U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Severe Accident Studies

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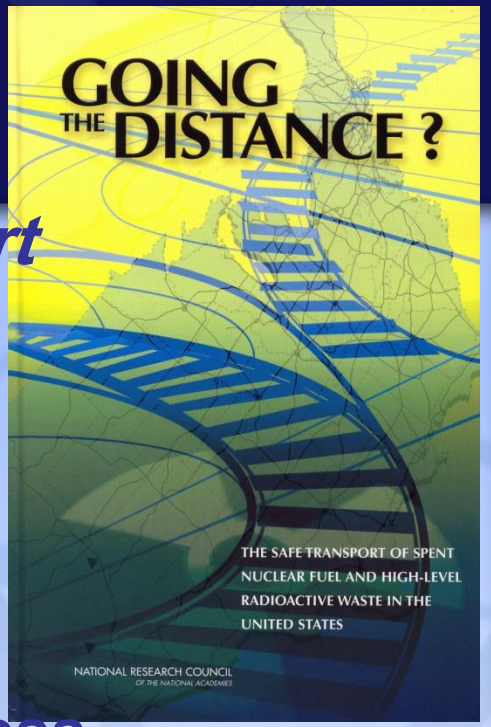
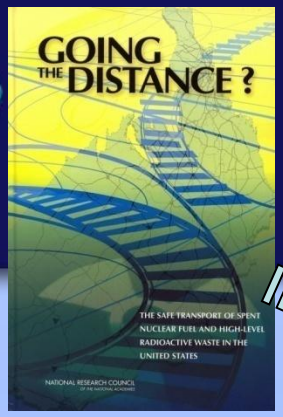
USNRC

2012 U.S. DOE National Transportation Stakeholders Forum (NTSF)
May 15 - 17, 2012
Knoxville, TN

NAS Transportation Study



- ***Going The Distance? - The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States***
  - **Released February 9, 2006**
- **Conclusions:**
  - **NRC safety regulations are adequate to ensure package containment effectiveness over a wide range of transport conditions, including most credible accident conditions.**
  - **The radiological risks are well understood and are generally low, with the possible exception of risks from releases in extreme accidents involving long duration, fully engulfing fires.**



- NRC "*undertake additional analyses of very long duration fire scenarios that bound expected real-world accident conditions for a representative set of package designs that are likely to be used in future…shipping programs*."

- These analyses would examine the need for **regulatory** or **operational** changes that could help **prevent** accidents that could lead to such a fire or **mitigate** their consequences.

Road Transportation

Rail Transportation

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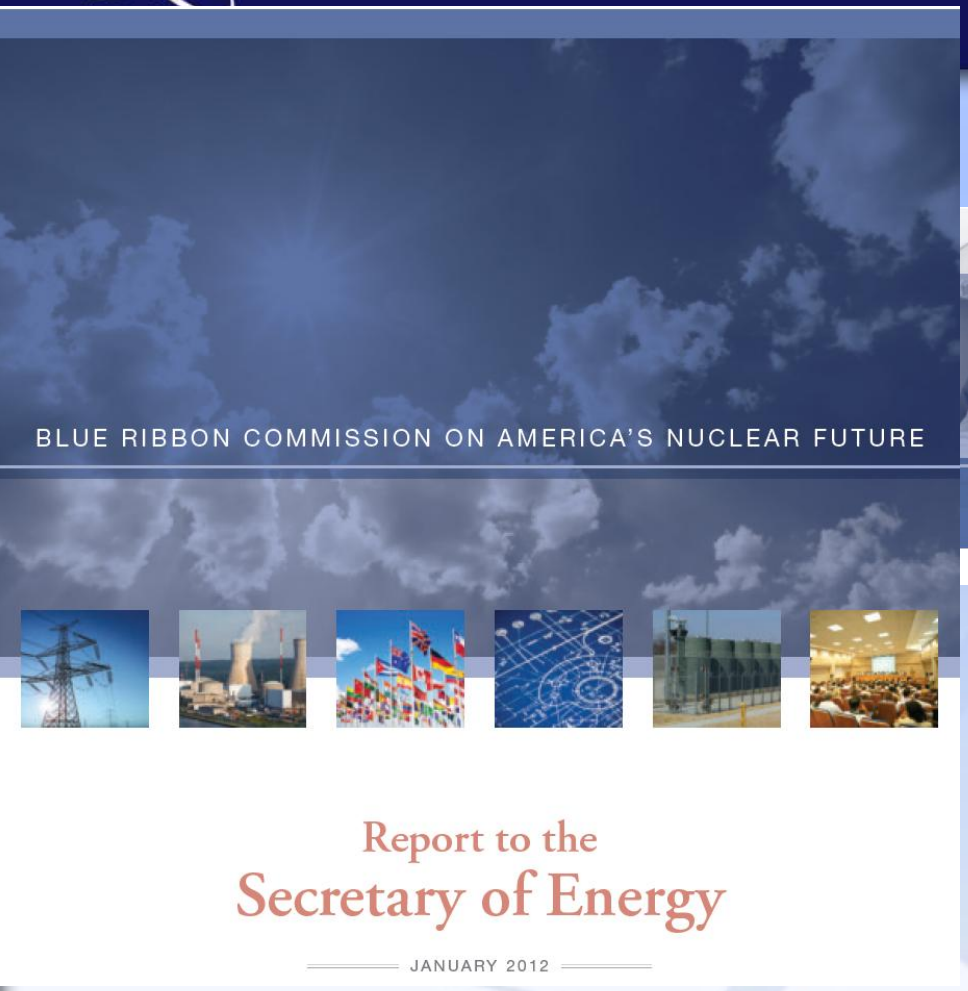
BRC Report Transportation Issues



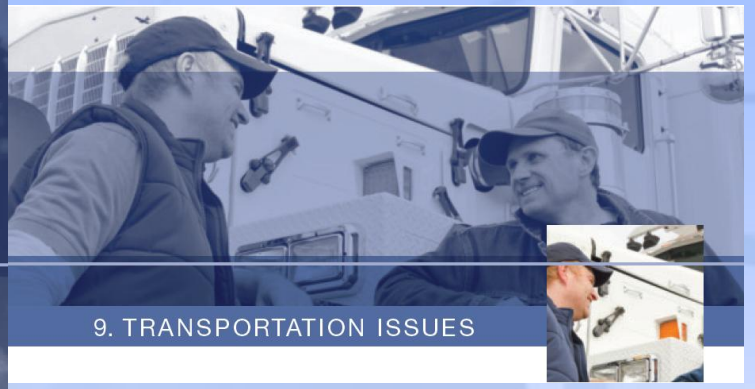


TABLE 3. RECOMMENDATIONS OF THE NAS
GOING THE DISTANCE REPORT AND THEIR CURRENT STATUS

Recommendation	Current Status (as of January 2012)
The NRC should analyze very long-duration fires, and implement regulatory controls to reduce the chances of a spent fuel shipment being involved in such a scenario.	The NRC has made a practice of studying real-world fires and analyzing how casks would perform under such conditions. The NRC has also worked with the Association of American Railroads to establish a "no pass" rule for tunnels that would be used to transport spent fuel, effectively precluding the possibility that other trains with flammable materials would be in a tunnel at the same time. This would prevent a long-duration fire of any significant size.

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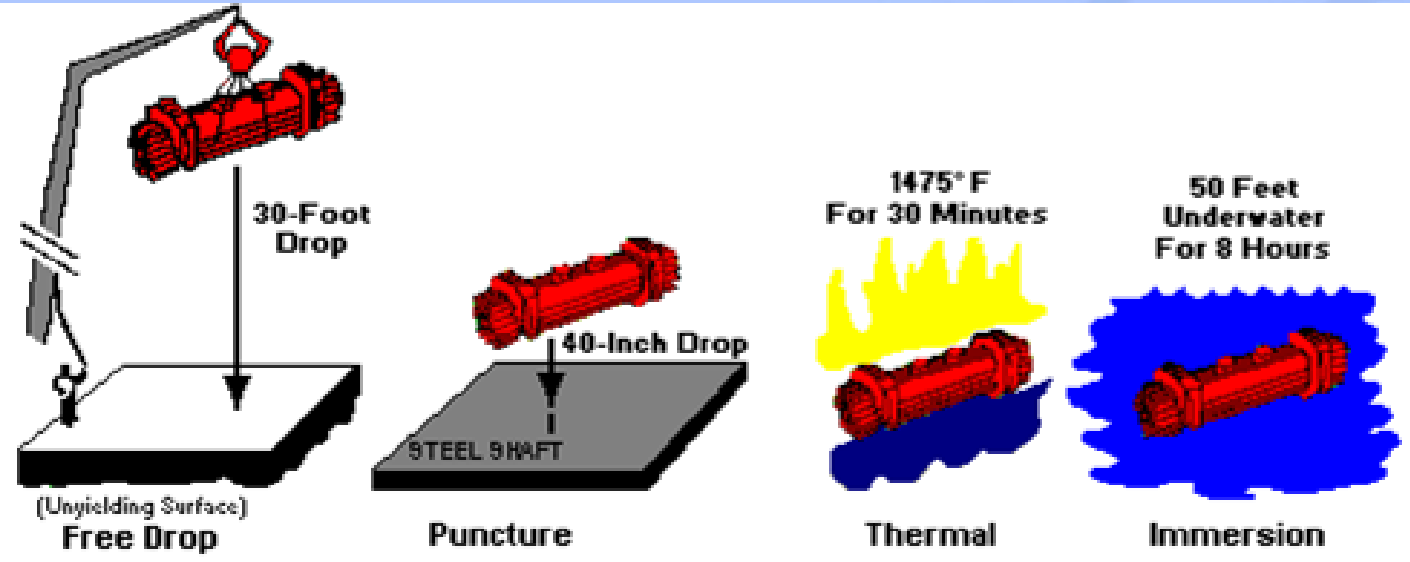
SFST Actions in Response to NAS Recommendations

- **Systematic, comprehensive assessments and documentation of the predicted performance of NRC certified spent fuel packages in real life severe accidents**
  - **Screening of Real Life Accidents**
  - **Case Studies of Most Severe Accidents**
  - **Examination and Explanation of Current Regulations**
  - **Consequences and Conclusions**

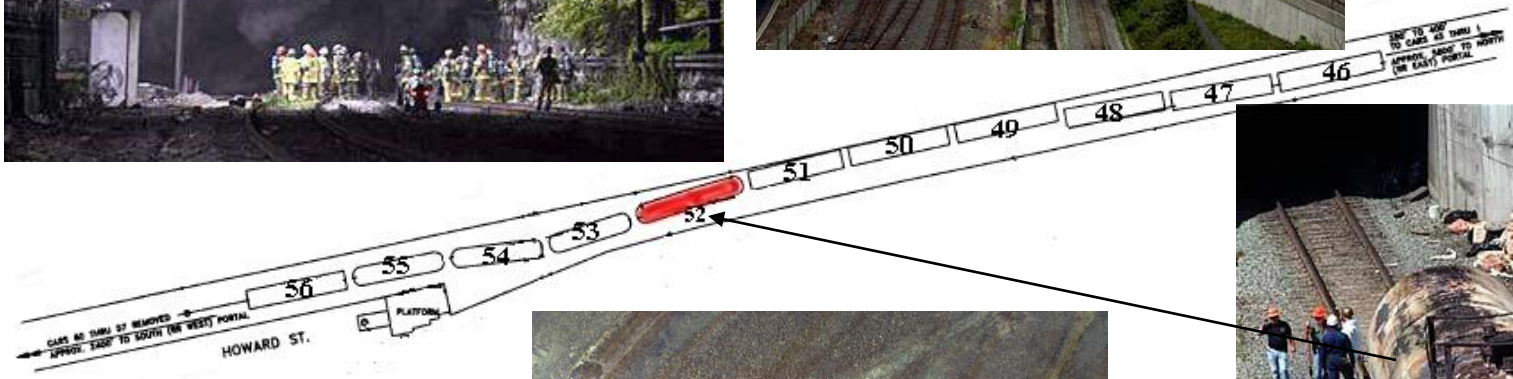
Requirements for Package Safety

- **NRC safety regulations, in 10 CFR 71.73 require that packages be evaluated for "Hypothetical Accident Conditions" including:**



- **Packages must exhibit little or no leakage of radioactive material after this series of tests**

Example of a Real World Accident: The Baltimore Tunnel Fire July 18, 2001



SOURCE: NTSB AND CSX TRANSPORTATION

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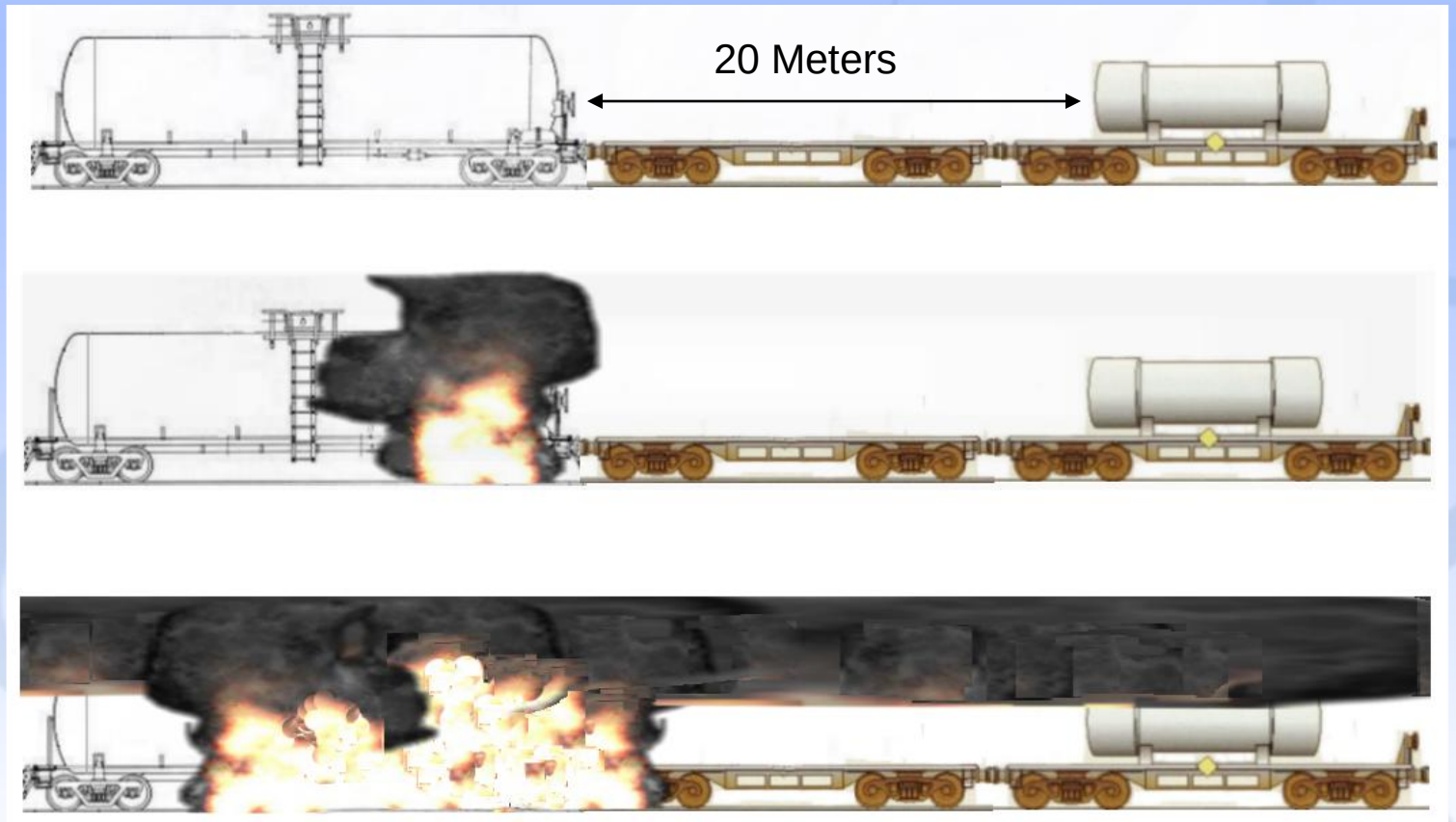
Fire Scenario for the Baltimore Tunnel Fire Involving a Spent Fuel Package



Casks Examined in the Baltimore Tunnel Fire

Cask Model	HI-STAR 100	TN-68	NAC-LWT[1]
Transport Mode	Rail	Rail	Truck/Rail
Loaded Weight LBS (KG)	277,300 (125,781)	260,400 (118,116)	52,000 (23,587)
Decay Heat Load (kW)	20	21.2	2.5
Contents	24 PWR[2] assemblies	68 BWR[3] assemblies	1 PWR assembly
Cask Closure Design Features	Bolted Overpack, Inner Welded Canister	Bolted Lid with O-rings	Bolted Lid with O-rings

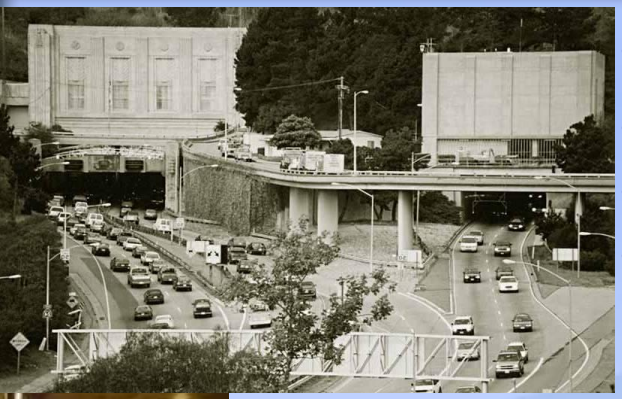
[1] Package within an ISO container for rail transport
[2] Pressurized Water Reactor (thermal design basis most limiting fuel and maximum decay heat loading assumed for each cask)
[3] Boiling Water Reactor (thermal design basis most limiting fuel and maximum decay heat loading assumed)

Consequences of the Baltimore Tunnel Fire

Cask Model	Potential Releases (calculated)	Comments	Number of A_2's released[1]
HI-STAR 100	None	Releases prevented By Inner Canister.	0
TN-68	3.4 Ci of ^{60}Co	Potential release due to CRUD. Cladding remains intact.	0.3
NAC-LWT	0.02 Ci of ^{60}Co	Potential release due to CRUD. Cladding remains intact.	0.002

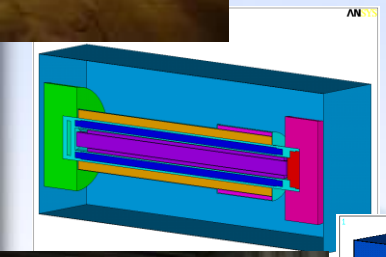
1 The potential releases of radioactive material from all three casks are well below the internationally accepted safety standard of an A_2 quantity per week. The A_2 quantity per week is based on limiting potential exposures to first responders and the public following a severe transportation accident to no more than the occupational dose of 5 Rem. The A_2 value for ^{60}Co is 11 curies.

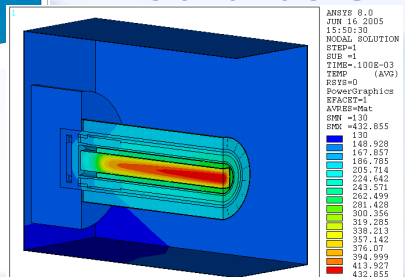
Caldecott Tunnel Fire



- Caldecott Tunnel near Oakland, California
- April 7, 1982 at 10:40 pm
- 8,800 gallon tank truck carrying gasoline
- One of the most severe highway tunnel fires to have occurred world wide since 1949.

- The analysis of NAC LWT truck transport package found:
  - Peak SNF cladding temperatures below the limits (1058°F).
  - Any release from this package would be small - less than an A_2 quantity, and within regulatory limits.





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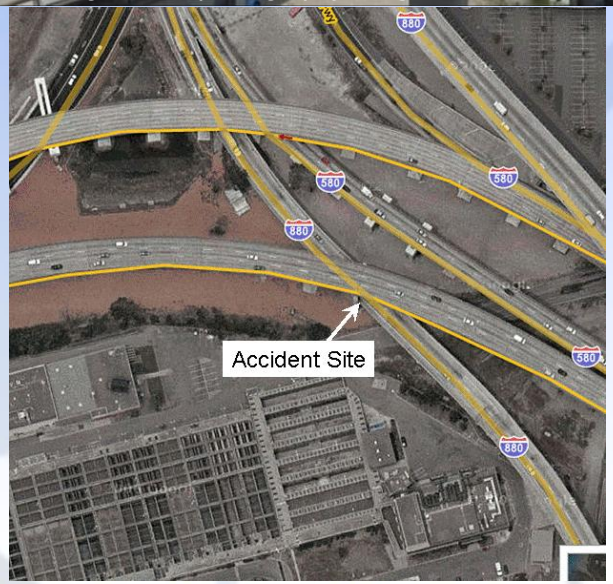
MacArthur Maze Fire

Photo: http://www.dot.ca.gov/dist4/photography/images/070429

- April 29, 2007 at about 3:45 AM
- Gasoline double tanker truck
  - 32,500 liters [8,600 gallons] of gasoline
- MacArthur Maze interchange connecting I-80, I-580, and I-880
- I-580 overpass collapsed approximately 17 and 36 minutes after the fire started



MacArthur Maze Fire Analyses

CNWRA
A center of excellence in earth sciences and engineering™

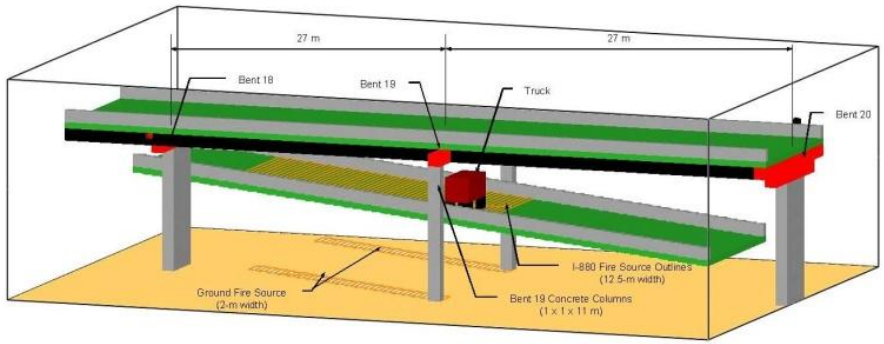
NIST National Institute of Standards and Technology U.S. Department of Commerce

SwRI®

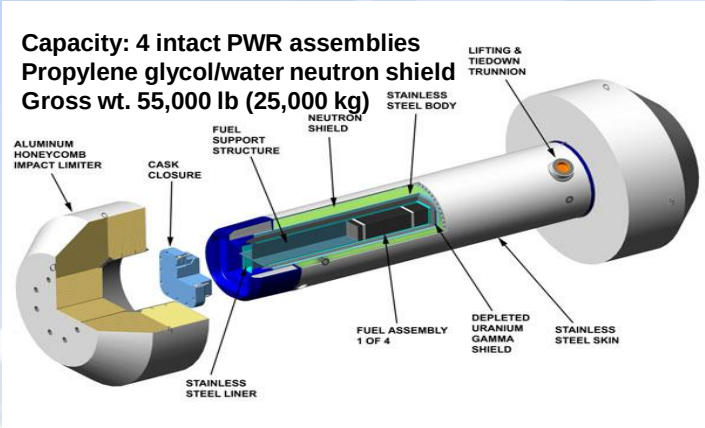
Pacific Northwest NATIONAL LABORATORY

Caltrans

CHP



- **A collaborative effort, led by NRC included materials analyses and fire modeling to determined fire temperatures:**
- **720°C [1,328°F] to 1,000°C [1,832°F]**
- **Thermal and structural analyses of GA-4 legal weight truck transportation package being finalized**



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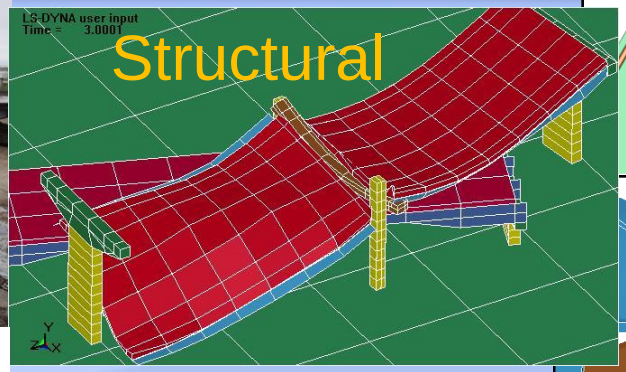
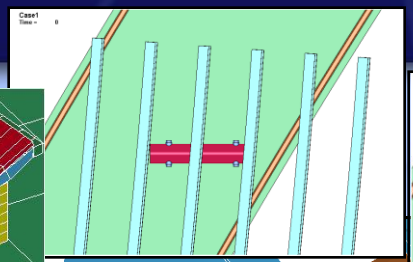
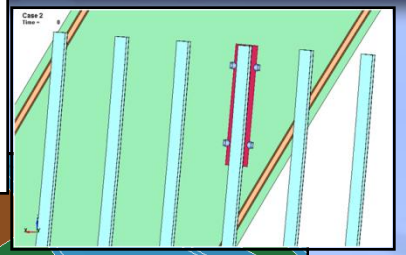
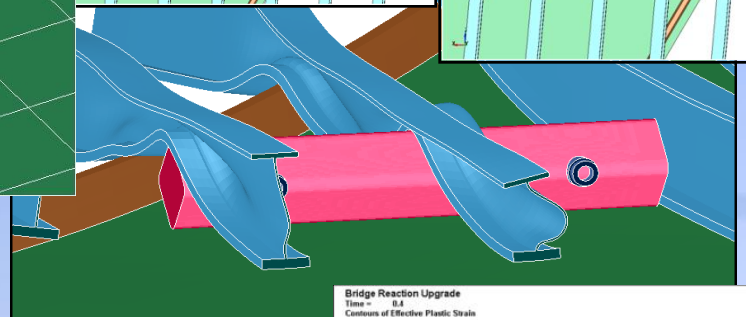
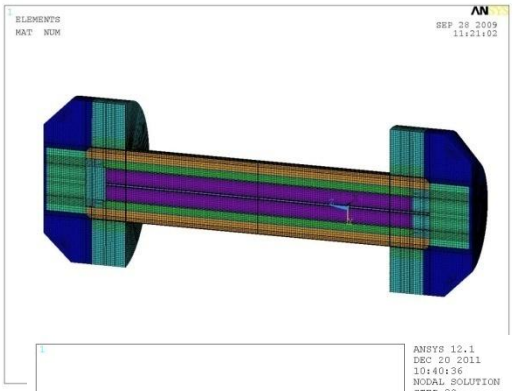
MacArthur Maze Analyses Models

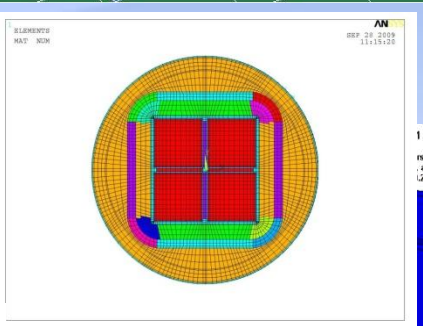


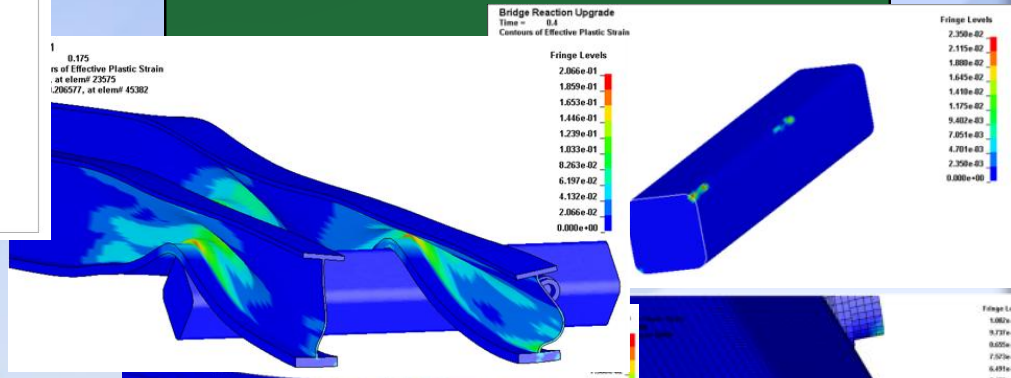




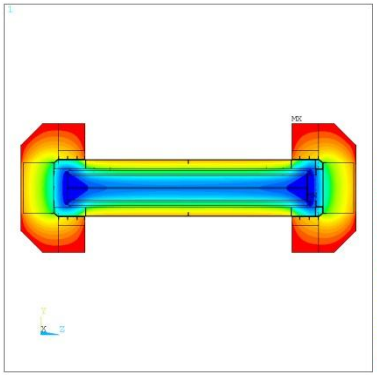


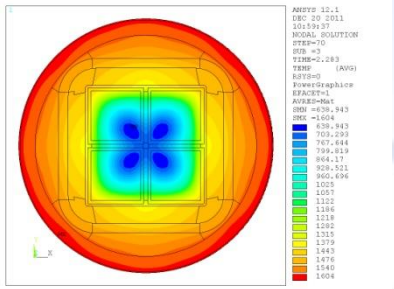


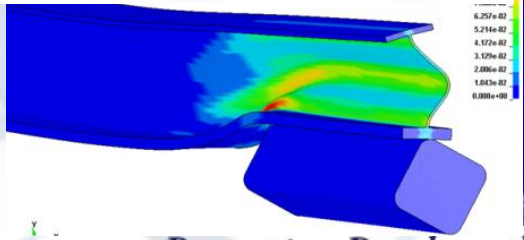


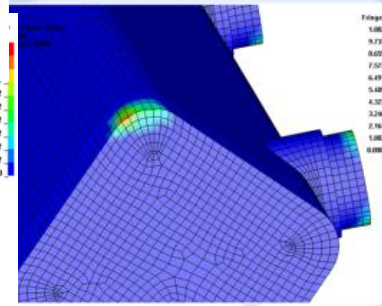


End of Fire









Thermal

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MacArthur Maze Analyses Results

- Two thermal analysis models were completed
  - ANSYS® (with Impact limiters) and
  - COBRA-SFS codes (without impact limiters)
- Fire Boundary Conditions (Derived from NIST model)
  - 1100°C for 37 minutes (pre-collapse)
  - 900°C for 71 minutes (post collapse)
  - 100°C ambient for cool-down

Preliminary Analysis Model Results [°C (°F)]

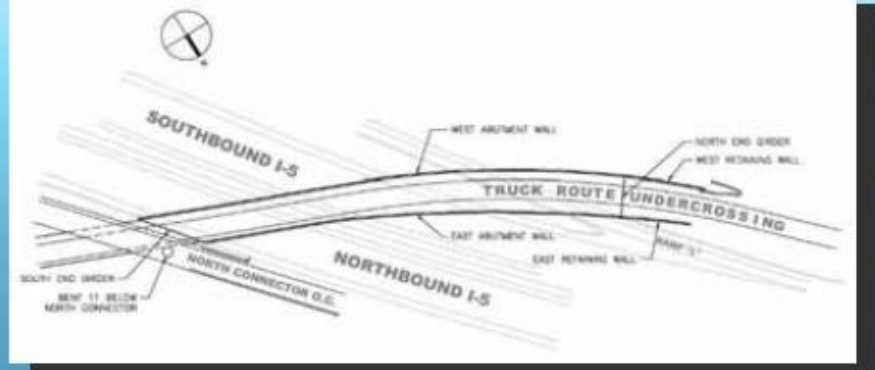
Component		NCT (Start of fire)		37 minutes (end of 1100°C fire)		108 minutes (end of fire)		4 hours (2.2 hrs after end of fire)	
		ANSYS	COBRA	ANSYS	COBRA	ANSYS	COBRA	ANSYS	COBRA
Fuel Cladding		306 (152)	293 (145)	551 (1023)	513 (955)	779 (1433)	753 (1388)	732 (1349)	730 (1347)
Seals	lid closure	131 (55)	144 (62)	136 (277)	983 (1802)	408 (766)	870 (1598)	575 (1068)	414 (776)
	gas sample port	129 (54)	145 (63)	87 (188)	895 (1643)	274 (526)	850 (1563)	515 (960)	466 (871)
	drain valve	134 (57)	150 (66)	87 (189)	909 (1668)	388 (730)	854 (1569)	589 (1092)	462 (863)

MacArthur Maze Fire Analysis Summary

- Preliminary results of this multi-faceted investigation of the MacArthur Maze fire scenario indicate that
  - Structural consequences for an SNF transportation package are likely to be less severe than HAC drop scenario in 10 CFR Part 71
  - Thermal consequences are likely to be significantly more severe than HAC fire in 10 CFR Part 71
    - Failure of package seals is expected
    - Failure of all fuel cladding is assumed
- Ongoing work:
  - Evaluation of potential releases from package, due to failure of seals and possible rupture of fuel rods due to extreme thermal environment of the fire scenario

Newhall Pass Tunnel Fire

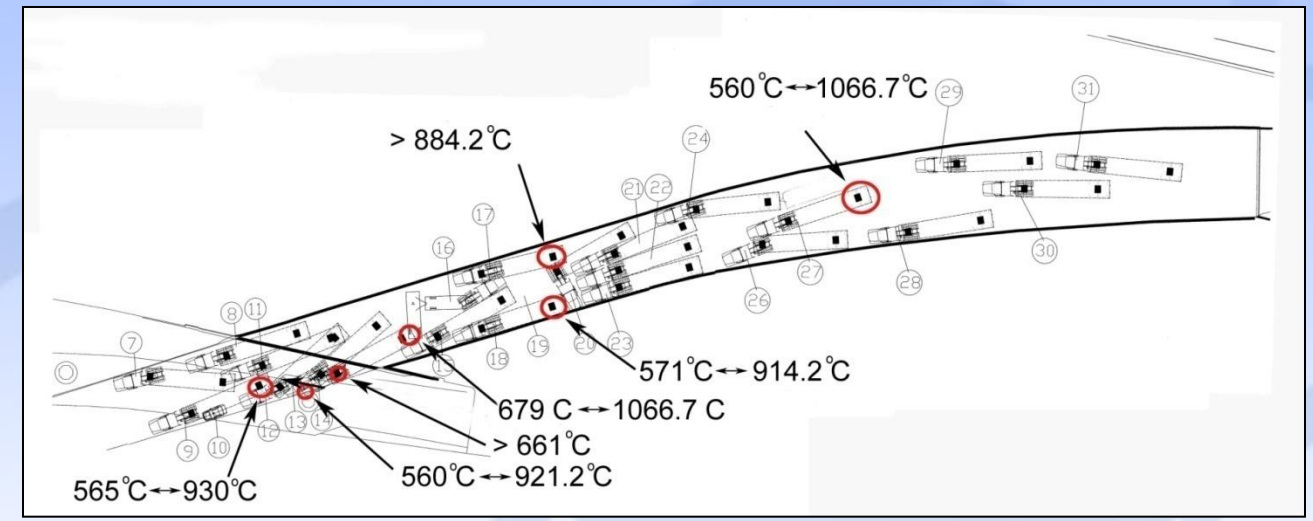
- October 12, 2007 at 10:40 pm
- Truck lost control hit a concrete median barrier
- 34 vehicles involved in the pile-up and 25 vehicles involved in the tunnel fire
- 3 fatalities, 23 injuries



Photos by Gene Blevins/LACOFD/Photo

Newhall Pass Tunnel Fire

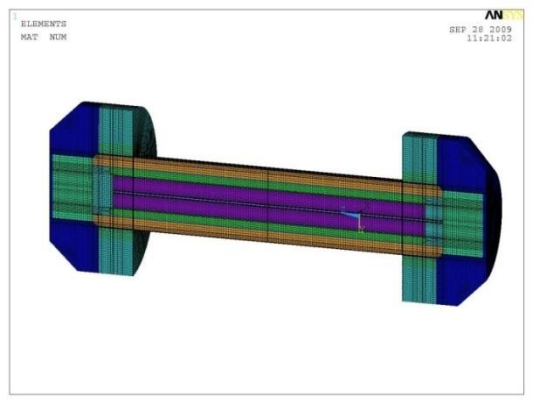
- **Samples collected from 5 out of the 25 incinerated vehicles were tested to determine temperatures**

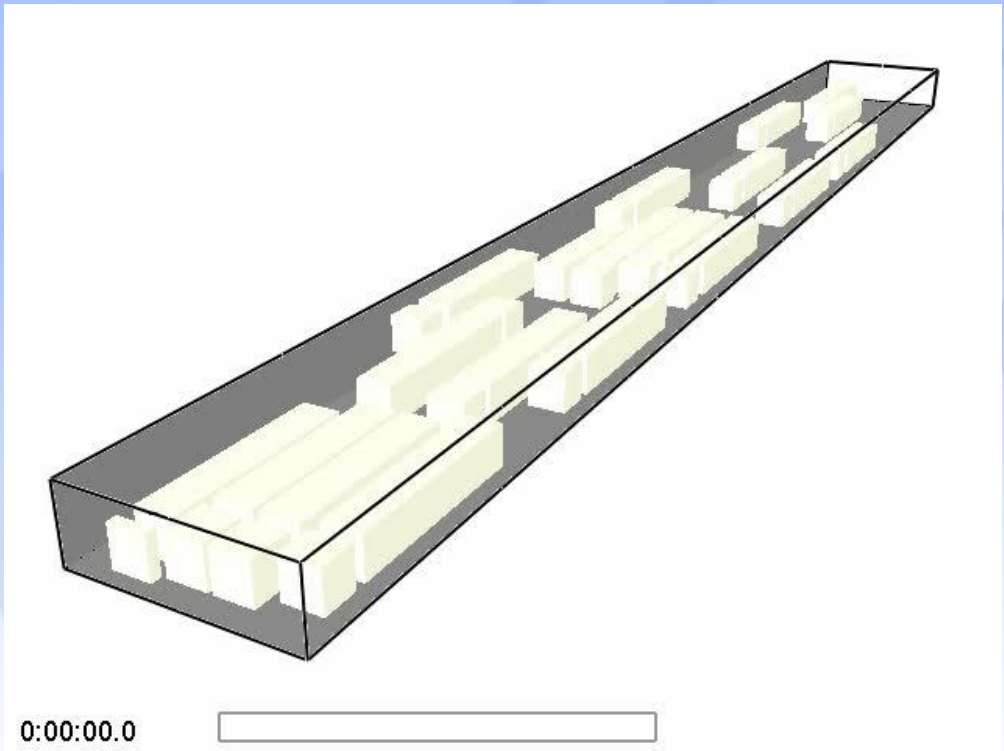


  - **Temperatures ranged from 450 to 1067ºC**

Newhall Pass Tunnel Fire

- Fire analysis and analysis of the performance of a SNF transportation package is complete





- Fuel cladding temperatures less than currently accepted short term limits
- No releases predicted
- NUREG/CR report to be issued this year

Road and Rail Accident Frequency Studies

- Determine accident parameters that could produce a severe fire with the potential to engulf a SNF transportation package
- Analyze and update statistics for accidents (e.g., frequency of road and rail accidents involving a long duration fire)
- Analyze accidents and determine trends associated with these accidents
- Findings are provided in two NUREG reports:
  - NUREG/CR 7034 - Analysis of Severe Railway Accidents Involving Long Duration Fires
  - NUREG/CR 7035 - Analysis of Severe Roadway Accidents Involving Long Duration Fires
- In short: for both road and rail transport, there is a very small frequency of severe fire accidents and, therefore, a very small likelihood that an SNF transportation package would be involved in a severe fire.

Schedule of Assessments

- **Screening of Real Life Accidents**
  - Completed 2011
- **Case Studies of Most Severe Accidents**
  - Baltimore Tunnel Fire (Completed 2006)
  - Caldecott Tunnel Fire (Completed 2006)
  - Ongoing for MacArthur Maze and Newhall Pass (Completion 2012)
  - Additional road and rail accidents to be assessed (Completion late 2012)
- **Comprehensive Review of Road and Rail Accidents Including Conclusions and Recommendations**
  - NUREG document (Completion scheduled for 2013)

Conclusions

- Severe transportation accidents happen.
- Some of these accidents (like the Macarthur Maze fire) could create environments beyond those specified in the regulations for SNF transportation packages.
- While the risk of SNF shipments being involved in these types of accidents are extremely low, the NRC is currently studying the potential consequences of long duration fire scenarios.
- The NRC remains confident that the current transportation regulations in 10 CFR Part 71 provide adequate protection to the health and safety of the public.

Communications

- On the MacArthur Maze Fire:
  - Materials analyses (NUREG/CR 6987)
    - http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6987
  - MacArthur Maze fire transportation package response
    - Report being finalized
- On the Newhall Pass Tunnel Fire:
  - Materials analyses (NUREG/CR 7101)
    - www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7101
- On the Baltimore Tunnel Fire (NUREG/CR 6886):
- http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6886
  - On the NIST FDS Analysis for BTF (NUREG/CR 6793):
    - http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6793
  - On the CNWRA Materials Analysis for BTF (NUREG/CR 6799):
    - http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6799
- On the Caldecott Tunnel Fire (NUREG/CR 6894):
  - http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6894