Exceptional service in the national interest

SAND2015-2693PE

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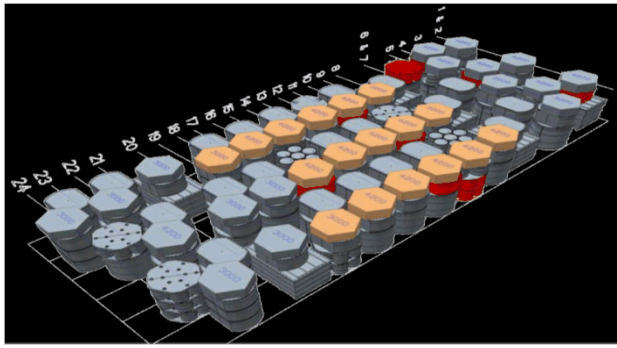


WIPP Technical Assessment Team (TAT)

Sandia: Building the Framework of the Event

Paul Shoemaker, Senior Manager & TAT Member

Defense Waste Management Programs Group

Leanna Minier, Manager

EM Dynamic and Reactive Science

April, 2015

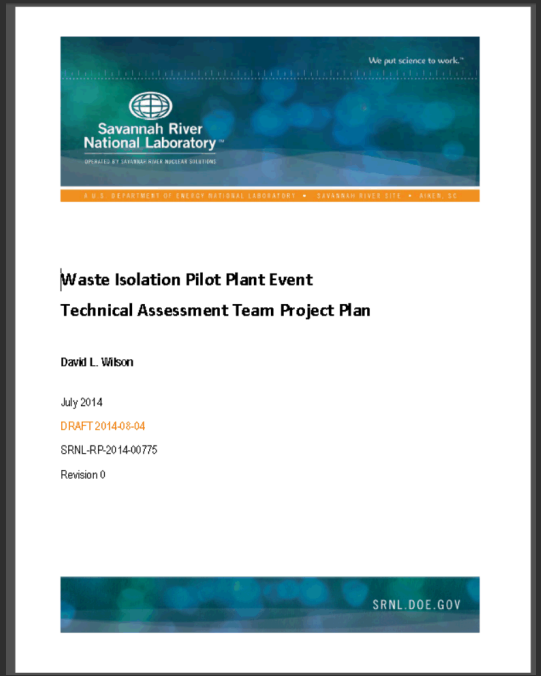
U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. This research is funded by WIPP programs administered by the Office of Environmental Management (EM) of the U.S Department of Energy. SAND2014-1952P

WIPP TAT Mission and Purpose

- DOE established the TAT to plan and conduct analyses and assessments to determine the mechanism(s) and chemical reactions that resulted in the drum failure and release of material in WIPP.
- The TAT's efforts will provide technical underpinning to the Department's determinations regarding the WIPP radiological event.
- The TAT will draw upon the technical and scientific expertise of the Department's national laboratories to form its core leadership team (Savannah River, Pacific Northwest, Sandia, Oak Ridge, and Lawrence Livermore National Laboratories).

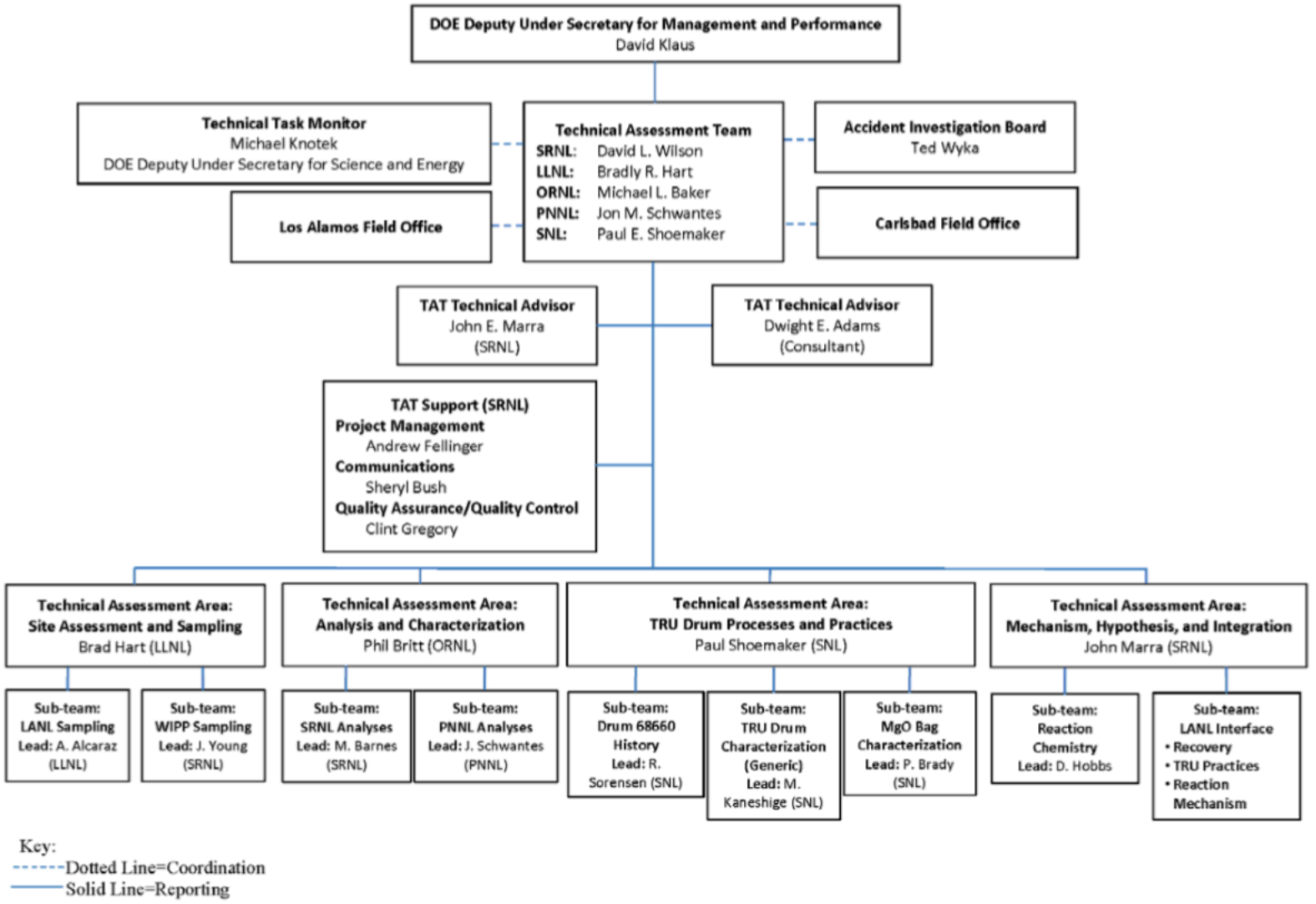


- The TAT will have independent authority to direct activities within its charter.
- The TAT's efforts will support and be effectively coordinated with the ongoing efforts of the DOE AIB.
- The TAT will report directly to the DOE Deputy Under Secretary for Management and Performance (David Klaus).
- The Deputy Under Secretary for Science and Energy (Mike Knotek) will serve as the Technical Task Monitor of the TAT.

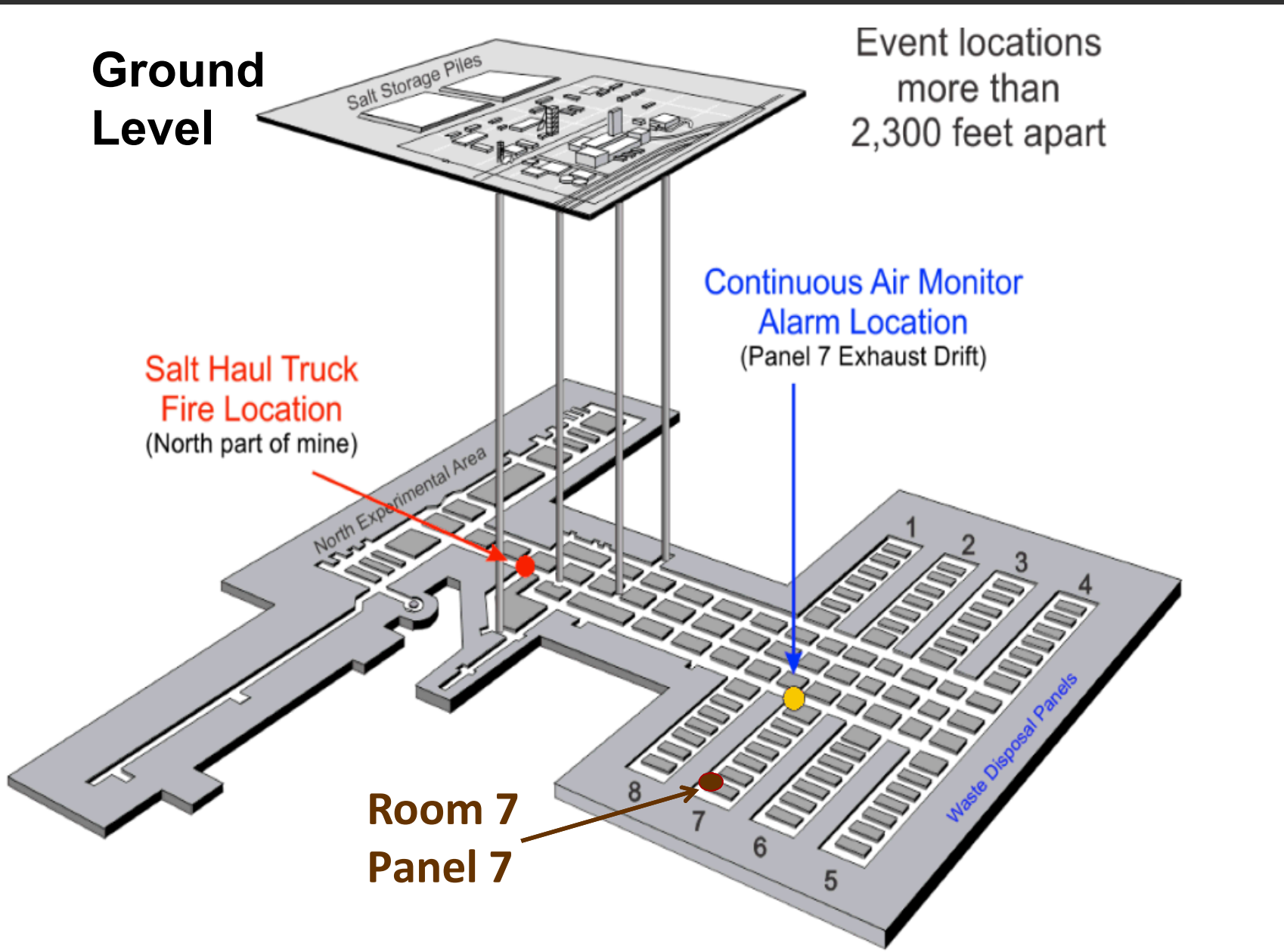
WIPP TAT Hallmarks

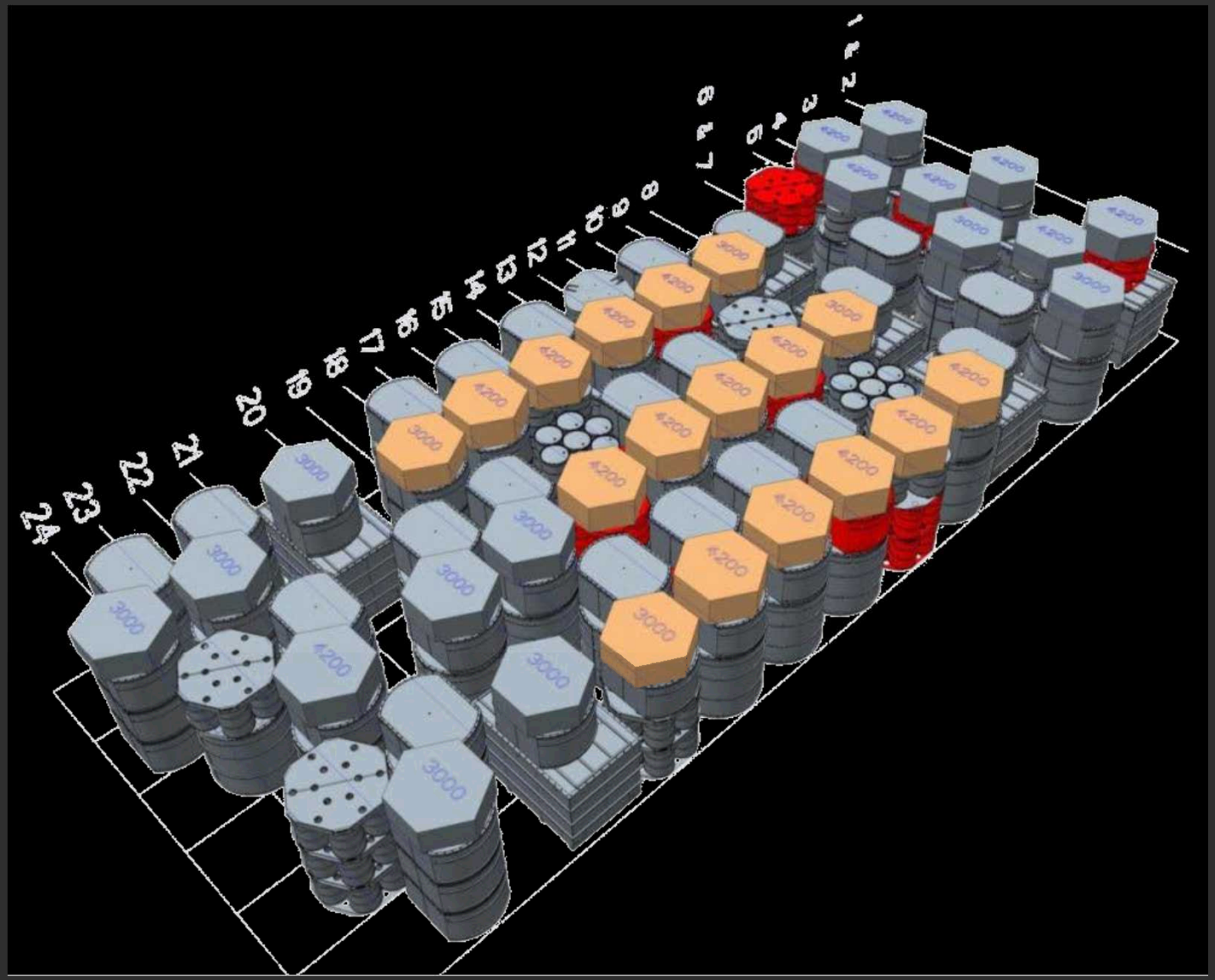
- Investigatorial approach (TAT lead is a former official of the FBI)
- Close and continuing data flow from LANL to the TAT
- Close collaboration and data sharing with the Accident Investigation Board
- Transparency to DOE/CBFO
- Frequent reporting to DOE/EM and higher level officials
- Collegial interactions among the five national labs who are members of the TAT
- Focus among the members on getting to the bottom of things, while avoiding the temptation to say more than we actually know
- Final report put forth March 26, 2015

WIPP TAT Organization



WIPP Underground Images


Ground Level
Salt Storage Piles
Event locations more than 2,300 feet apart
Continuous Air Monitor Alarm Location
(Panel 7 Exhaust Drift)
Salt Haul Truck Fire Location
(North part of mine)
North Experimental Area
1
2
3
4
5
6
7
8
Waste Disposal Panels
Room 7
Panel 7



Schematic of Waste Stack in Room 7

Perspective

Front Face of Panel 7 Room 7

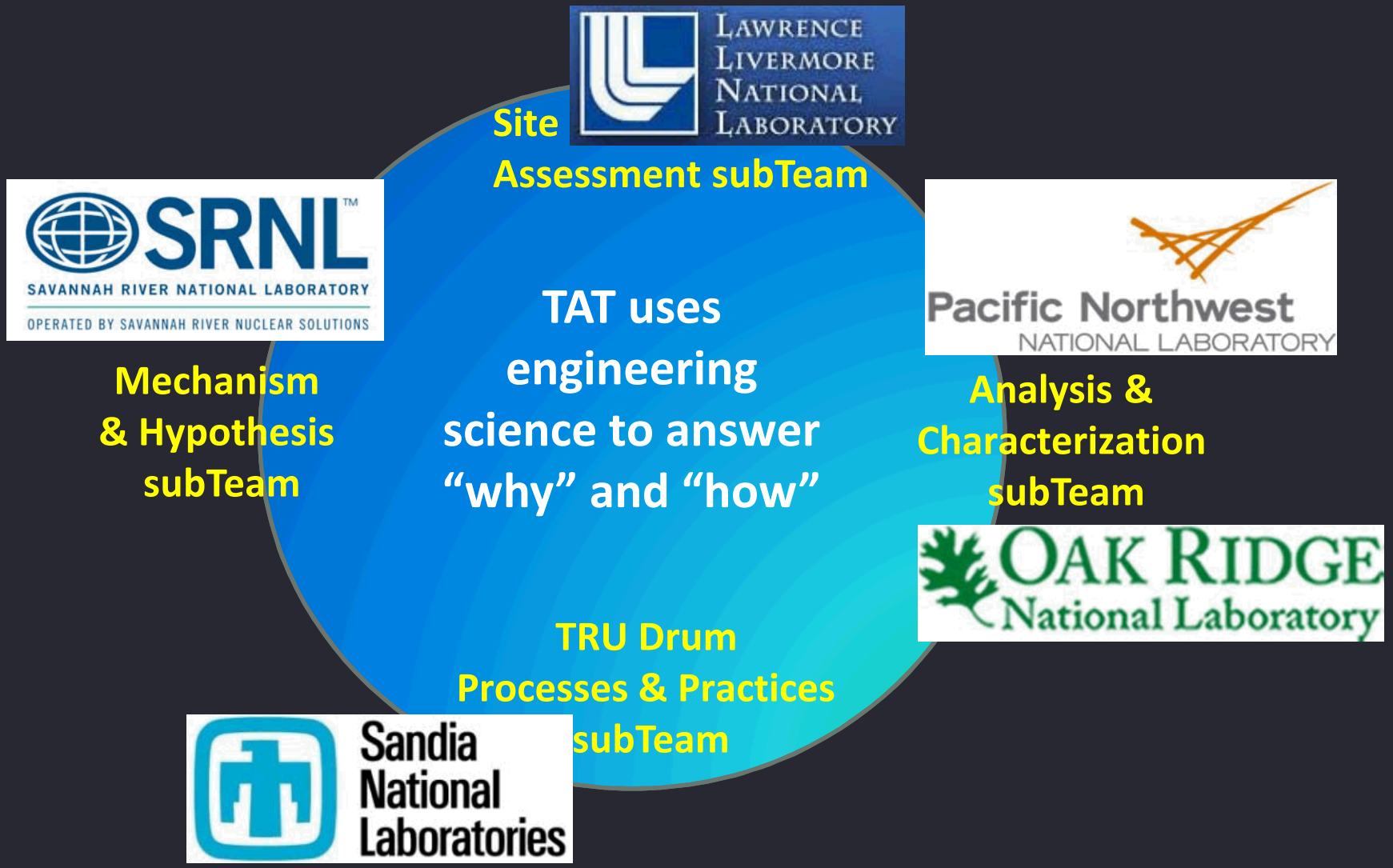
Breached Drum (68660)

Uncontained MgO

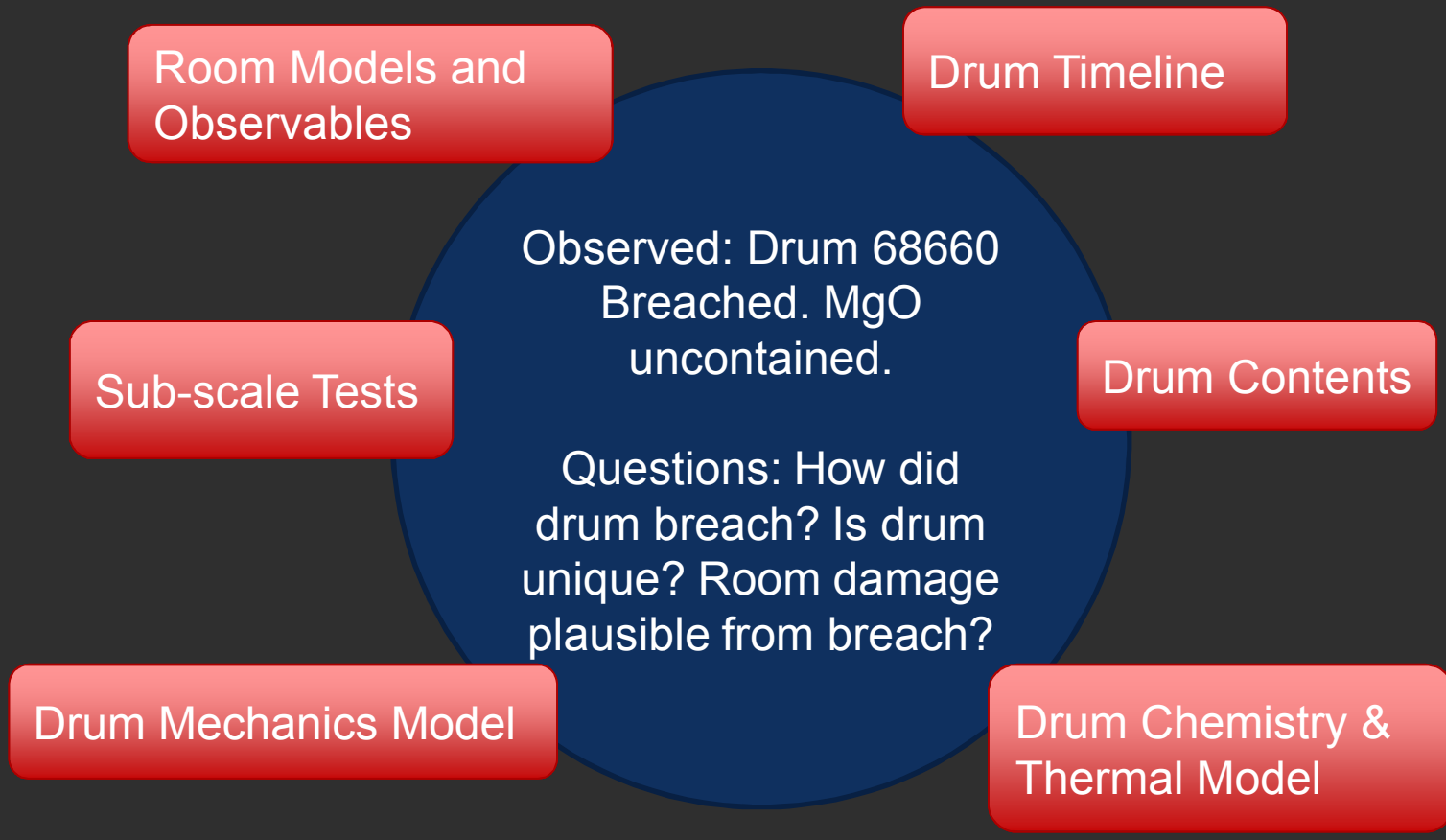
Project Reach 90 ft. Boom

February 14, 2014

Anatomy of TAT



SNL Role: Build and validate modeling framework. Link to observables.



…and provide consultation and review

multi-organization, multi-disciplinary team

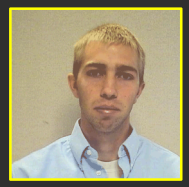
P. Shoemaker 6210

J. Redmond 1550

J. Moya 2550

L. Minier 2554

R. Hogan
1514



J. Tencer
1514

M. Kaneshige
2554

R. Sorensen
1818

M. Larsen
1514

M. Hobbs
1516

D. Rosenberg
2555

J. Smith
1555

Room Models and Observables

Drum Timeline

Sub-scale Tests

?

Drum Contents

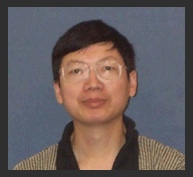
Drum Mechanics Model

Drum Chemistry & Thermal Model

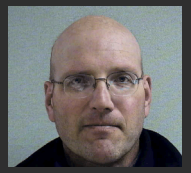
C. Beppler
2555

S. Hightower
2555

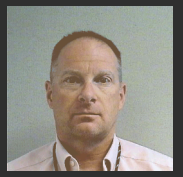
C. Leigh
6212



Y. Xiong
6212



P. Brady
6910



D. Wheeler
1714

timeline tat

AIB images P7R7

release

TAT formed

P7R7 Samples acquired

TAT begins report

work

TAT Report issued

truck fire

AIB formed

2014

Feb

Mar

Apr

May

Jun

Jul

Aug

Sept

Oct

Nov

Dec

2015

Jan

Feb

Mar

10-gal expmts

cookoff expmts

materials expmt

modeling of room observables

drum mechanics modeling

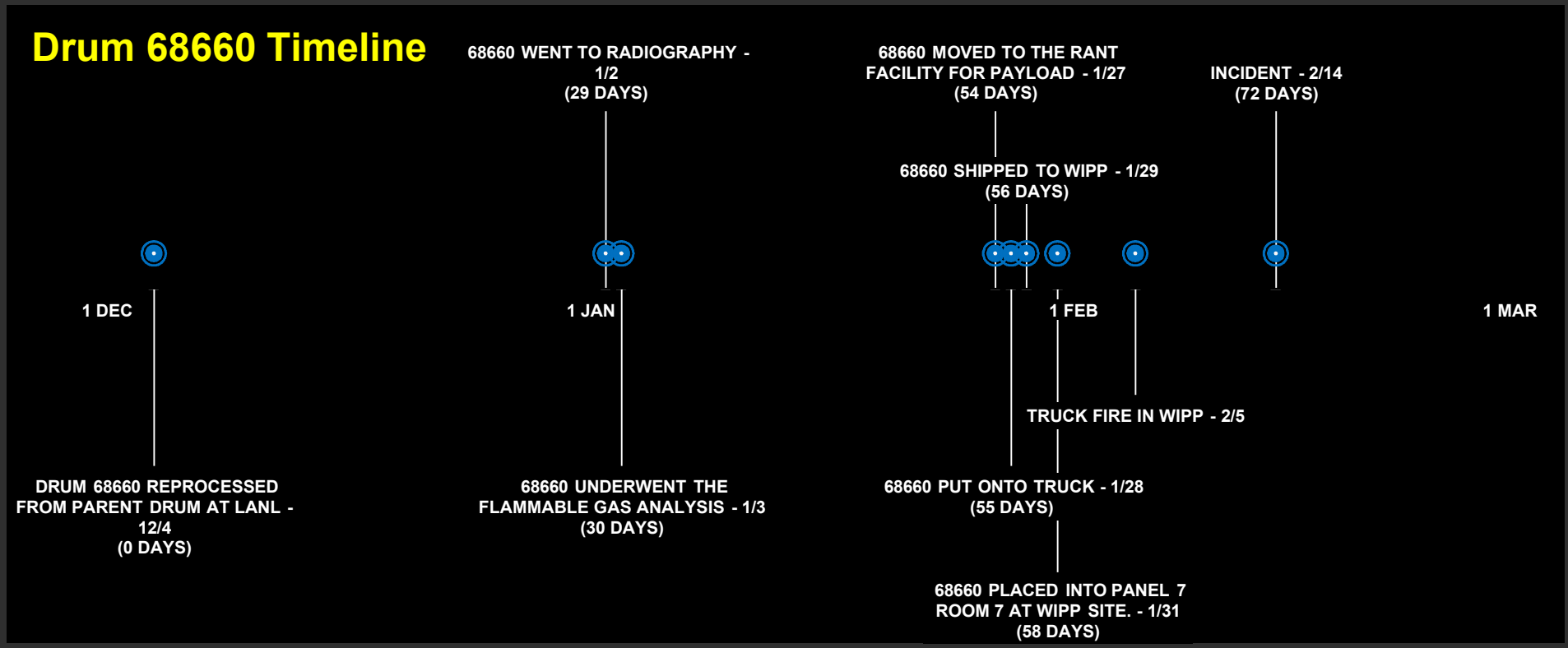
cook-off model

sandia timeline

Timeline

?

Drum 68660: Birth to Breach



Rob Sorensen (SNL) , Joe Giaquinto (ORNL)

Drum 68660 contents (pre-breach)

Sandia National Laboratories

? Drum Contents

Questions:

- Can contents thermally runaway?
- Are product gases combustible?

Answers:

Equilibrium calculation (CTH-TIGER)

- Forms oxygen-rich organic products
- Combustible products
- High adiabatic flame temperature: form and release H2 and CO

Model

Drum #68660 (Model)

Air
Mass, 0.091 kg
Volume, 0.0823 m^3 (21.7 gallons)
Density, 1.1 kg/m^3

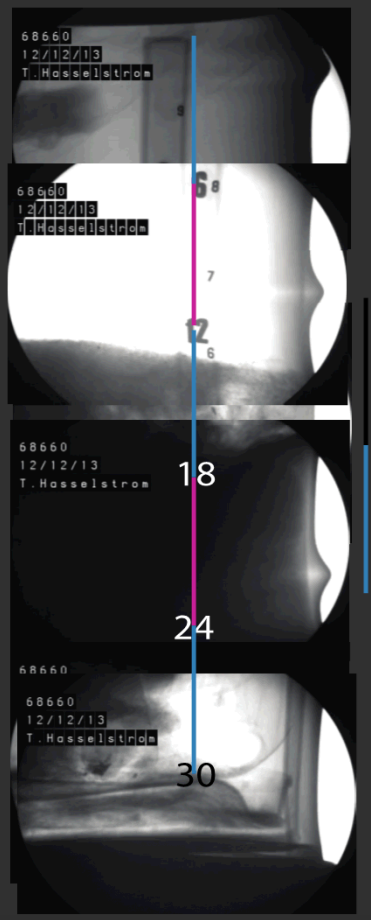
*Gross weight, 115.7 kg
- Drum/packaging, 33.4 kg
- Remediated salts 39.2 kg
- Remediated liquids, 32.1 kg
- Trash, 11 kg

Remediated salt layer
Mass, 39.2 kg (13.0 kg Swheat, 26.2kg nitrate salt)
Volume, 0.053 m^3 (14.0 gallons)
Density, 738 kg/m^3

Remediated liquid layer
Mass, 32.1 kg (10.5 kg acid, 8.0 kg neut., 13.6 kg Swheat)
Volume, 0.038 m^3 (10 gallons)
Density, 848 kg/m^3

Trash Layer
Mass, 11 kg (glove, plastic, rubber)
Volume, 0.0403 m^3 (13.2 gallons)
Density, 273 kg/m^3

Radiography
Drum #68660 (X-rays)



***** Uncertainties: nitric acid molarity, volume of neutralizer, Swheat moisture, volume ratio of Swheat to nitric salts, etc.***

SNL: Mike Hobbs. Rob Sorensen, Dave Rosenberg

?

Chemistry & Thermal Model

What are the decomposition gases? What are the gases that might be vented due to a pressure burst?

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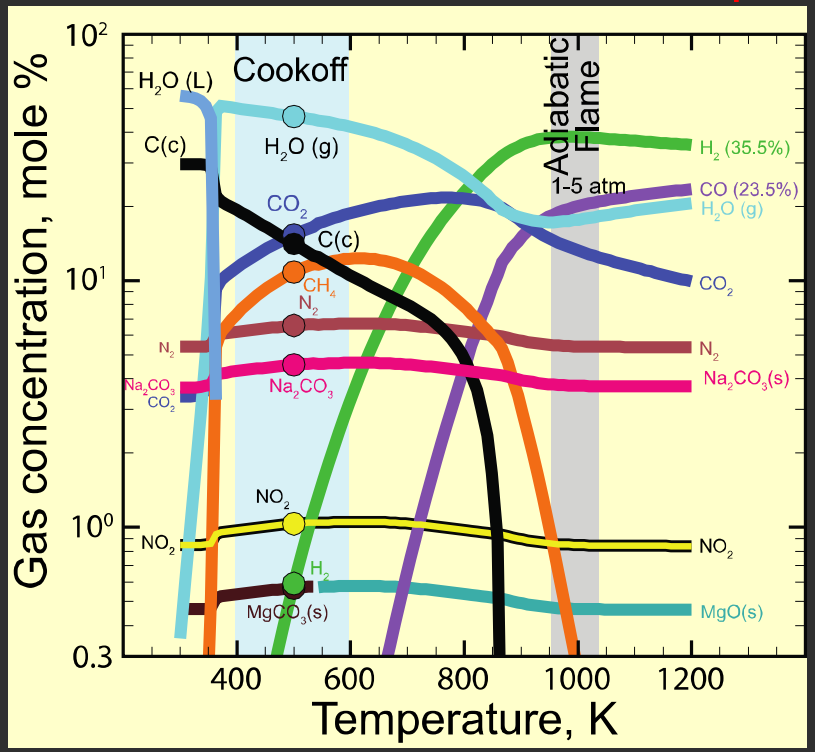
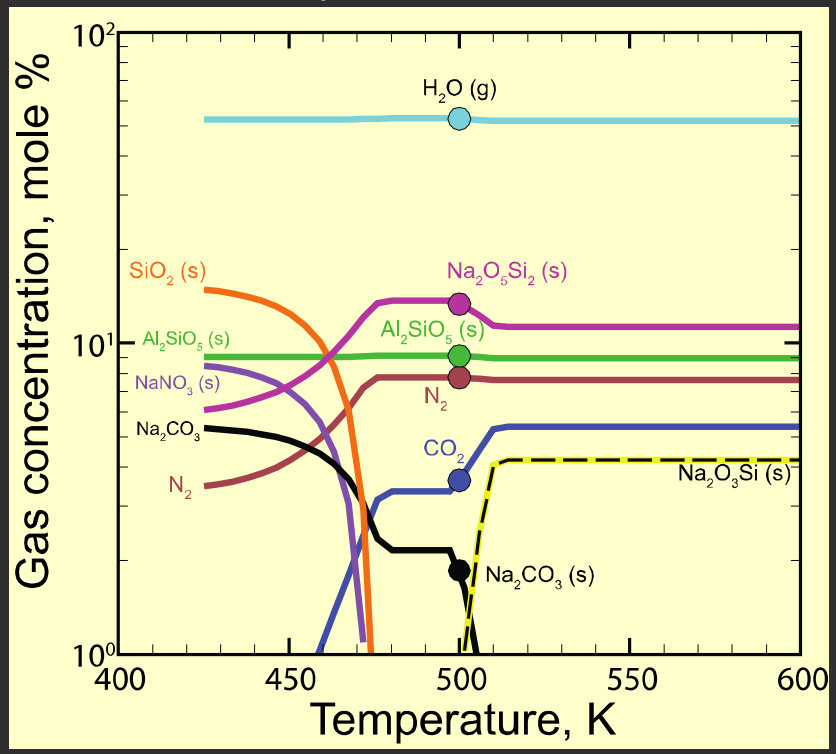
Equilibrium CTH-TIGER calculations

Waste composition with Swheat Scoop®



Waste composition with zeolite



Adiabatic flame composition is fuel rich and should ignite when vented.

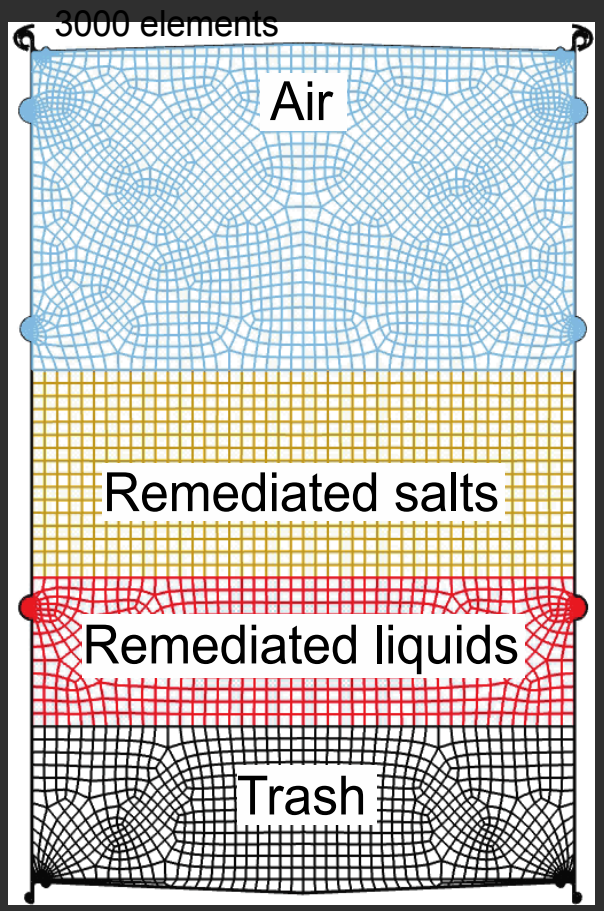
Thermal Runaway ~ 70 days

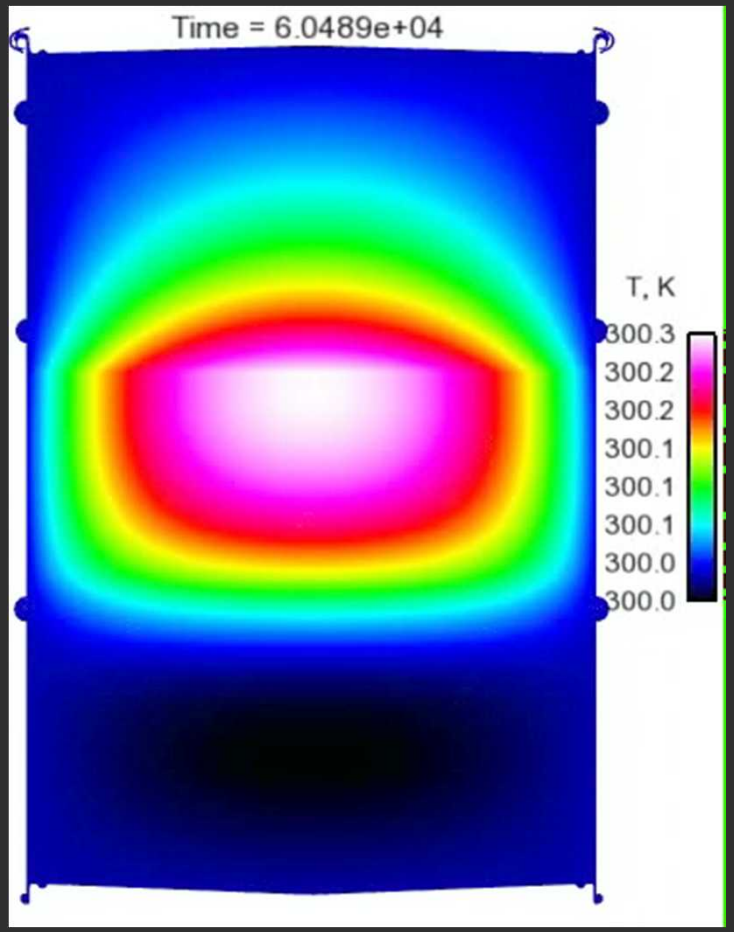
?

Chemistry & Thermal Model

- 3-step chemical model
- accelerating reaction rates
- solved conductive-energy equation
- Background rad. heat
- ~70 days to cookoff
- Zeolyte base (NON-SWEAT) calculation: **NO COOKOFF**

Cookoff Model Results (CUBIT, ARIA, ENSIGHT)

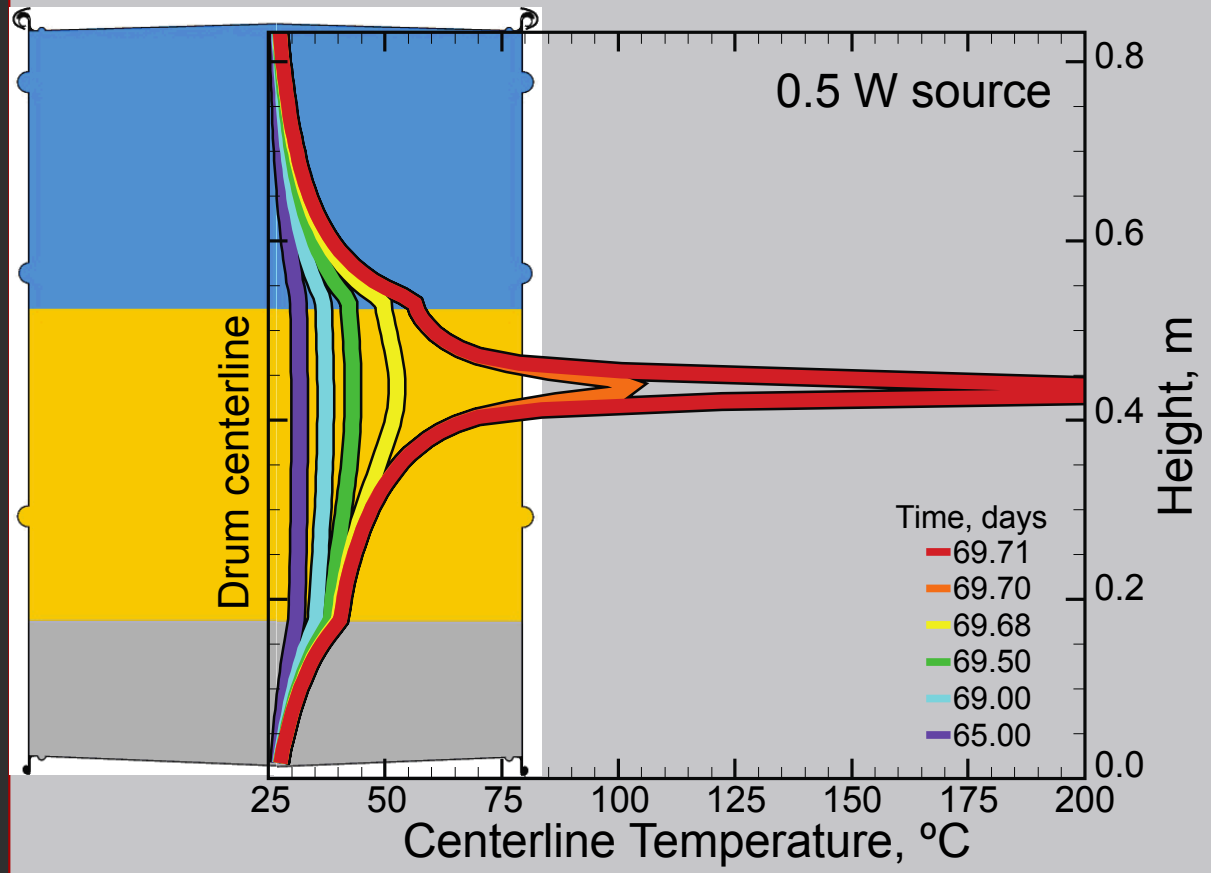


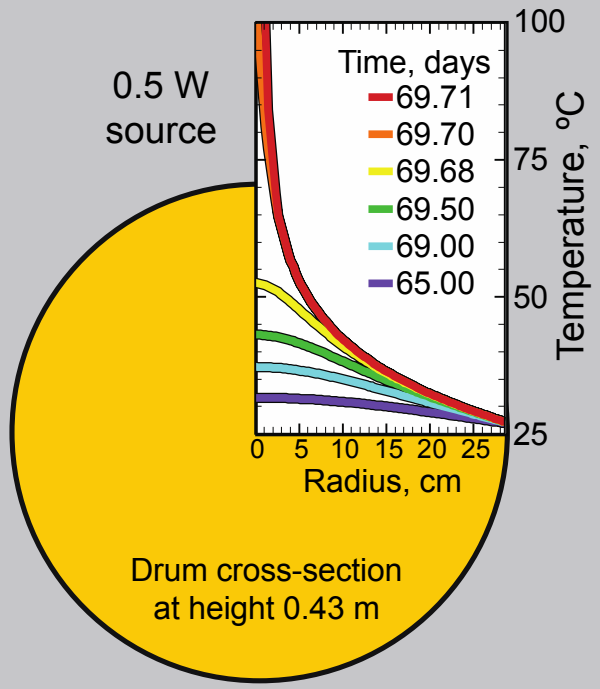


Thermal profile prior breach

?

Chemistry & Thermal Model





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Drum Mechanics Model

Established drum mechanical model to test loading mechanisms

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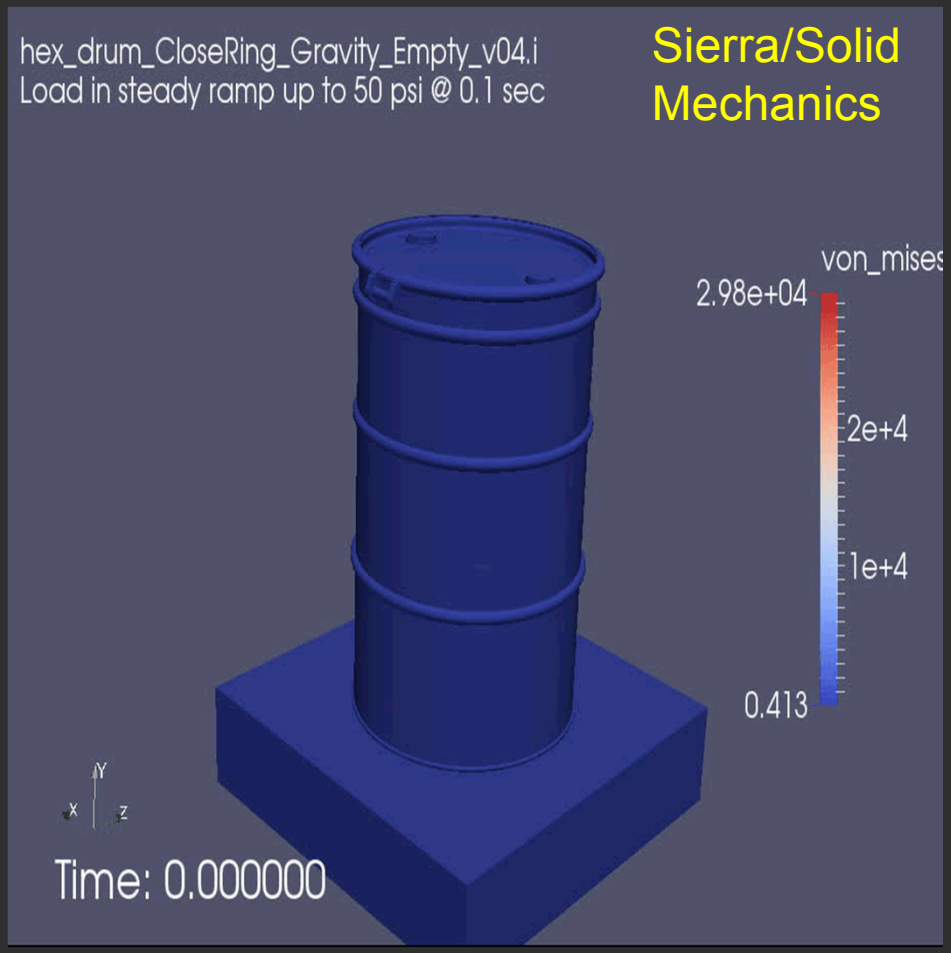
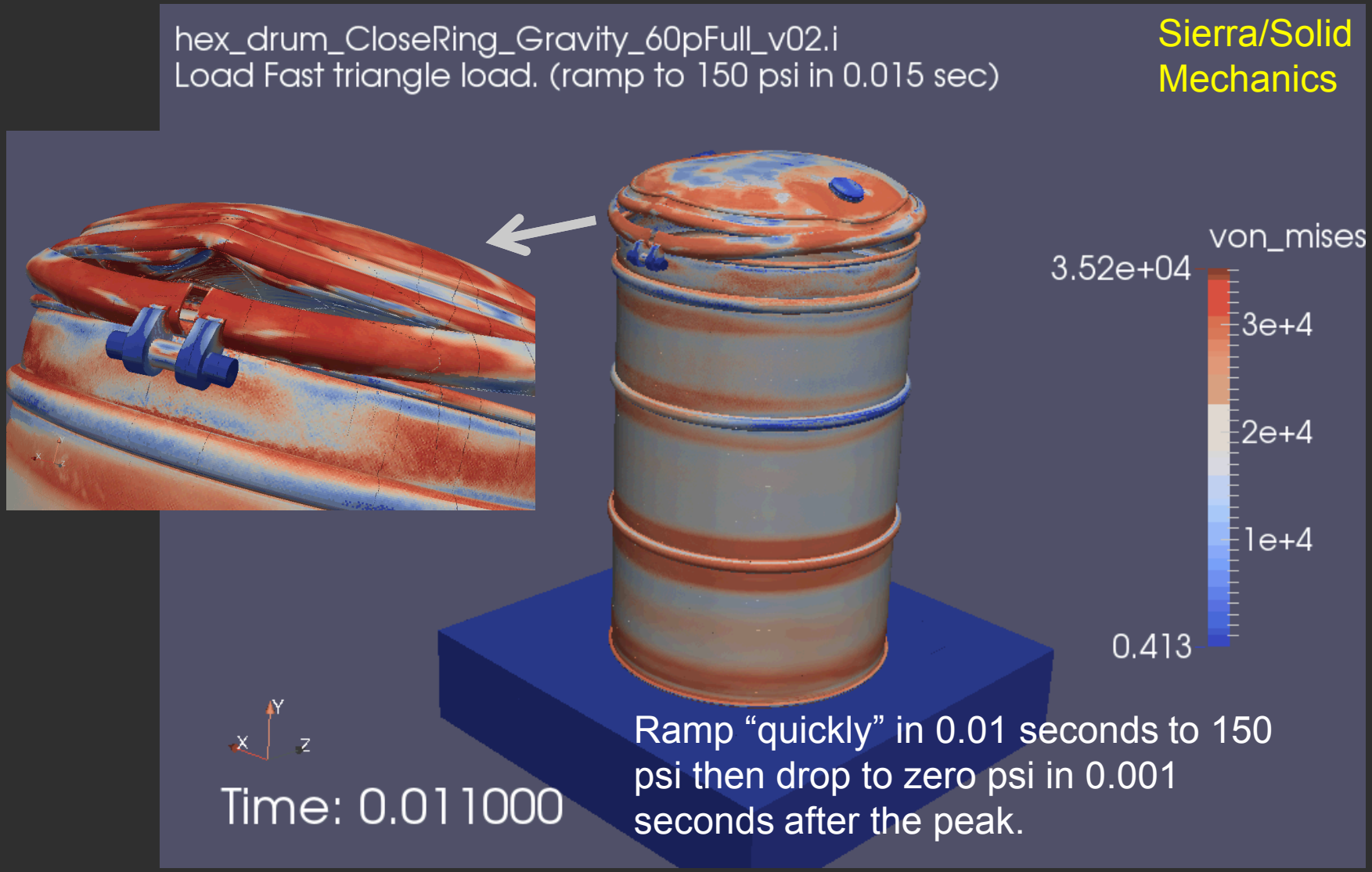


Characteristic failure on filled drum



Simulation conditions provide key insights

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Sierra/Solid Mechanics

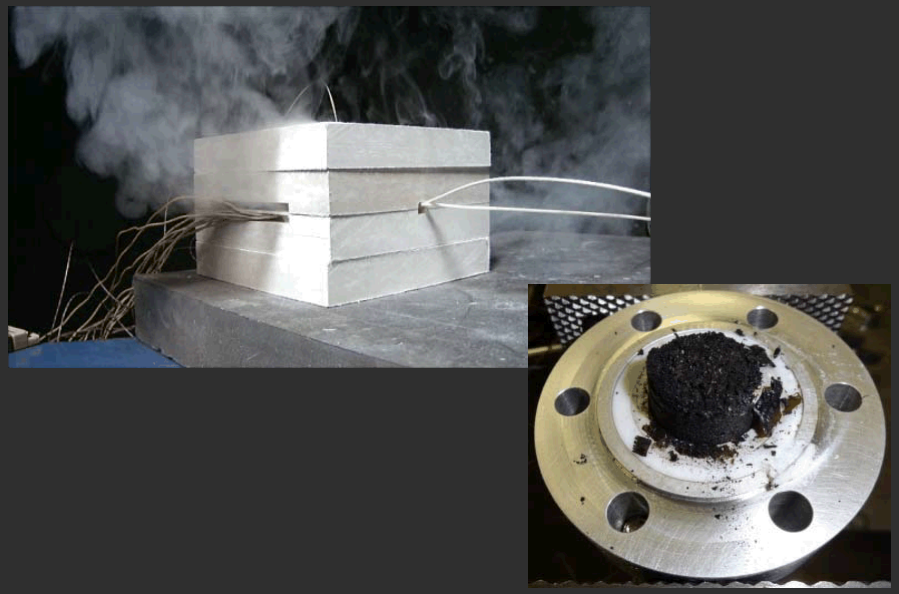
Sub-scale Tests

?

Sub-scale Testing

Objective: Validate hypothesized relevant reactive mixtures by combining with intermediate scale and in situ diagnostics.

Small-scale cookoff tests



10-gal drum tests

David Rosenberg, David Wheeler

Room Models & Observables

?

One breached drum did this? External or internal initiation?

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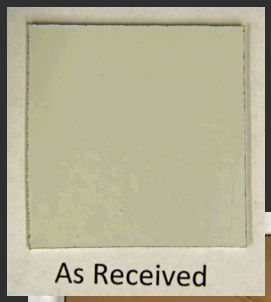
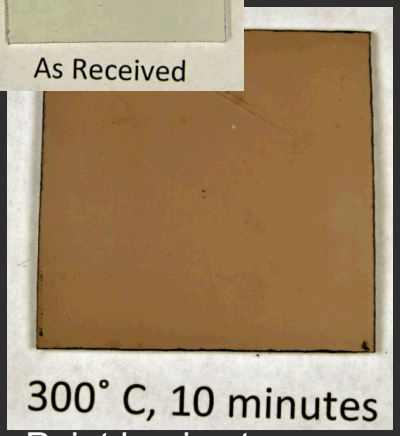
Drum started out as white – look at it now!

Thermal testing:

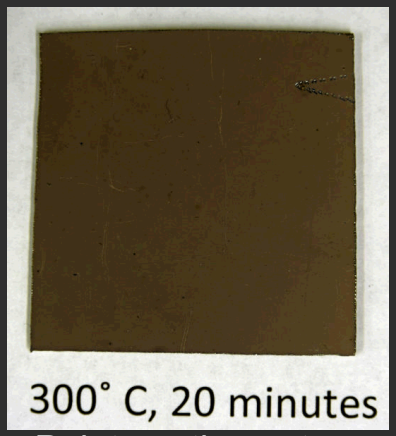
insight into events

Drum paint provides time clues

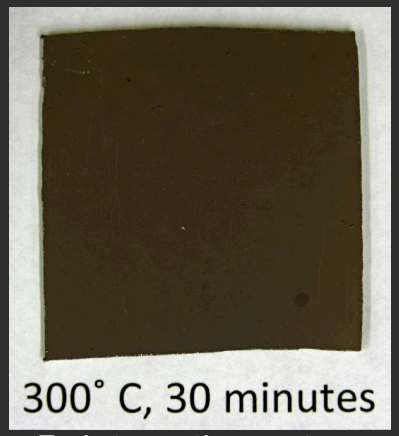




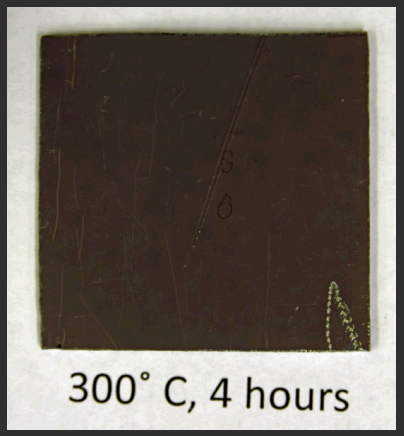
Paint begins to darken (almond color)



Paint continues to darken (brown)

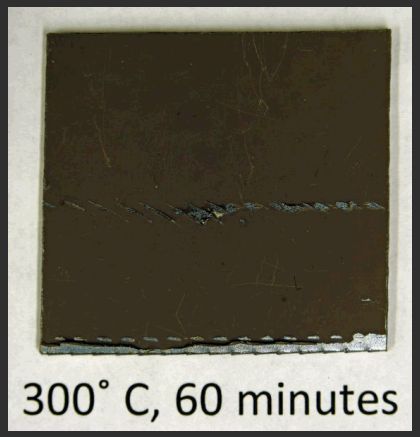


Paint continues to darken

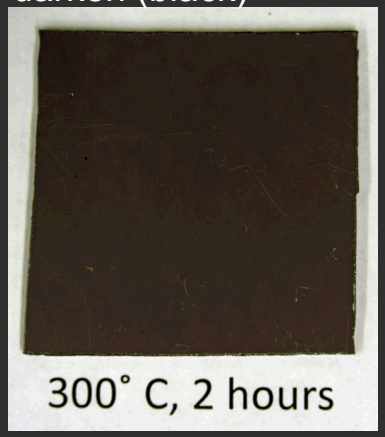


Paint continues to darken

Paint begins to darken (brown/black)



Paint continues to darken (black)



What do we know about the external damage?

Several hypotheses addressed to examine external initiation possibilities

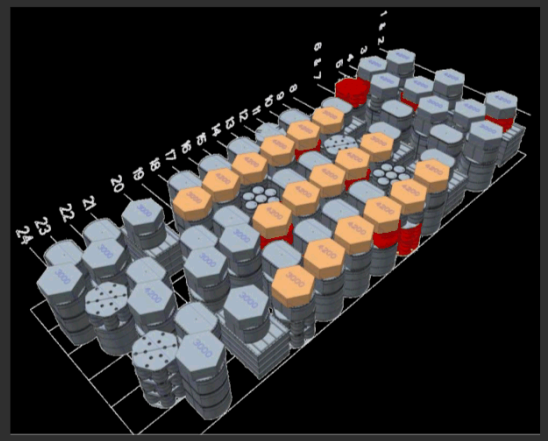
- Truck fire not causal
- MgO hydration or carbonation not a potential trigger
- Drum-to-drum heating not a viable mechanism
- Accumulation of heavy flammable gases unlikely

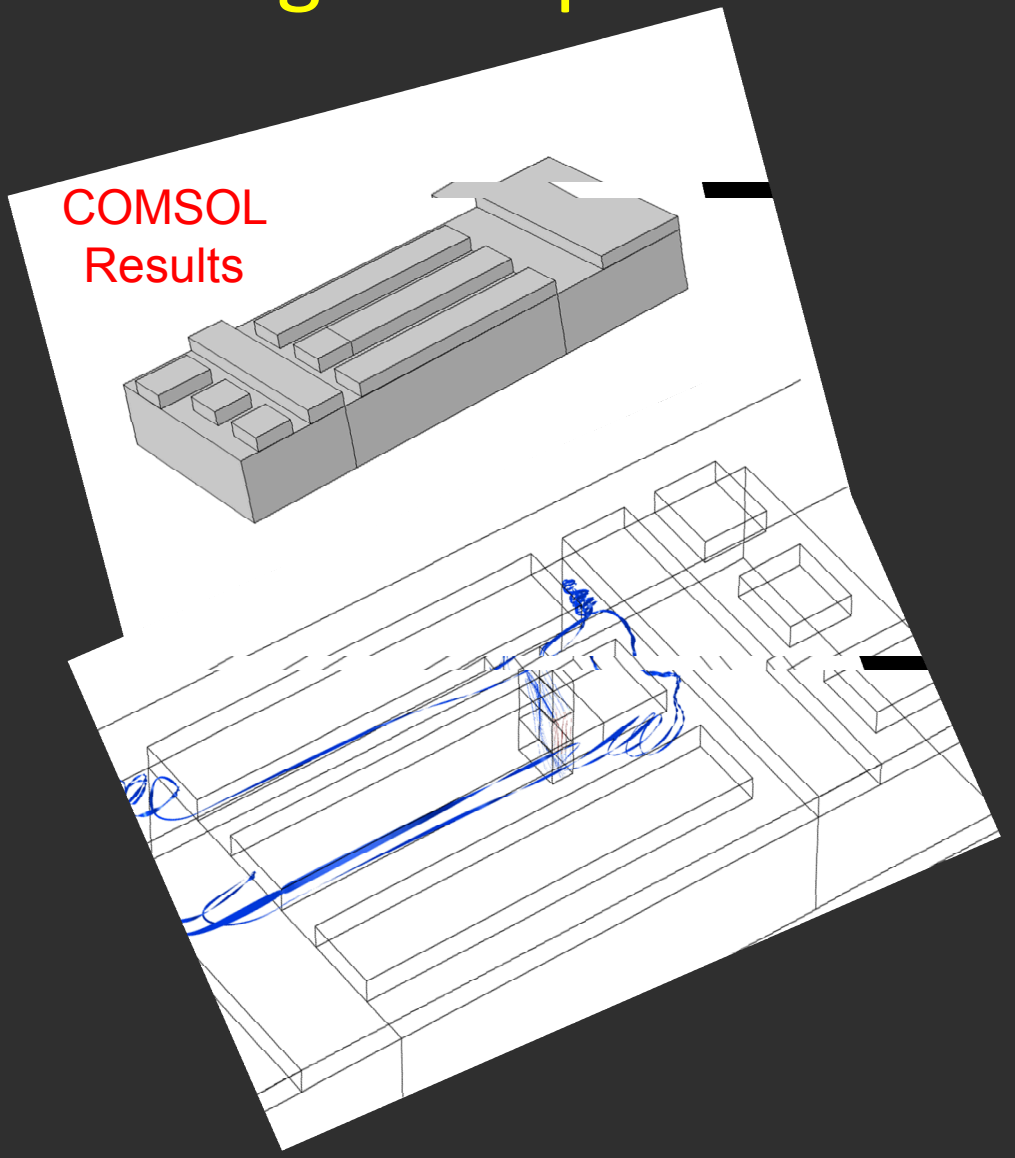
CFD simulations allow parametric studies of plume / fireball temperature, volume, duration, etc.

Thermal testing of materials constrains environmental conditions during event

Event duration is coupled to radiation detection and event characterization (slow burn vs. quenched ignition)

CFD Model to address damage footprint



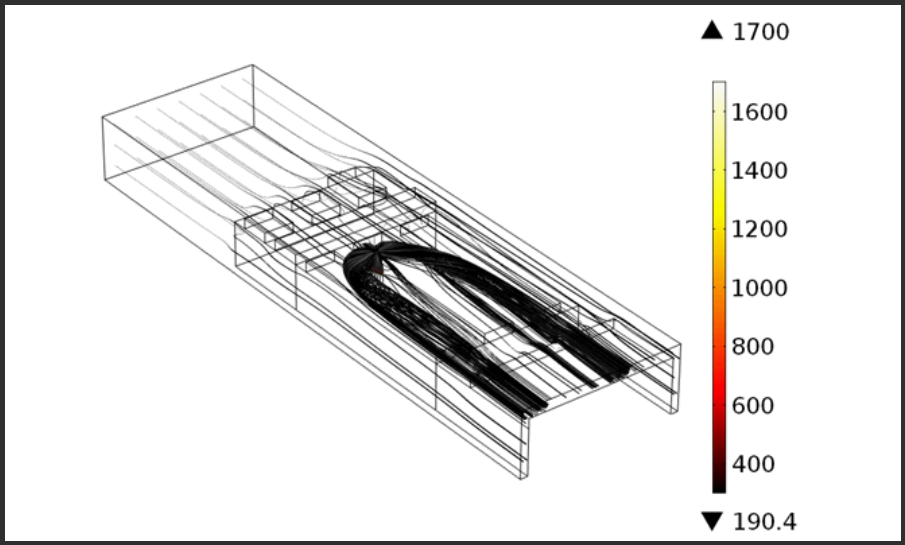


- What types of bulk flow patterns existed in P7R7 prior to and during the release event?
- Could recirculation zones have allowed flammable gases to accumulate in the waste array?
- Can convective heat fluxes account for the damage footprint seen of MgO bags?

SNL: Roy Hogan, Marvin Larsen, John Tencer

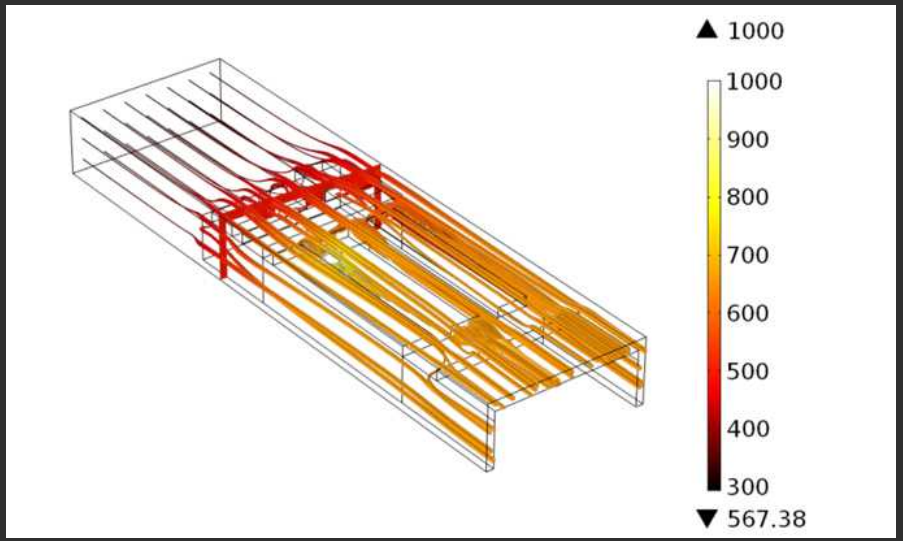
CFD Modeling of Approximate Room Geometry

COMSOL Results



Lower Temp Boundary

Higher Temp Boundary



TAT Conclusions

- Drum contents chemically incompatible
- Drum breach due to internal pressurization
- Breached drum caused radiation contamination
- Breach due to internal thermal runaway process
- Non-detonating post-breach release caused room damage