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FY14 DOE Used Fuel Disposition Storage and Transportation R&D Activities

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MPACT Working Group Meeting

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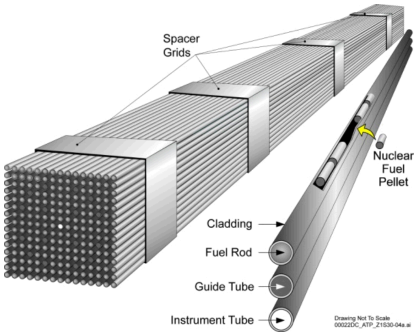
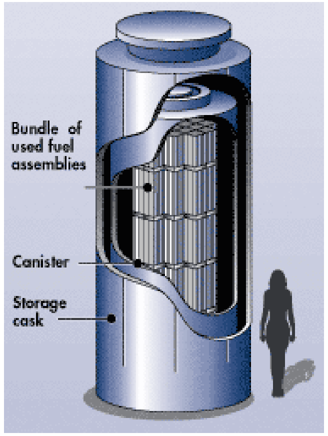


http://energy.gov/sites/prod/files/styles/



www.nrc.gov/waste/spent-fuel-storage/

www.connyankee.com/

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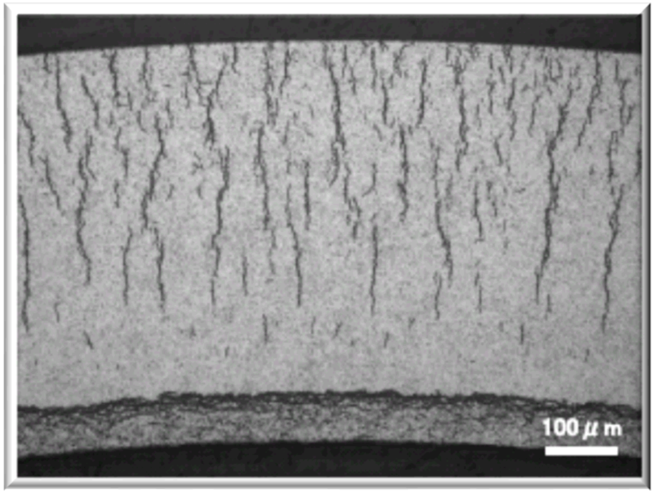
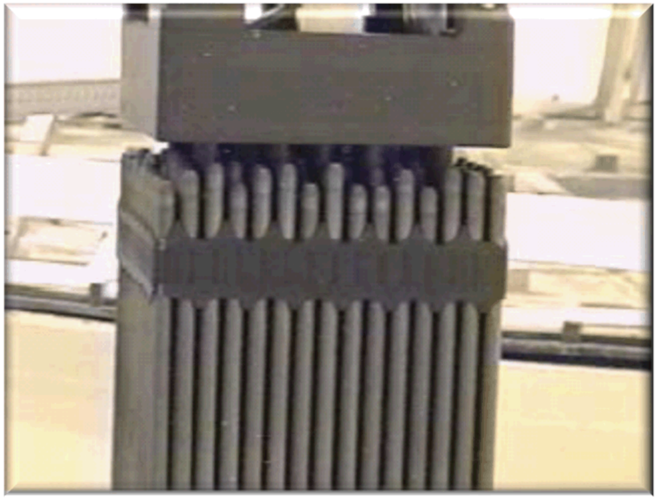
Storage and Transportation R&D Objectives

Overall Objectives:

- Develop the technical bases to demonstrate *high burn-up used fuel integrity for extended storage periods*.
- Develop technical bases for fuel *retrievability and transportation* after long term storage.
- Develop the technical basis for *transportation of high burnup fuel*.





Storage System Component "High" and "Medium" priorities

System Component	Issue	Importance of R&D
Cladding	Annealing of Radiation Effects	Medium
	Oxidation	Medium
	H_2 effects: Embrittlement	High
	H_2 effects: Delayed Hydride Cracking	High
	Creep	Medium
Assembly Hardware	Stress corrosion cracking	Medium
Neutron Poisons	Thermal aging effects	Medium
	Embrittlement and cracking	Medium
	Creep	Medium
	Corrosion (blistering)	Medium
Canister	Atmospheric corrosion (marine environment)	High
	Aqueous corrosion	High

Source: Gap Analysis to Support Extended Storage of Used Nuclear Fuel, January 2012

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Storage System Component "High" and "Medium" priorities

System Component	Issue	Importance of R&D
Bolted Direct Load Casks	Thermo-mechanical fatigue of bolts/seals	Medium
	Atmospheric corrosion (marine environment)	High
	Aqueous corrosion	High
Overpack and Pad (Concrete)	Freeze/Thaw	Medium
	Corrosion of steel rebar	Medium

Cross-cutting or General Gaps

- *Temperature profiles for fuel* — *High*
- *Drying issues* — *High*
- *Monitoring* — *High*
- *Subcriticality* — *High*
- *Fuel transfer options* — *High*
- *Re-examine INL dry cask storage* — *High*

Identification of these data gaps are used to inform new initiatives for FY15

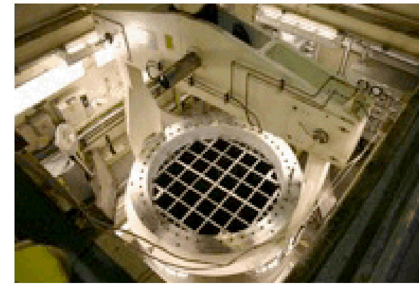
Source: Gap Analysis to Support Extended Storage of Used Nuclear Fuel, January 2012

FULL-SCALE HIGH-BURNUP DEMO

Purpose: To collect data on high-burnup fuel in realistic storage conditions.

High Burnup Dry Storage Confirmatory Demo

- **Goals:**
  - provide confirmatory data for model validation and potential improvement,
  - provide input to future SNF dry storage cask design,
  - support license renewals and new licenses for Independent Spent Fuel Storage Installations (ISFSIs), and
  - support transportation licensing for high burnup SNF.



View of Fuel Basket within a Typical TN-32 Cask

Lid Installation of a TN-32 Cask

High Burn-up Confirmatory Data Project: Dry Storage R&D Project

2017: Load a TN-32B storage cask with high burn-up fuel in a utility storage pool

- Loaded with well-understood fuel
- Remove sister pins for baseline analysis and data collection (some sister pins will have been pulled in 2015)
- Cask will have instrumentation for monitoring

2017: Dry the cask contents using typical process

2017- 2028: House cask at the utility's dry cask storage site (North Anna)

- Continually monitored and inspected for >10 years.

2028: Open cask investigate condition of fuel. (Location TBD)

Picture from North Anna ISFSI

High Burn-up Confirmatory Data Project: Data to be Monitored

- **Fuel cladding temperature (indirect via thermocouple lances)**
- **Cavity gas monitoring is being evaluated to check for damaged fuel and residual water**
  - Temperature
  - Composition
    - Fission gasses
    - Moisture
    - Hydrogen
    - Oxygen
  - Pressure
- **Active methods for sampling the gas were analyzed**
- **Use of remote sensors were evaluated to gather the needed data**
- **Gas sampling on the pad is still be investigated**

Picture from North Anna ISFSI

High Burn-up Confirmatory Data Project: Rod Testing to Establish the Baseline

- **Testing of similar rods as those to be loaded in the cask**
  - Some fuel rods (25 or less) will be shipped in existing licensed cask to a hot cell for baseline rod characteristic data
  - Some rods will come from sister assemblies and some rods from assemblies to be stored in the TN-32
  - Location to receive the shipment is still under discussion
- **Schedule for obtaining pins of similar nature as to be loaded in the cask (similar pins)**
  - Similar pins will be pulled in 2015
  - Similar pins will be shipped in 2015 or 2016

Picture from North Anna ISFSI

Field Demonstration:
Sensor Technology Development

- **Assess sensor technologies to interrogate dry storage canister systems for:**
  - thermal conditions
  - humidity conditions
  - fission gas release
  - crack characteristics associated with stress corrosion cracking
  - Assess both internal and external sensor technologies
  - Collaborate with industry to align sensor technologies with operational constraints
- **Support dry storage license extension certification efforts**
- **Support confidence in licensee's ability to detect cracks, assess crack growth rate, and determine inspection intervals that support site Aging Management Plans (AMPs)**

EXPERIMENTS

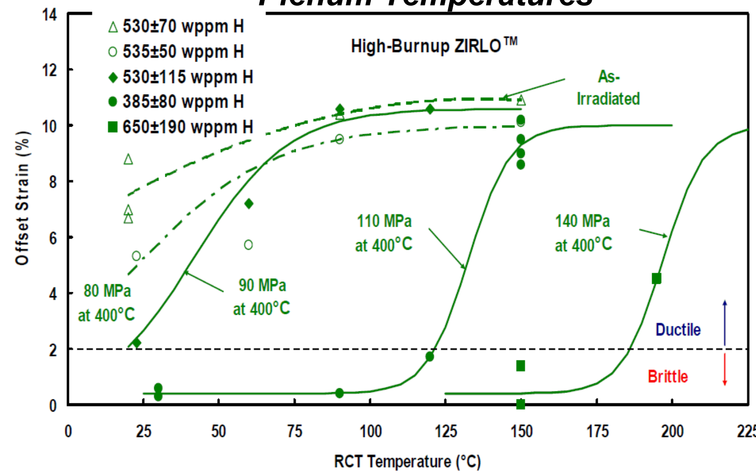
Purpose: Collect data on material properties, and environmental conditions that could affect performance.

MPACT: Will the fuel, cladding, and canister stay intact?

Experiments:
High Burnup Fuel Cladding Material Properties

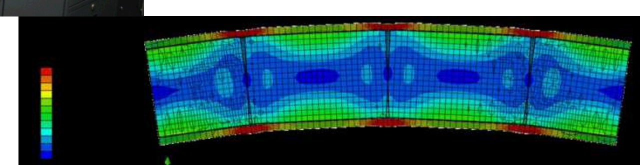
- **Separate effects test to determine effects of hydrides, hydride reorientation, radiation damage, thermal annealing, and clad thinning on materials properties and performance.**
- **Hydrides and reorientation**
  - Ring Compression Tests and determination of Ductile-Brittle Transition Temperature (ANL)
  - Cladding bend test and effects of fuel/clad bonding and pellet/pellet interfaces (ORNL)
- **Radiation damage and thermal annealing**
  - Irradiate cladding in HFIR reactor at ORNL without all other effects.

DBTT data for Ziro clad with Varying Internal Plenum Temperatures



Billone, Argonne National Laboratory, EPRI ESCP Meeting, Dec. 2013

Used fuel rod stiffness Experiments (in hot cell and out) and analyses of stress distribution



Jy-An, Wang; Oak Ridge National Laboratory, WM2014 Conference, March 2014

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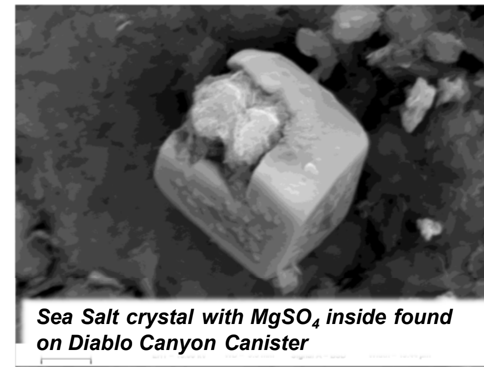
Experiments:
Stainless Steel Canister Corrosion

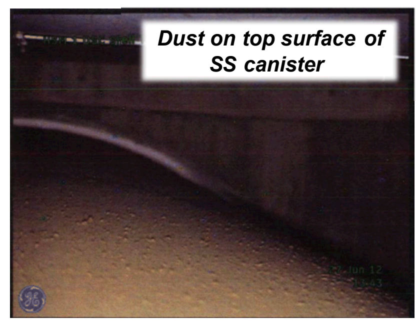
Purpose: Better understand canister degradation, support Aging Management Plans, and license extensions.

- **Develop data to understand initiating conditions for corrosion conditions and progression of SCC-induced crack growth**
- **Obtain site data to assess atmospheric conditions and compare with initiating conditions.**
- **Procure a full scale (diameter) welded SS canister to investigate residual stresses due to plate rolling and welding.**

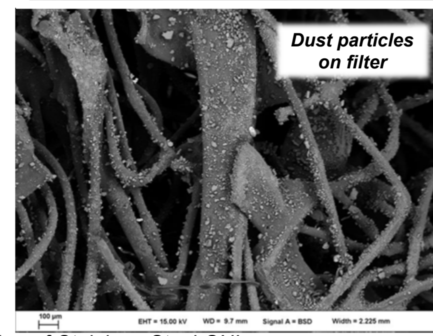
Collecting dust samples at Diablo Canyon



Sea Salt crystal with $MgSO_4$ inside found on Diablo Canyon Canister

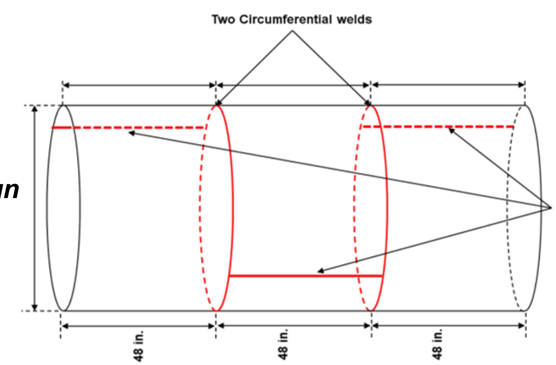


Dust on top surface of SS canister



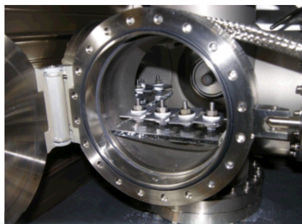
Dust particles on filter

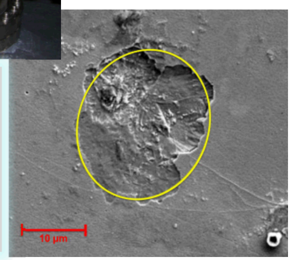
Enos, et al., Data Report on Corrosion Testing of Stainless Steel SNL Storage Canisters, FCRD-UFD-2013-000324



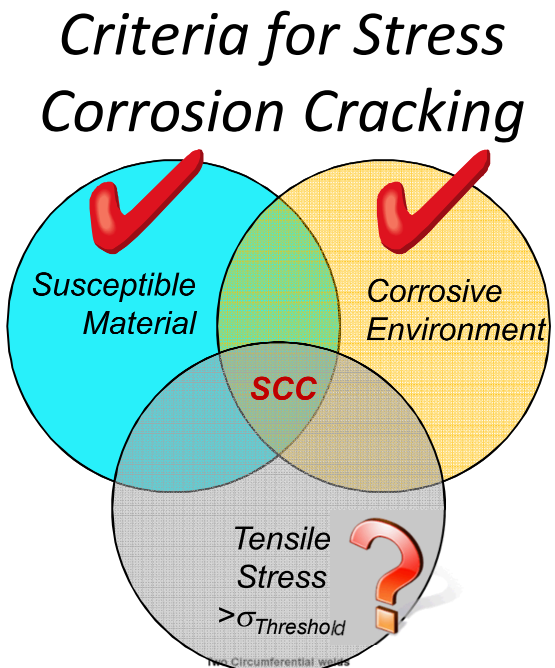
Conceptual design for full-scale (diameter) SS welded canister

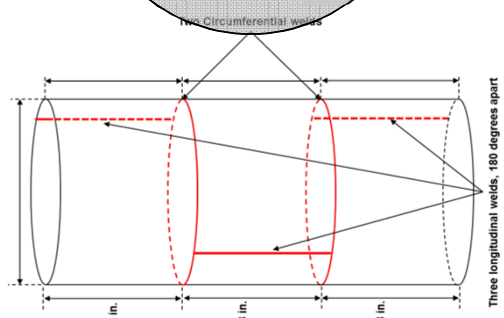
Corrosion: 4 of the High Priority Gaps





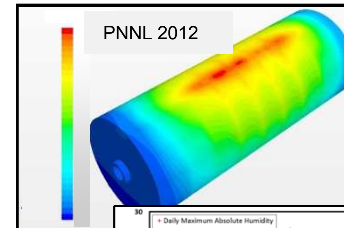
304, 304L, and 316 SS are susceptible to SCC. Bryan, 2014

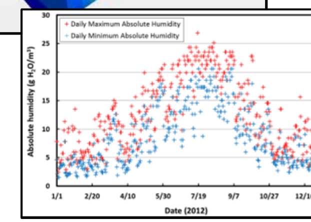




A Corrosive Environment Needs:

1. *Water (relative humidity)*
2. *Chemically Aggressive Environment*





Mg-sulfate within a sodium chloride crystal. SNL 2013

TRANSPORTATION

Purpose: Will the fuel remain intact during transportation?

MPACT: Is the fuel intact during and after transportation?

Transportation:

Normal Conditions of Transport – Loading on fuel assemblies

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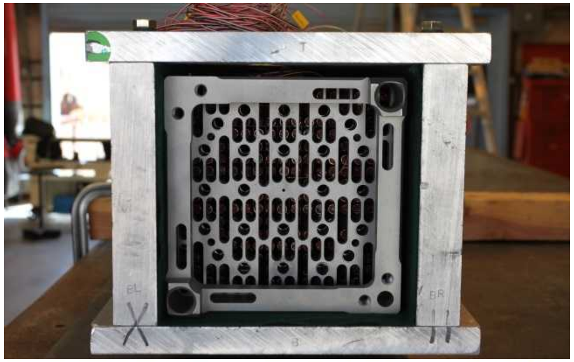
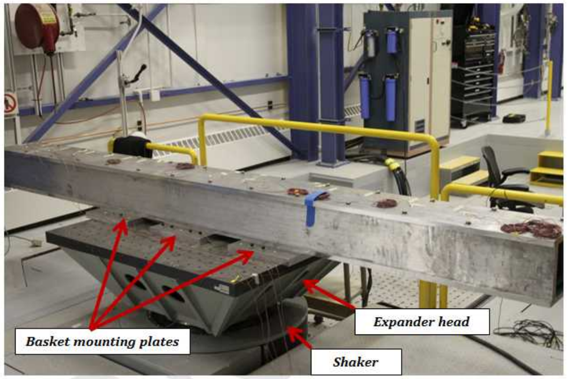
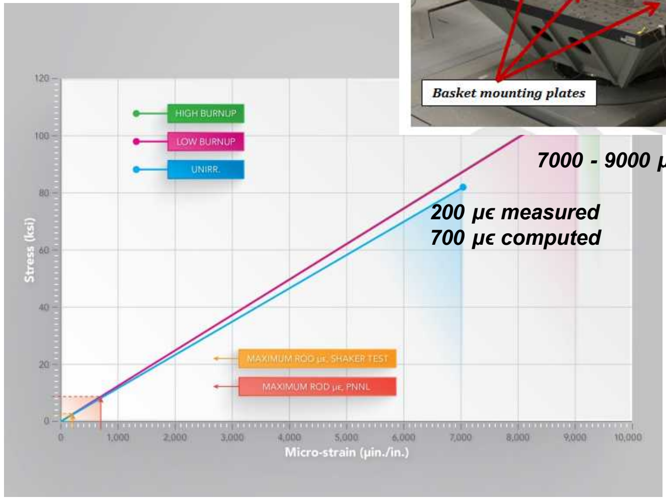
- **A surrogate assembly was subjected to truck data from a 700 mile trip on a shaker table and 50 miles on a real truck with representative weight.**
  - Data results were >10 times below yield strength.
  - The strains measured in both were an order of magnitude lower than either an irradiated or unirradiated Zircaloy rod yeild strength.

- **If high burnup fuel can maintain its integrity during transport, pressure will be taken off experimental R&D efforts associated with hydride effects on cladding strength and ductility.**

Sorenson, K., Determination of Loadings on Spent Fuel Assemblies During Normal Conditions of Transport, SAND2014-2043P.







Data collection and analysis for NCT loads on a surrogate fuel assembly

ANALYSIS

Purpose: Develop predictive models of material behavior to establish the technical bases for extended storage and transportation.

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Analysis

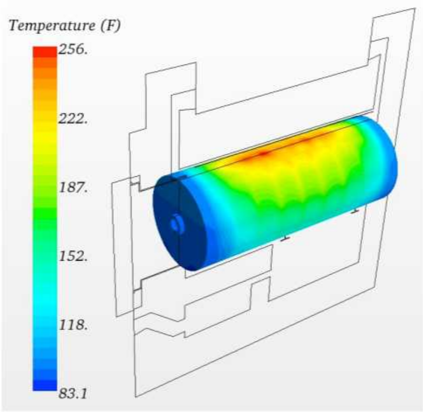
Predictive modeling

- Thermal Analysis (PNNL) to predict cool down, Ductile to Brittle Transition, deliquescence, etc.
  - HBU Demonstration fuel selection and cool down
  - Modern, high heat load, high capacity systems
  - In-service inspections validation data
- Hybrid hydride reorientation model (SNL)
- Structural uncertainty analysis at assembly and canister level (PNNL)
- Finite element analysis validation with CIRFT and application to out-of-cell testing (ORNL)

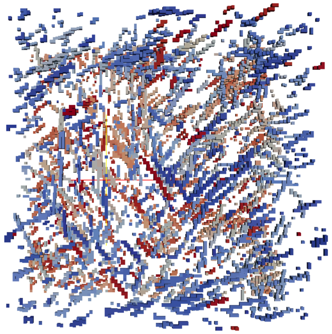
Thermal profile analyses

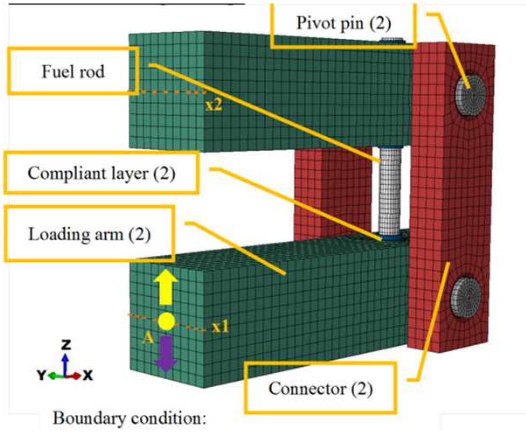
- Detailed thermal analyses for 2-3 licensed dry storage systems (PNNL FY15)

CFD Thermal Analysis of Dry Storage Casks
Suffield, et al, PNNL-21788

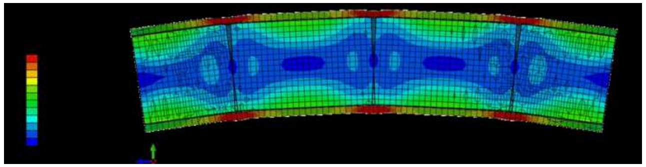


Model for Simulation of Hydride Precipitation, *Tikare et al, FCRD-UFD-2013-000251.*





FE Model of Rod Bend Tests
Jy-An Wang et al, ORNL



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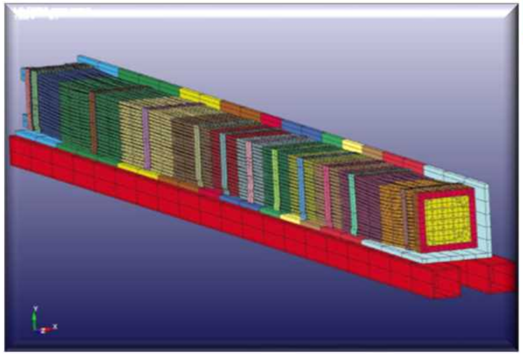

FE Models of Assembly
Klymyshyn, et al, PNNL, FCRD-UFD-2013-000168

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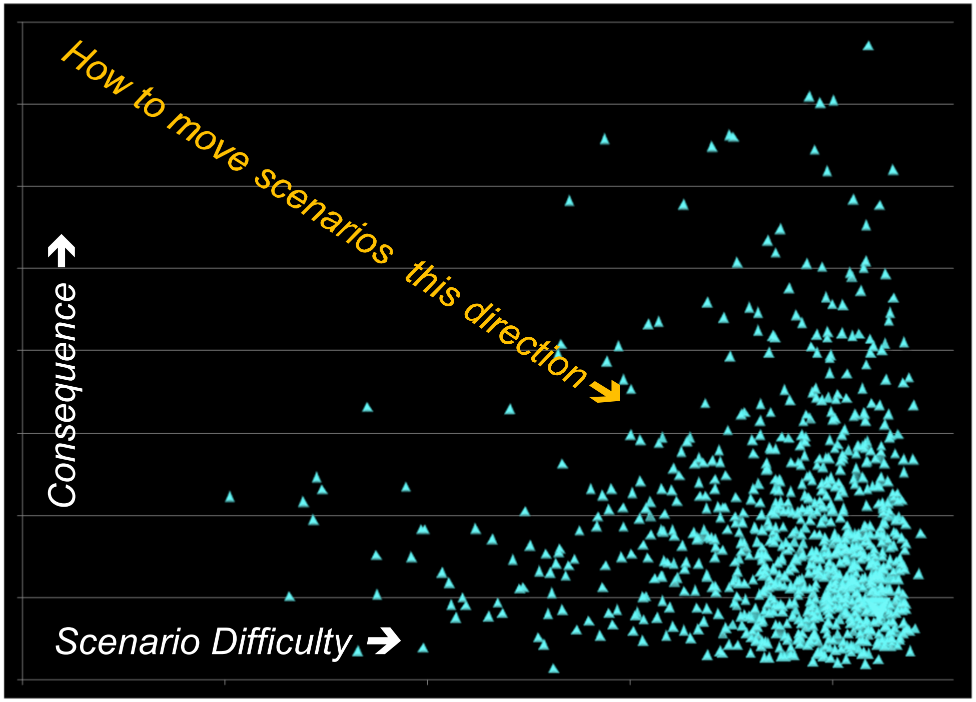
SECURITY

Purpose: Understand our vulnerabilities and how to mitigate risk.

Security: Assessing Security Risk For Transportation

- **The RIMES methodology focuses on the *degree of difficulty* for an adversary to successfully accomplish an attack**
  - An expert panel will be used to develop scenarios and determine the degree of difficulty
  - This work builds off the MPACT work on used fuel storage security.

Attack scenarios that are both easier and higher consequence are of greater risk. Focus security investments on these "high-risk" scenarios.



THANK YOU!

QUESTIONS?