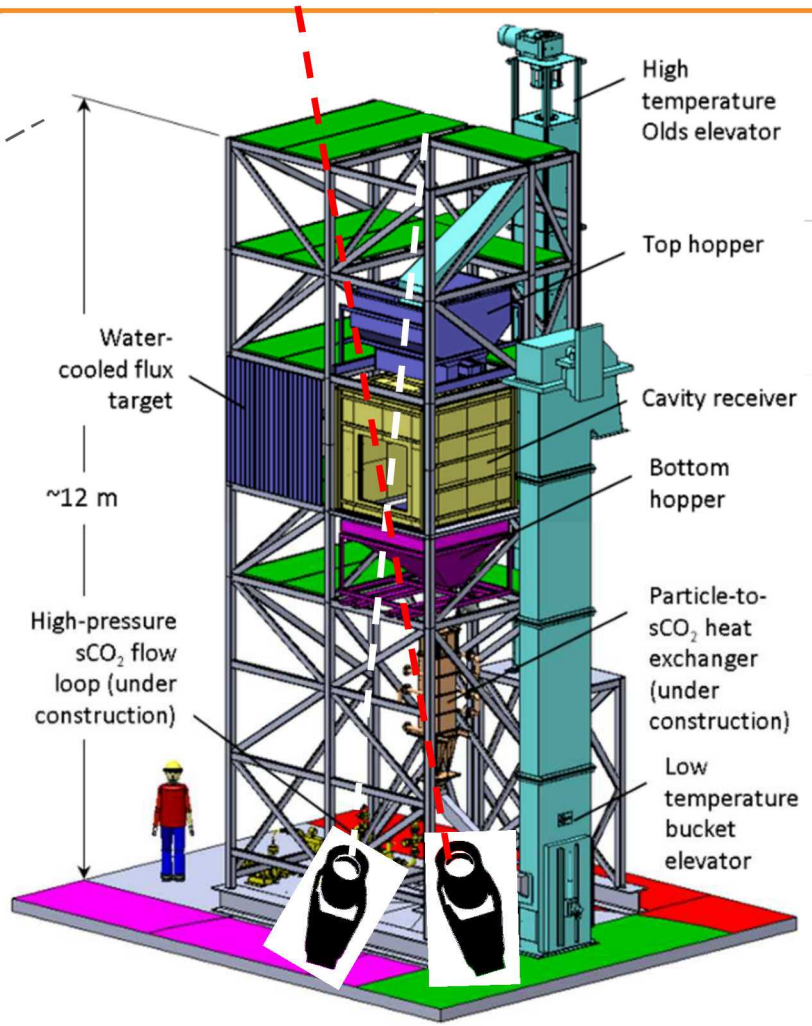
- Particle emissions measured during on-sun tests
  - Measured particle emissions very low relative to OSHA standards (PM10 << 15 mg/m^3)
- Lab-scale tests characterized particle fines generation
  - Small particle generation rate ~$1x10^{-5}$ % of original mass
- Modeling performed to evaluate particle dispersion and environmental impacts
  - Results showed that expected particle concentrations were much lower than national ambient air quality standards
  - Particle emission rate would need to be increased by a factor of 400 (1e-3% of total particle mass flow through the receiver) to approach limits for PM 2.5 and PM 10

Acknowledgments

- This work is funded in part or whole by the U.S. Department of Energy Solar Energy Technologies Office under Award Number 33869
  - DOE Project Managers: Matthew Bauer, Andru Prescod

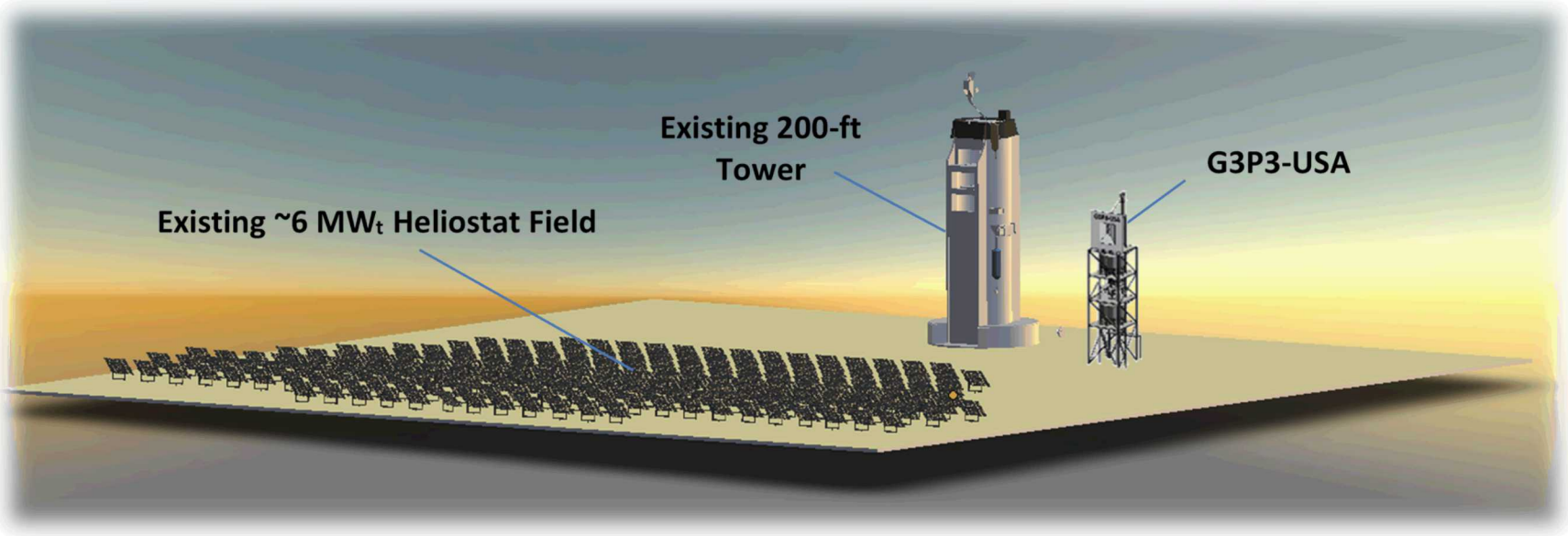
Questions?

On-sun particle receiver testing at the National Solar Thermal Test Facility at Sandia National Laboratories, Albuquerque, NM



High-Temperature Particle Receiver

Questions?



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BACKUP SLIDES