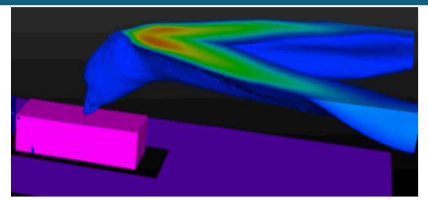
SAND2020-8750PE

Sandia Work on Hydrogen for Transportation Systems



Presented by:

Brian Ehrhart

8/20/2020

Introduction EBMUD

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SAND2020-XXXX PE

Sandia National Laboratories Overview

"Exceptional Service in the National Interest"

Federally Funded Research and Development Center (FFRDC)

- Government owned, contractor operated

Sandia is the largest National Lab in the U.S

Main sites: Albuquerque, NM and Livermore, CA

- Other sites: Kauai, HI; WIPP, Carlsbad, NM; Pantex Plant, Amarillo, TX; Tonopah, NV

FY19 Budget: $3.8B

- Sponsors: DOE, DOD, DHS, DOT, NRC, etc.

>14,000 employees (>12,000 in NM; >1,600 in CA)

- Staff has grown by over 5,000 since 2009 to meet all mission needs

Sandia HQ: Albuquerque NM

Livermore CA

Hydrogen program

- 60+ years of work, in a wide range of areas: H2 storage, production, delivery, development of regulations, market transformation
- Market Transformation: Zero Emission H2/Fuel Cell Maritime and Rail Programs

Sandia's Hydrogen and Fuel Cells Research Program

Sandia provides deep, quantitative understanding and a scientific basis for…

Materials – for hydrogen production, storage and utilization

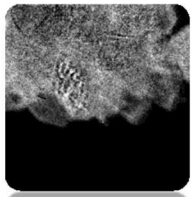
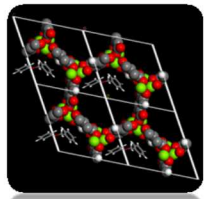
Safety – risk analysis and the creation of risk-informed standards

Hydrogen Production from Renewables


Advanced water-splitting materials and technologies for large-scale H_2 production

Hydrogen Storage Materials and Solutions

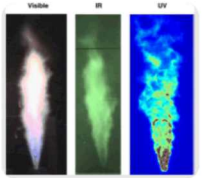
Discovering the behavior and performance of solid storage materials


Hydrogen-Materials Compatibility

Low-cost, hydrogen-compatible materials and the science basis for their qualification


Hydrogen Fueling Infrastructure



H_2 release behavior and risk assessment to define the safety envelope for storage & delivery

Technologies for Non-Vehicle Applications

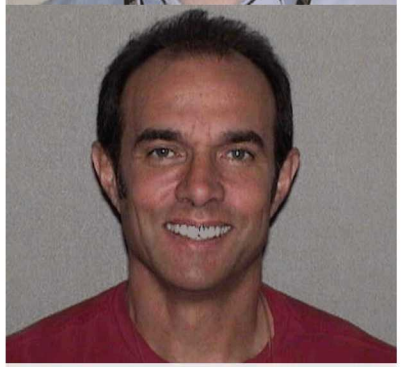
Marine and rail applications


Fuel Cells

Membrane systems for enhanced electrochemical performance

Our Team- Hydrogen Transportation Systems

Brian Ehrhart
R&D Chemical Engineer
Safety Codes and Standards Railway & Light Duty Vehicle Applications

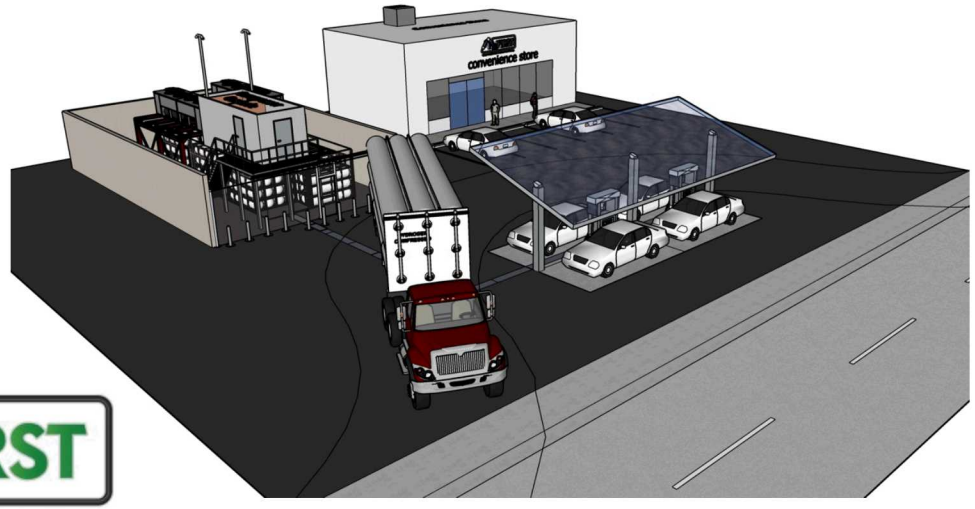


Lennie Klebanoff
R&D Physics
H2 Storage Materials, Railway & Maritime Applications

Cheri Markt
System and Mechanical Engineer
Safety Codes and Standards Railway Applications

Outline

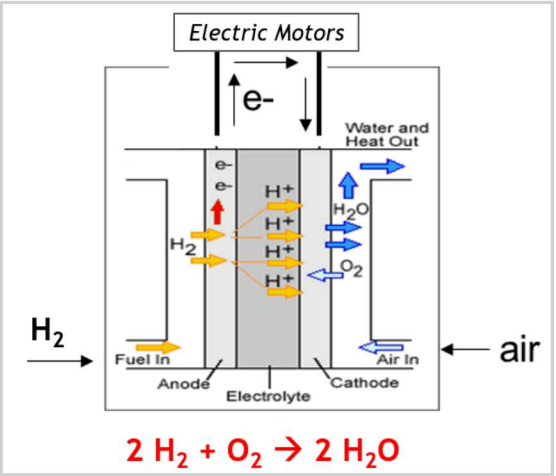
1. Benefits of H_2 as a Fuel Source
2. H_2 Risk and Safety
   - Modeling and Simulation, Experimental Testing
3. Feasibility Studies for New Applications
   - Cost, Safety, Vehicle Performance, Regulations



H2FIRST
Hydrogen Fueling Infrastructure Research and Station Technology

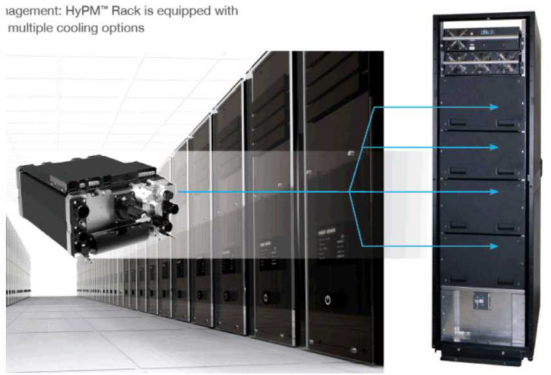
Benefits of H_2 as a Fuel Source

- H2 produces ZERO pollution or greenhouse gas at point of use
- Commercially available
- More energy efficient than diesel generators
- Eliminates fuel spills, greatly reduces noise
- Emissions can only arise from H2 production/delivery
- No "thermal runaway" possible
- Rapid refueling/recharging process



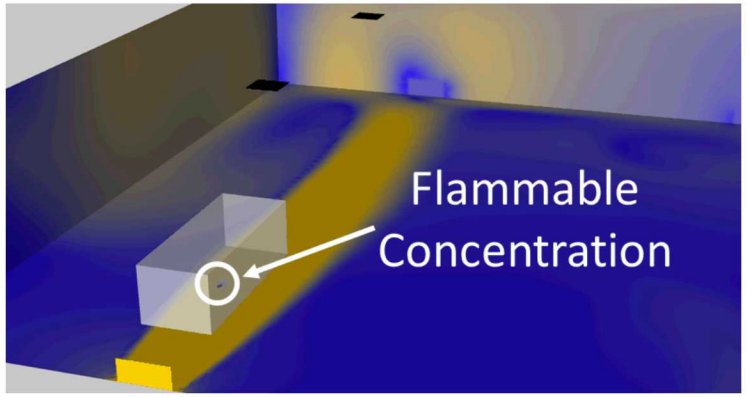
Going In:
H2 and air

Going Out:
Electricity
Waste Heat
Warm humidified air

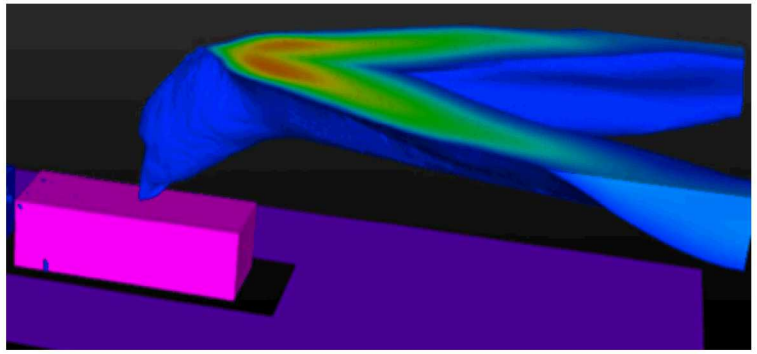


Photos Courtesy Ryan Sookoo, Hydrogenics

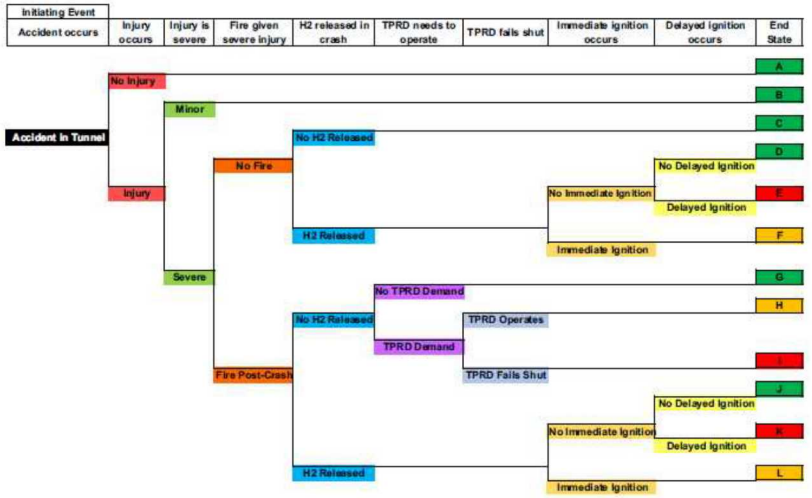
Hydrogen Risk Assessments and Consequence Modeling



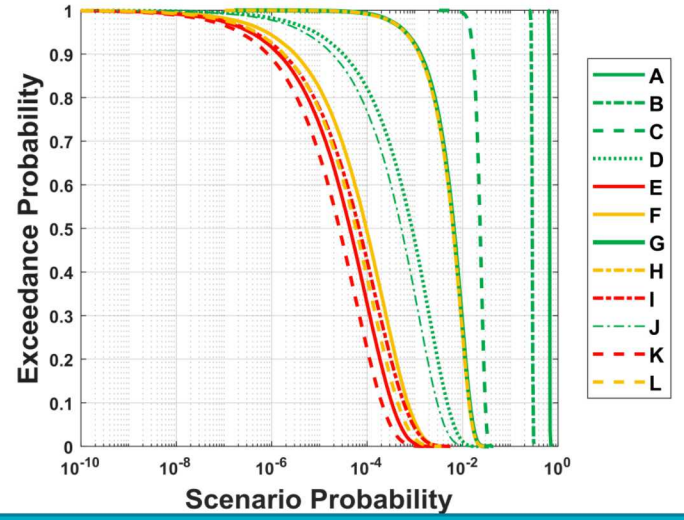
Dispersion modeling of leak with ventilation in repair garage



Jet fire modeling of effect of hydrogen leak on tunnel



Event tree for hydrogen vehicle in crash



Probability/likelihood of outcomes with uncertainty

https://energy.sandia.gov/programs/sustainable-transportation/hydrogen/quantitative-risk-assessment/

Hydrogen Risk and Safety

Safety Codes and Standards

- NFPA 2, 55, 70 Hydrogen Fuel Cells Technology Office
- 29 CFR (Dept of Labor)
- 49 CFR (Dept of Transportation)
- ARR Federal Association of Railroads
- AIAA/ANSI American Institute of Aeronautics and Astronautics

Guidance Related To

- Storage tanks
- Transfer areas
- Leak detection
- Electrical enclosures
- Bonding and grounding of equipment and buildings
- Worker safety procedures
- Emergency response planning
- Roadway and area surfaces
- Transfer piping
- Building design

Sandia contributes to the development of Safety Codes & Standards

Planned Future Work – H_2 Rail Safety Topics (DOT FRA)

Assessment of post-crash outcomes for passenger and freight rail

- Developing event sequence diagram with uncertainty quantification for hydrogen on both freight and passenger rail
- Modeling of consequences scenarios (CFD and/or reduced-order)

Recommendations on emergency response

- Recommendations on the minimum evacuation times and distances for passenger or freight rail following accidental release of hydrogen fuel

Recommendations on best-practices for human performance to ensure and maintain safety during refueling operations

- Review of the human factor issues surrounding refueling of hydrogen fueled train
- Develop recommendations on best practices and procedures for refueling

Identify potential mechanical loading environments experienced in railroad operations that may lead to hydrogen embrittlement concerns

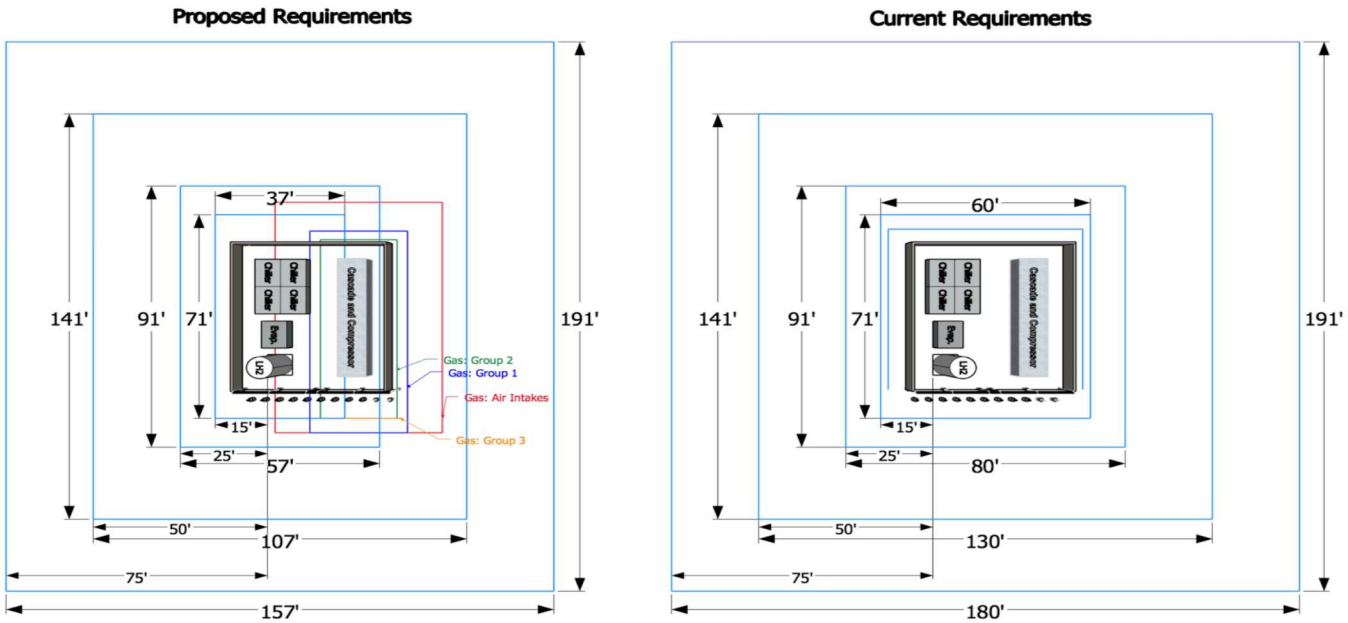
- Literature review to identify where existing hydrogen studies overlap the mechanical loading conditions experienced in normal railroad operations and identify potential areas where further experimental research would be beneficial

Light-Duty Vehicle Infrastructure Studies

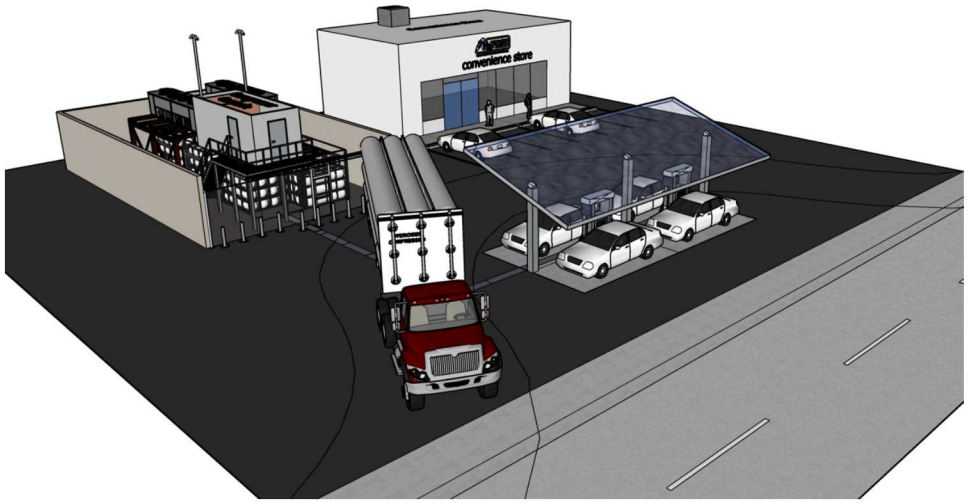
H2FIRST
Hydrogen Fueling Infrastructure Research and Station Technology

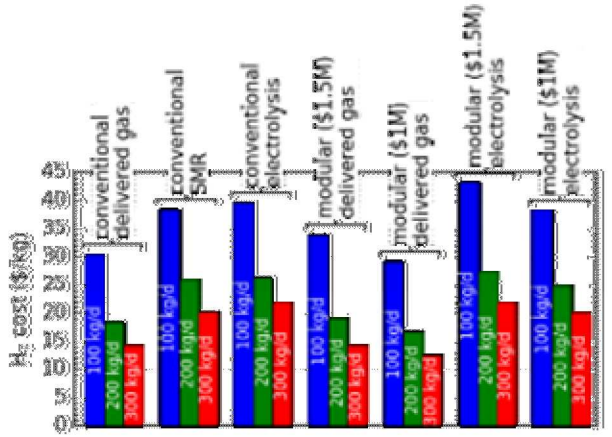
Publicly available system designs for stakeholders

Focusing on NFPA 2 code



Layout footprint quantification and comparison





Economic Comparisons

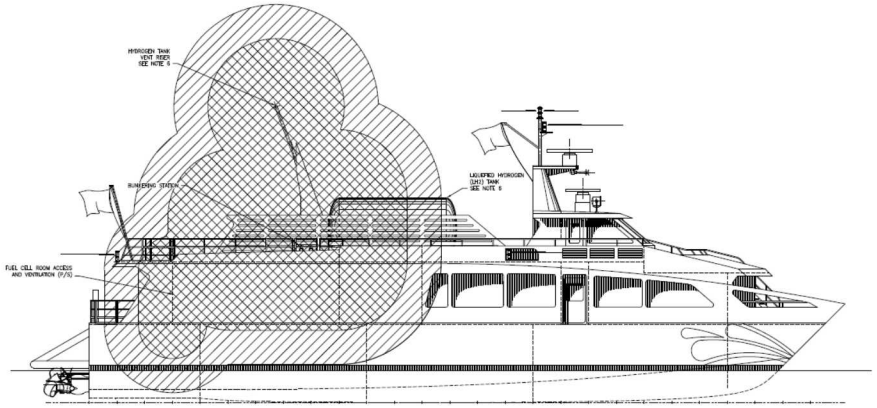
https://energy.sandia.gov/programs/sustainable-transportation/hydrogen/infrastructure/

Bringing Zero Emission H_2 Technology to Maritime

Feasibility studies funded by DOT/MARAD

SF-BREEZE high-speed hydrogen fuel cell ferry
- 1,000+ kg/day hydrogen demand

Zero-V hydrogen fuel cell coastal research vessel
- 2,400 nautical mile range
- Refueled with ~11,000 kg of LH2



https://energy.sandia.gov/programs/sustainable-transportation/hydrogen/market-transformation/maritime-fuel-cells/

Bringing Zero Emission H_2 Technology to Rail (H2@Rail)

Class I Freight Trade Study H_2 vs Electric
Class I Freight Fueling Stations, Cost Study

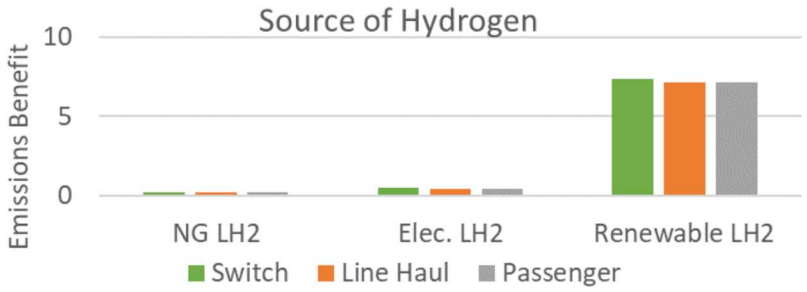
Emissions reduction benefit from hydrogen depends on the source of hydrogen

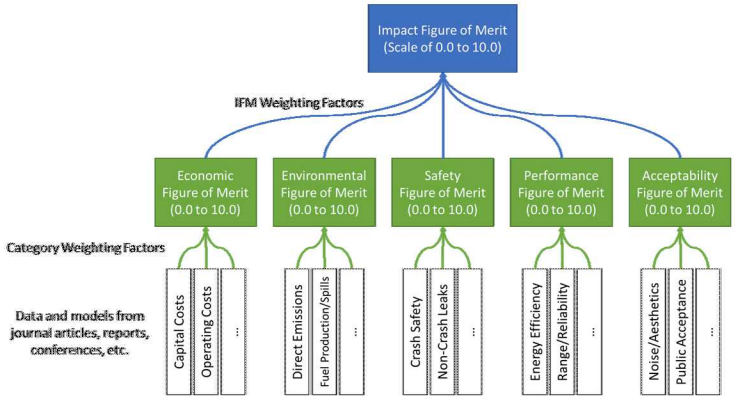
Reliability and cost of hydrogen locomotives needs to be investigated

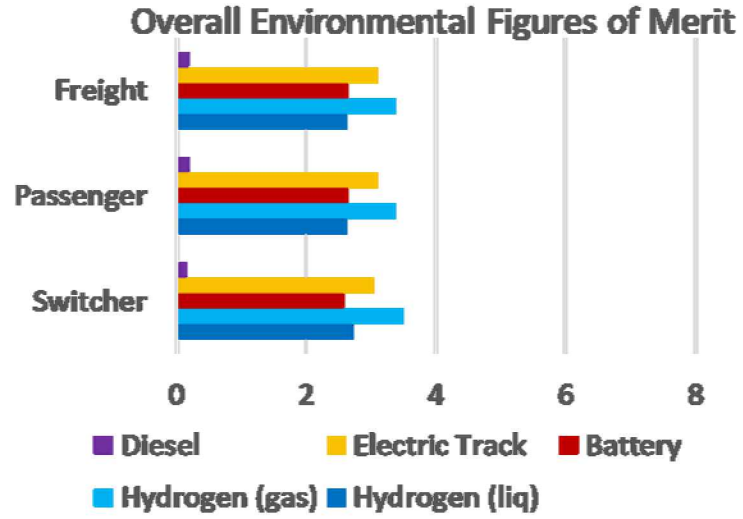
- Impacts performance and economics

Fueling infrastructure needs to be investigated further

Safety needs to be investigated further







https://www.energy.gov/sites/prod/files/2019/04/f62/fcto-h2-at-rail-workshop-2019-ehrhart.pdf

Future Work – Hydrogen Heavy-Duty Trucks (DOE HFTO)

Multiple proposals submitted on multiple projects to analyze refueling facilities for heavy-duty trucks

- Leveraging past work on H2FIRST Reference Station Projects

Stay tuned…

Thank you! Questions?

Brian Ehrhart bdehrha@sandia.gov

Lennie Klebanoff lekleba@sandia.gov

Cheri Markt cmarkt@sandia.gov