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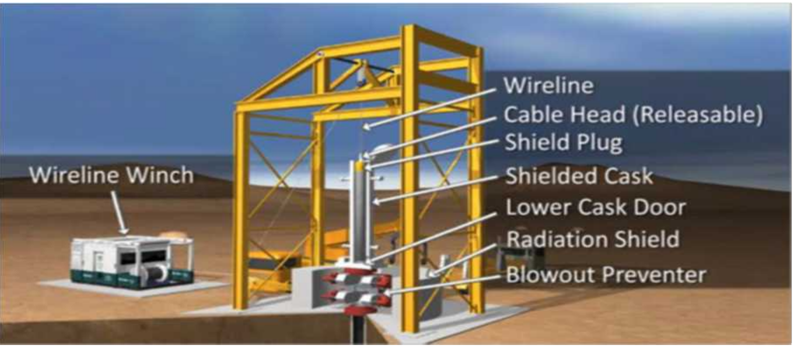


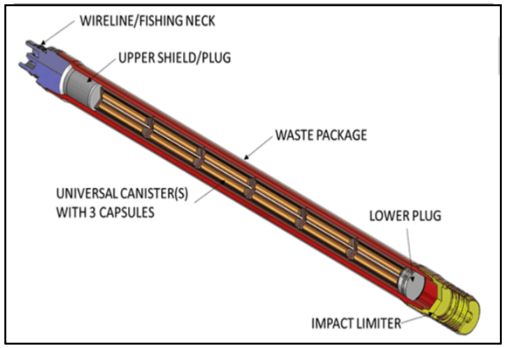


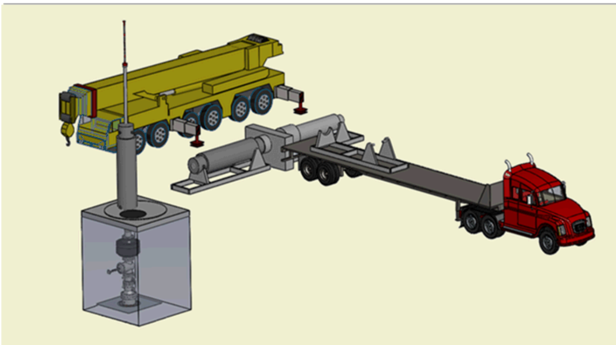

# Waste Package Handling and Deployment: DBFT Engineering Overview

**Ernest Hardin**, Andrew Clark, John Cochran, Elena Kalinina, Fred Peretz & Jiann Su

14 June 2016

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

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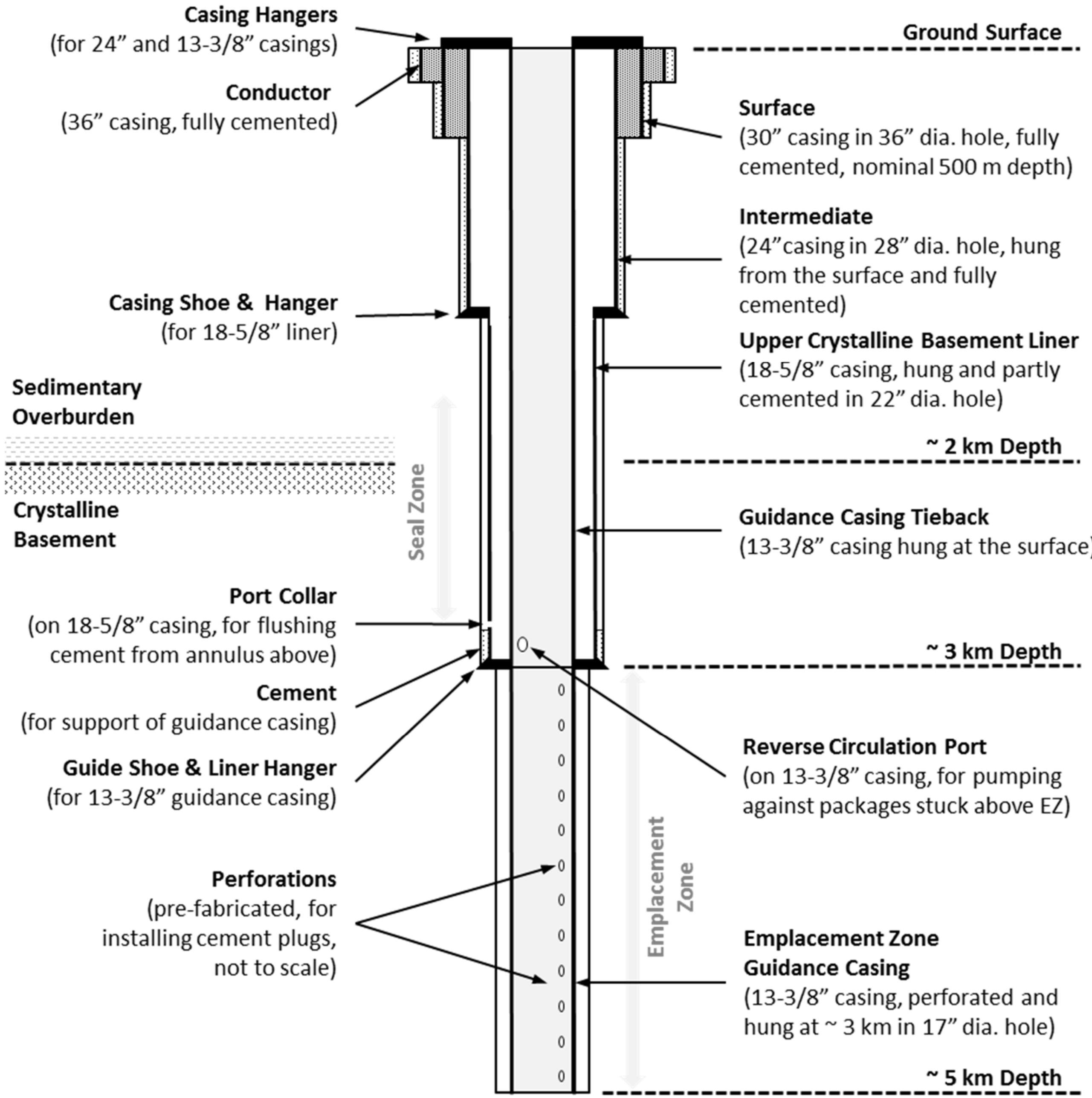
# DBFT Engineering Overview: Outline

- Field Test Borehole
- Emplacement Method Selection for Field Test
- Waste Packaging Concepts
- Dropped Package Fragility Analysis
- Impact Limiters
- Electromechanical Package Release
- Terminal Sinking Velocity Analysis
- Surface Handling/Transfer Concept

*No radioactive waste materials will be used in the Deep Borehole Field Test.*

# Field Test Borehole

- 17” Dia.
  @ 16,400 ft.
- 13-3/8” Guidance Casing to TD
- 22” Dia. Sealing Zone
- Modeled After Reference Disposal Concept (Arnold et al. 2011)



# Spent Fuel Test–Climax: Nevada Test Site 1978-83
# Eleven Irradiated PWR Assemblies Stored 3 yr






# DBFT Engineering Overview: Compare Emplacement Methods

| | Meets Security | Multi-Package Emplacement | Emplacement Cost | Comments |
|---|---|---|---|---|
| Free Drop | No | | $ | • Status uncertain during descent |
| Electric Wireline | Yes | | $$ | • Impact limiter on every package |
| Coiled Tubing | Yes | ✓ | $$$ | • Limited tubing life (much less than needed to load a borehole)<br>• (Unless packages are threaded together in strings → basement)<br>• Don't force packages downhole |
| Drill-String | Yes | ✓ | $$$$ | • Heavy strings<br>• Packages threaded together<br>• Complex basement |
| Conveyance Casing/Drill-String | Yes | ✓ | $$$$ | • Packages stacked in conveyance casing at the surface, then lowered<br>• Heavy strings<br>• Packages smaller/borehole larger |

✓ = Requires a "basement" facility for assembling package strings

# DBFT Engineering Overview:
# Emplacement Method Cost-Risk Analysis

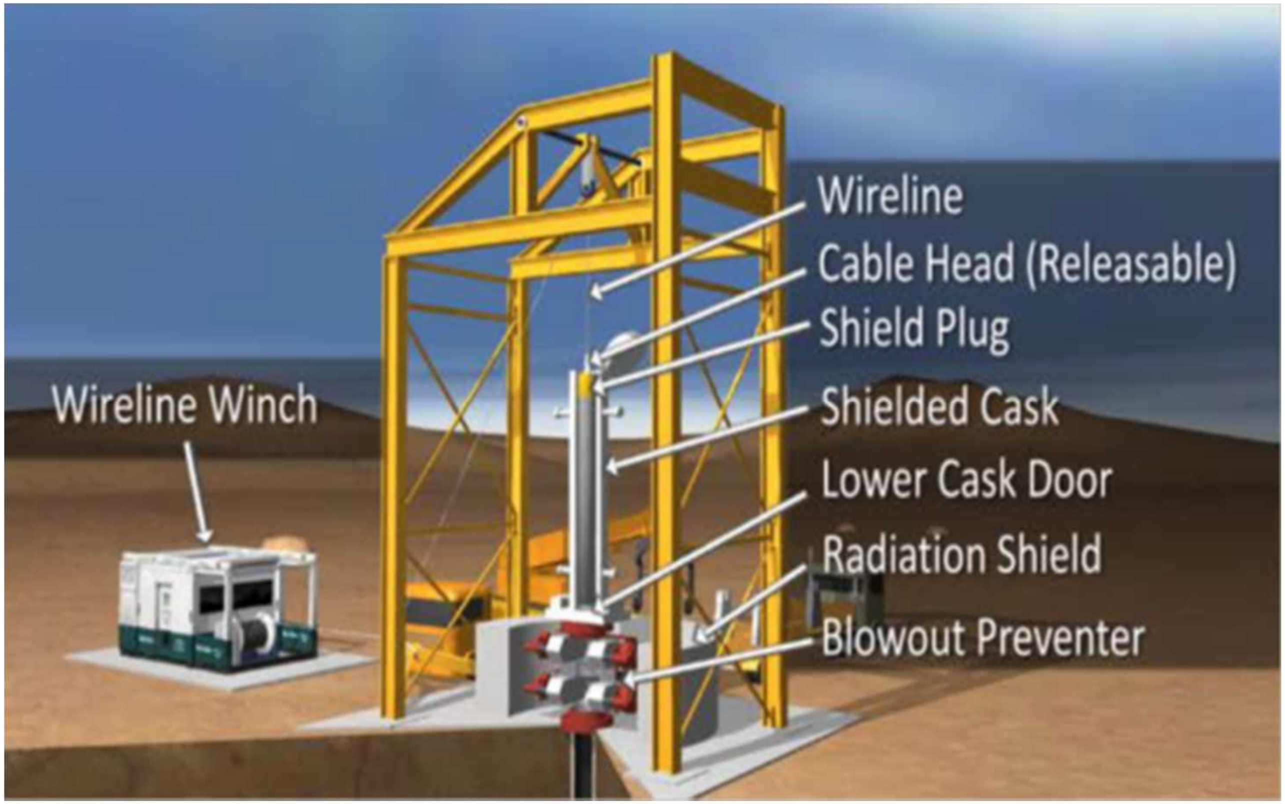
- Results Summary:
  ***Drill-String Emplacement Would Be ~52× More Likely to Cause a Radiological Release Than Wireline Emplacement***
  - Prototype borehole, 400 packages total
  - Assemble and emplace strings of 40 packages

| | Initial Results | |
|---|---|---|
| | **Wireline** | **Drill-String** |
| **Probability of incident-free emplacement of 400 WPs** | **97.83%** | **99.24%** |
| **Approximate total costs if successful ($ million)** | **23.5** | **41.9** |
| **Expected performance against the defined performance metrics** | | |
| Expected value of costs ($ million) for outcomes weighted by probabilities, considering both normal and off-normal events | 23.7 | 43.9 |
| Expected total time of operations (days) for outcomes weighted by probabilities, considering both normal and off-normal events | 430 | 434 |
| Aggregated probability of radiation release | 1.35E-04 | 7.08E-03 |

**SNL 2016. *Deep Borehole Field Test: Conceptual Design Report.* FCRD-UFD-2016-000070. June 30, 2016.**

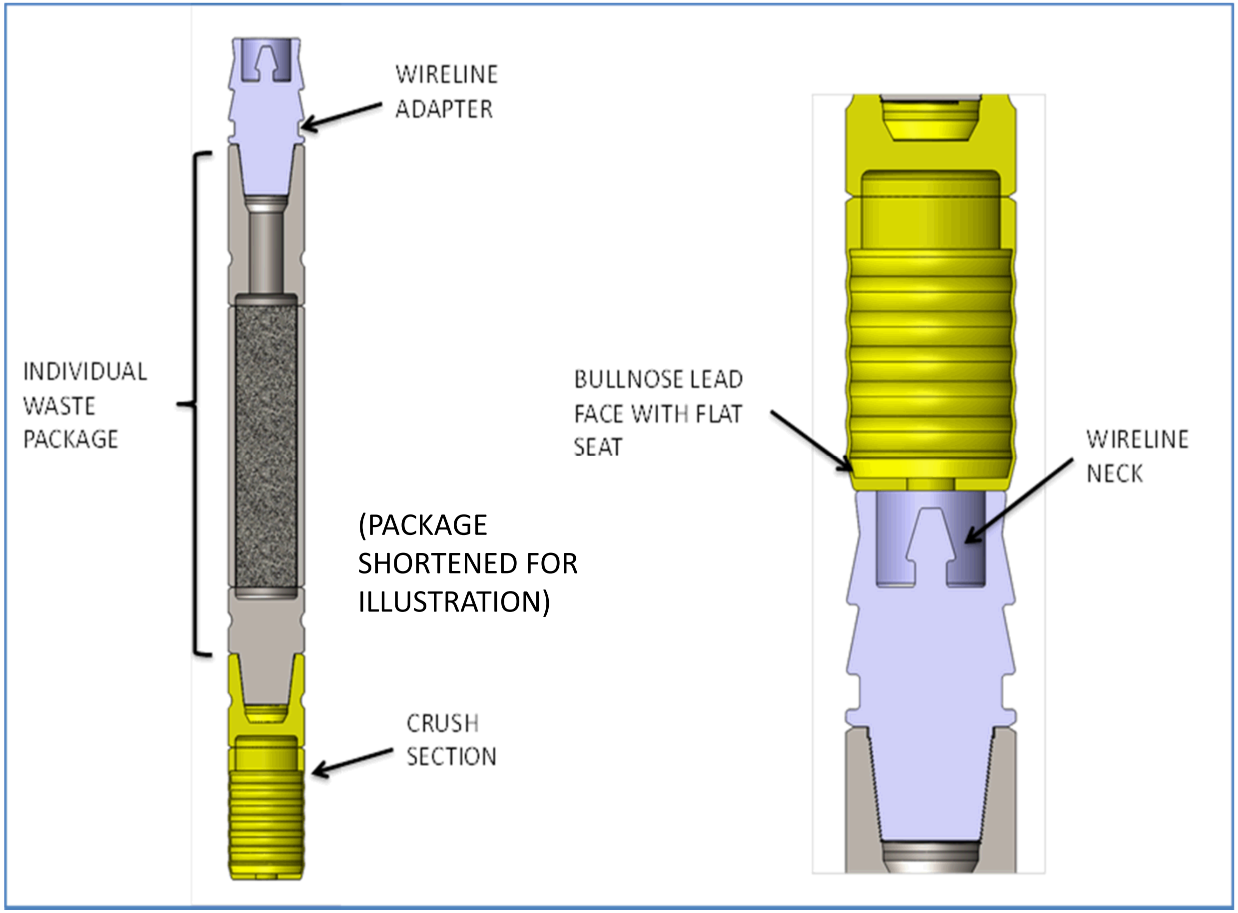
# DBFT Engineering Overview: Wireline Emplacement Concept

- Modern Electric Wireline
  - Tuffline® or equiv.
  - 12,000 lb w/out capstan
  - No "seasoning"
- Electromechanical Release
- Shielded "Pit"
- Headframe



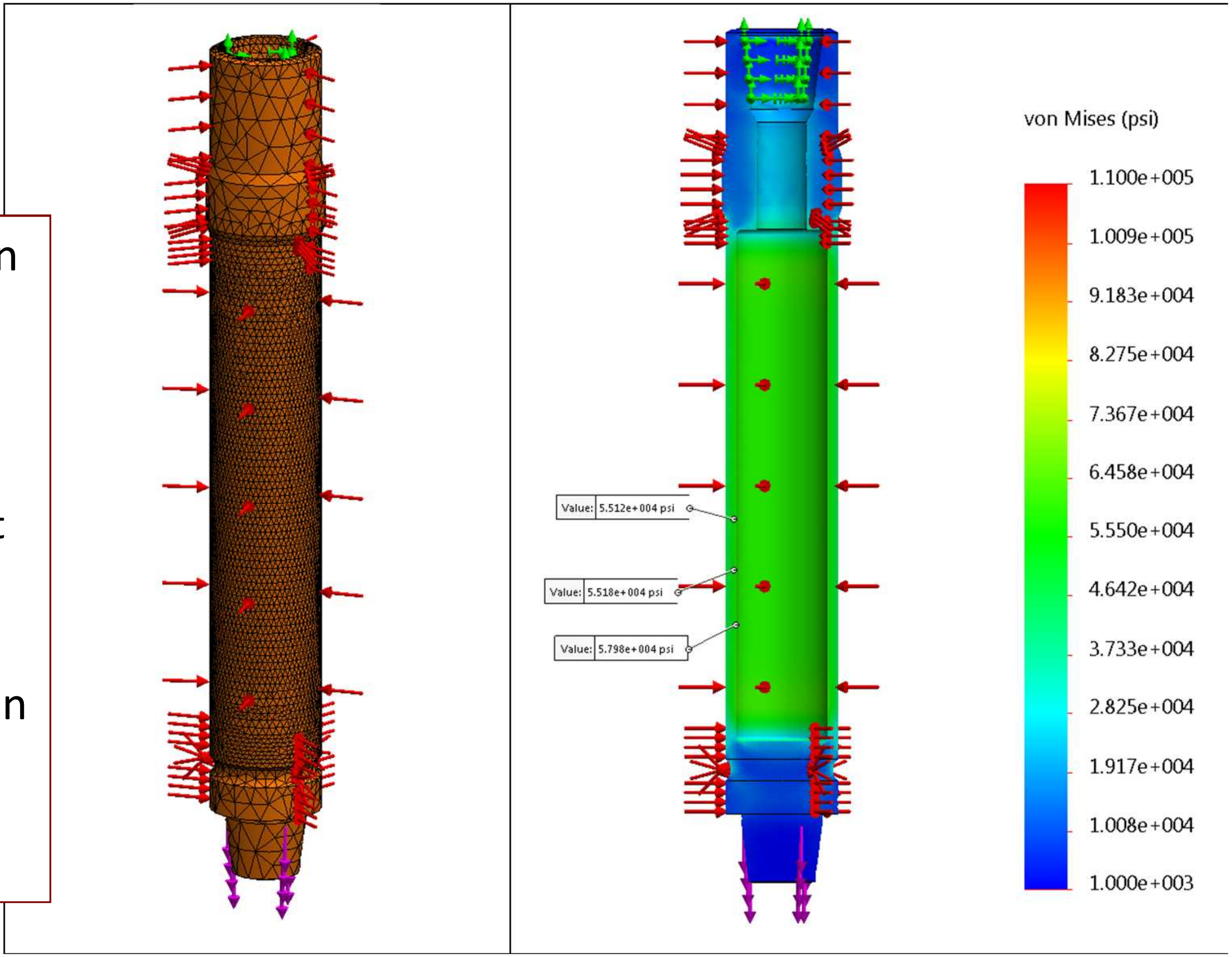
# DBFT Engineering Overview: Packaging for Wireline Emplacement

- Flask-Type Shown
- Attachments
  - Wireline latch and fishing neck (upper)
  - Impact limiter (lower)
- End Plugs Welded and Heat-Treated
- Tapered Fill Plug
- API NC-77 Threads Provide Containment Backup



# Package Stress Analysis

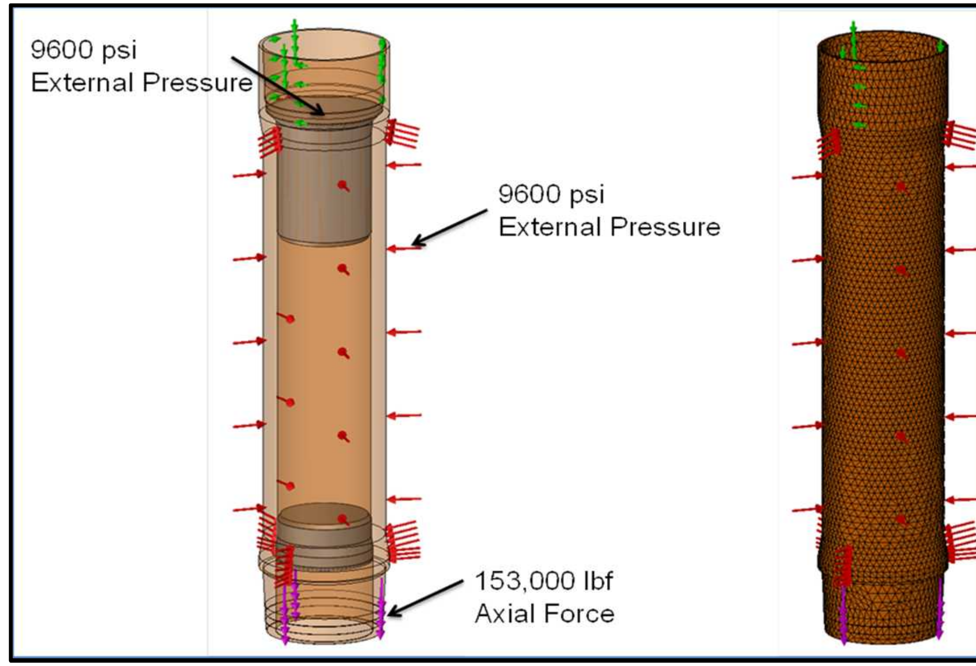
- Flask-Type Shown
- Analyze for
  - 9,560 psi fluid pressure
  - 154,000 lb weight of 40 reference packages
- Axial Compression *Decreases* von Mises Stress

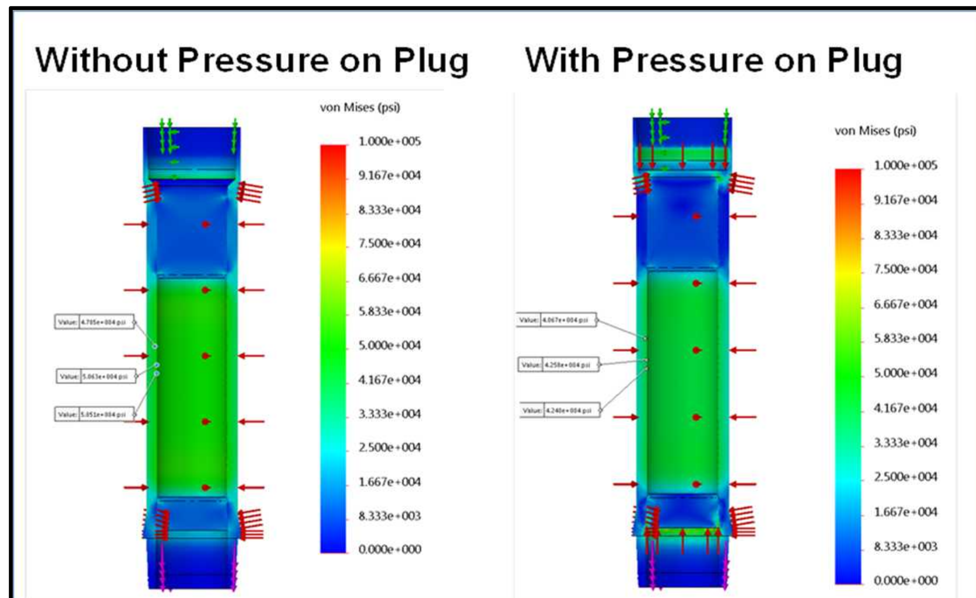



**Numerical factor of safety: 2.1 for 110 ksi material**

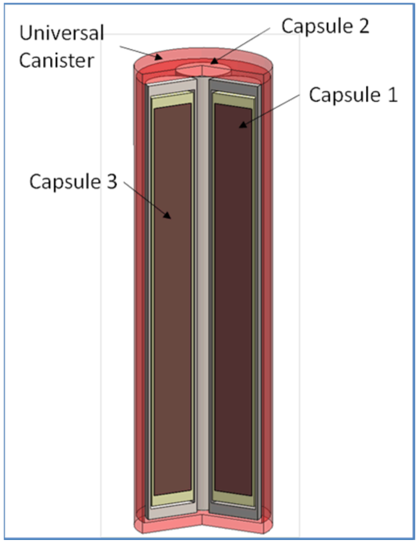
# Internal Semi-Flush Disposal Overpack

- Tapered Fill Plug (upper shield plug) with Metal-Metal Seal
- Welded & Heat-Treated Lower Plug
- Mating Box & Pin Threads on Attachments
- Take Credit for Casing Threads as Pressure Backup
- Thread Leakage *Decreases* von Mises Stress on Fill Plug

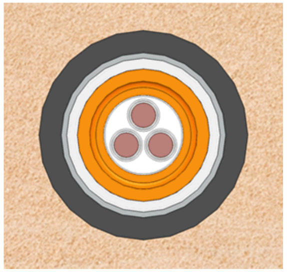


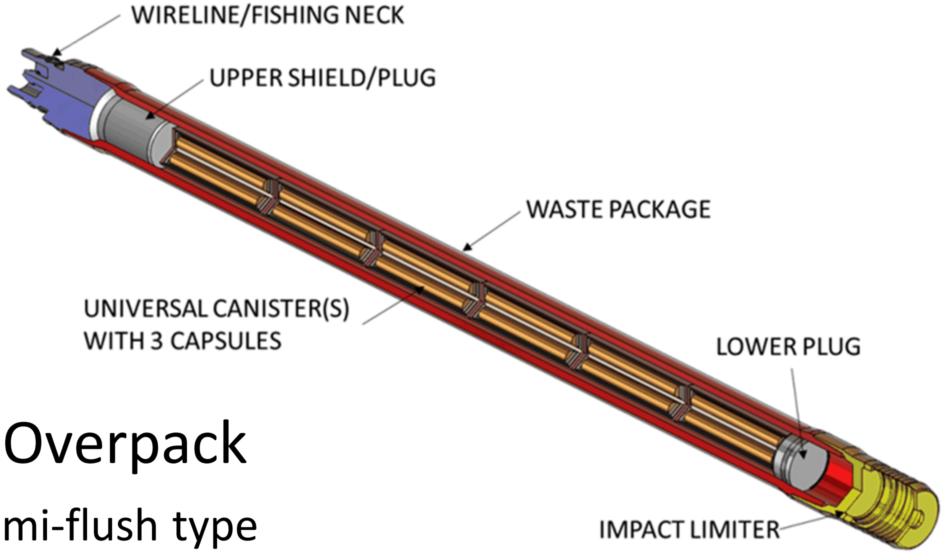



# Overpack Concept for Pre-Canistered Cs/Sr Capsules




**Cs/Sr capsule 3-packs, canistered**






- Disposal Overpack
  - Internal semi-flush type
  - Holds 18 capsules (fits NAC LWT cask)
  - Internal semi-flush type, medium size
  - Max. OD 9.044”, min. ID 6.671”
  - P110 medium-carbon steel
  - Tube wall thickness 0.93”
  - Overpack wall temperature limit 250°C

# DBFT Engineering Overview: Packaging Concept Summary Data

| WP Type | Waste Type | Casing Grade | Tube OD (in) | Tube ID (in) | Tube D/t Ratio | Connection | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ID (in) | OD (in) | Casing Size [A] (in) | Casing ID [A] (in) | Radial Gap [B] (in) |
| Internal semi-flush | Cs/Sr capsules (end-to-end) | P110 | 5.00 | 3.88 | 8.9 | 3.80 | 5.00 | 7.00 | 6.37 | 0.68 |
| Internal semi-flush | Cs/Sr capsules (3-packs) [C] | P110 | 8.63 | 6.75 | 9.2 | 6.67 | 9.04 | 10.75 | 10.05 | 0.50 |
| Flask-type | Bulk waste (e.g., calcine) | Q125 | 10.75 | 8.65 | 10.2 | 4.75 [D] | 10.75 | 13.37 | 12.62 | 0.93 |

Notes:

[A] Guidance casing selected for mechanical support and minimal differential pressure.

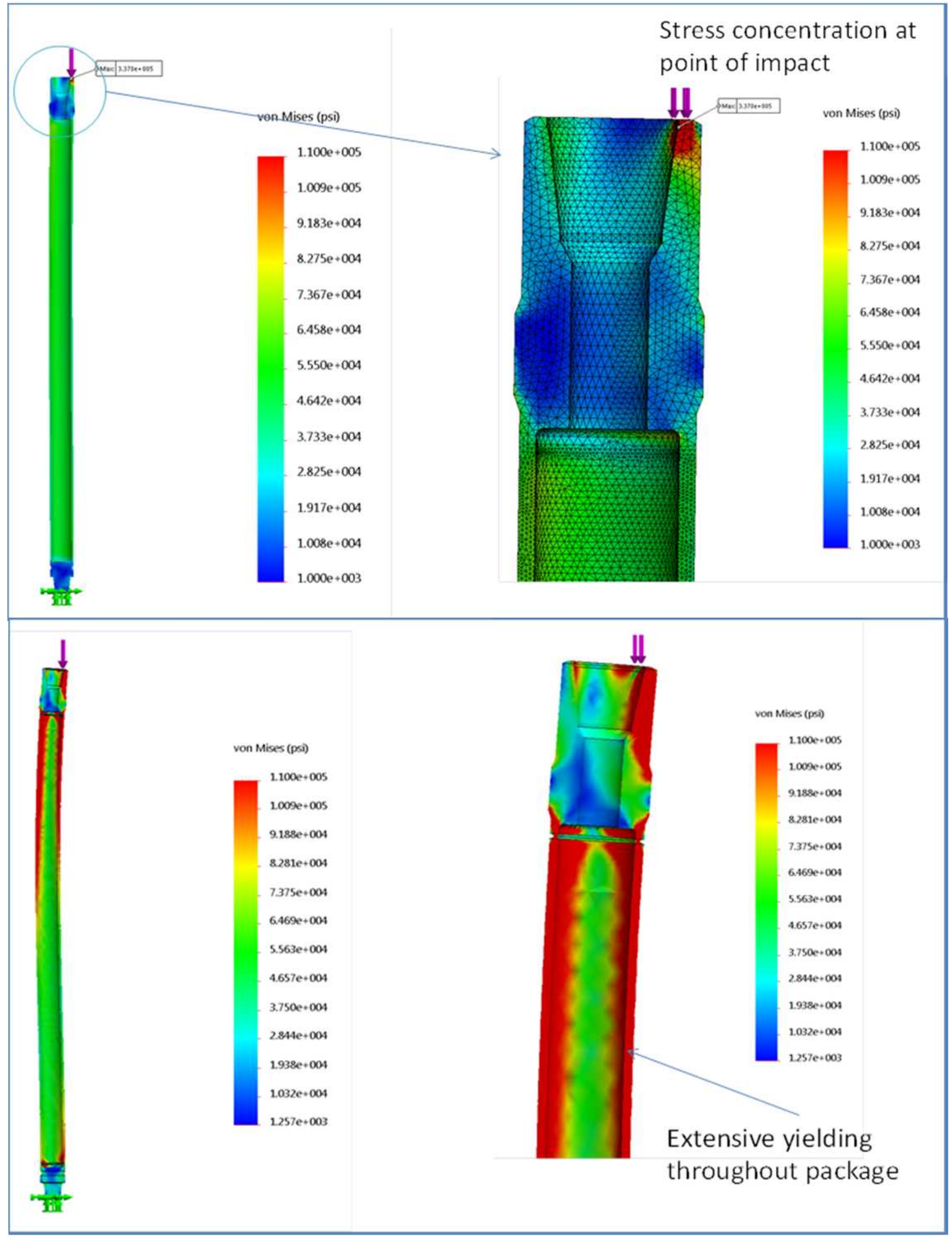
[B] Minimum gap along the length of a package including end connections, based on nominal dimensions, for use with sinking velocity calculations.

[C] Universal canister (3-pack) OD assumed to be 6.500 inches.

[D] Inner dimension for API NC-77 thread.

# Quasi-Static Fragility Analysis for Dropped Packages

**One package** dropped at 2.5 m/sec

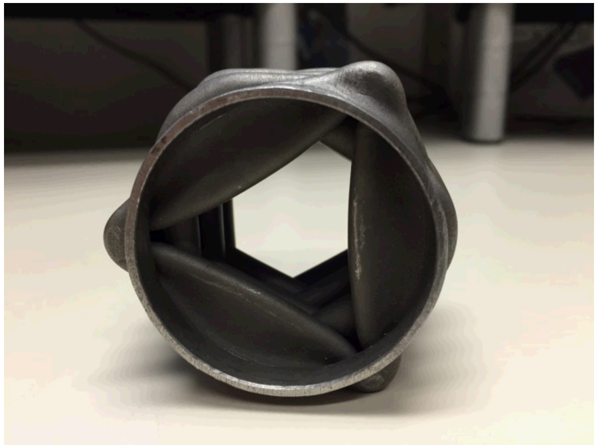



- Quasi-Static Stress Analysis
- Impulsive Force Concentrated Over 40° of Perimeter
- Strings of 1, 5, 10 or 20 Dropped
- von Mises Stress (110 ksi yield)
- 20× Horizontal Exaggeration
- Conclusion: Strings of >1 Package Produce Extensive Yielding

String of **20 packages**, threaded together, and dropped at 2.5 m/sec

# Impact Limiter Example
# Hanford Multi-Canister Overpack Absorber

- Single Axis
- Compositionally Stable Downhole (all metallic)
- Operates in Fluid
- Design for Progressive Collapse
- Design for No Jam-Up



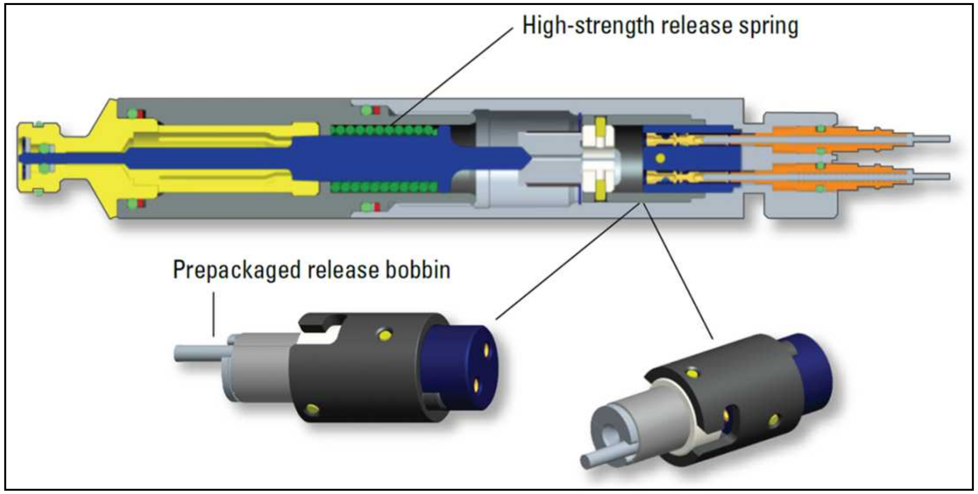
**Objective: Limit deceleration of a dropped package to ~3g on impact with borehole bottom**

See also:

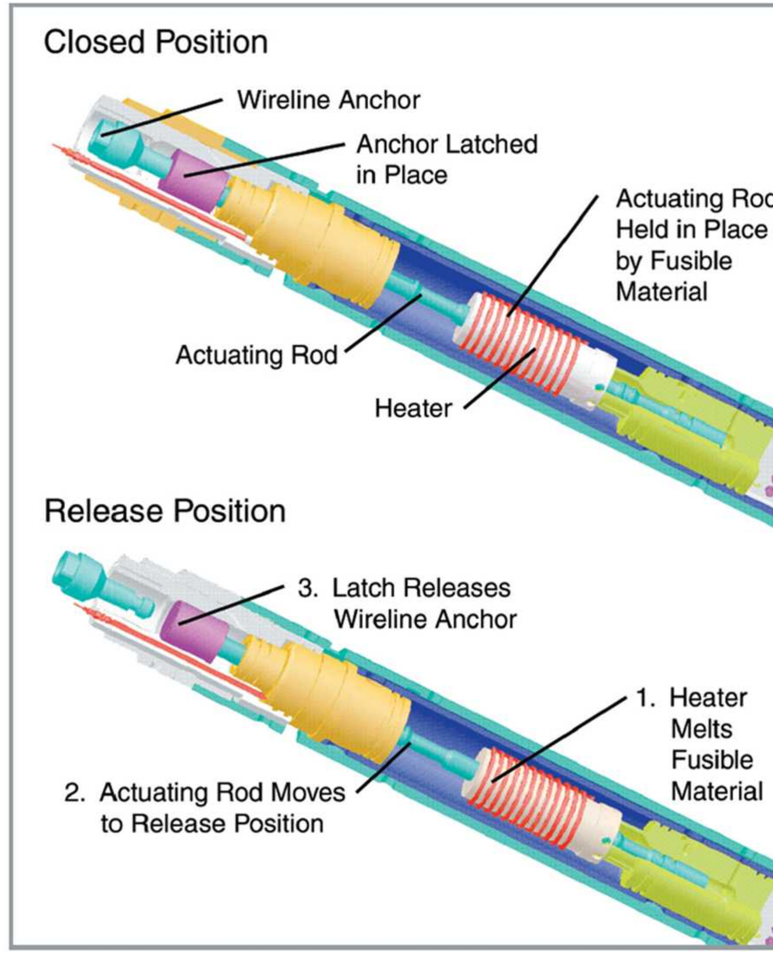
Noss, P.W., J.C. Nichols, and S.R. Streutker 2000. “MCO Impact Absorbers Using Crushable Tubes.” WM 2000 Conference, Tucson, AZ.

***Photos from: Brad Day, Sandia National Laboratories, Carlsbad NM.***

# Releaseable Wireline Cable Tools



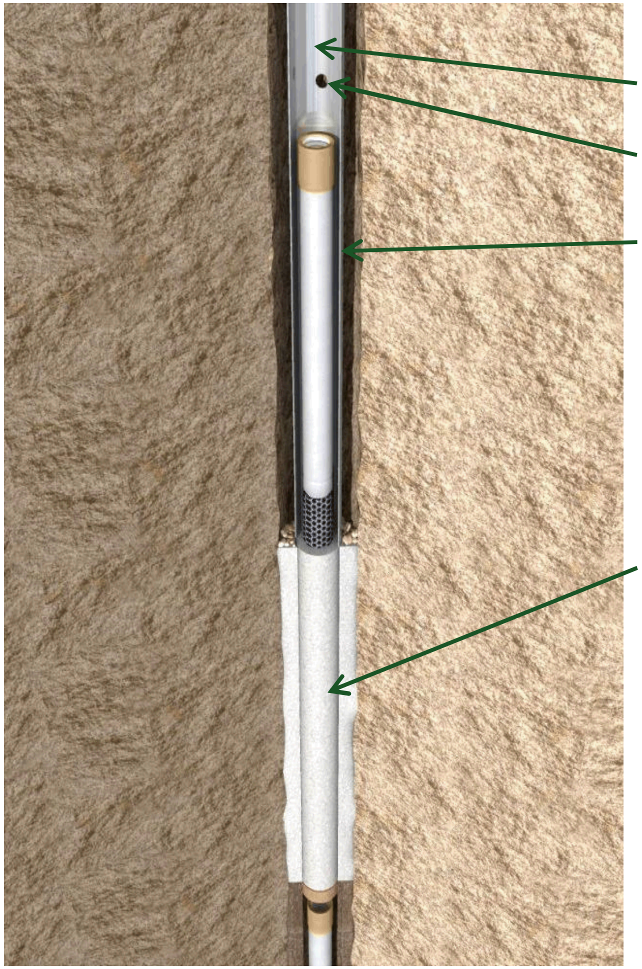

- SLB SureLOC 12000®
  - Up to 12,000 lb working load
  - Temperature & pressure rated
  - Single-shot
  - Releases at up to 1,000 lb load




- Haliburton RWCH®
  - Load capacity > any wireline
  - Temperature & pressure rated
  - Single-shot

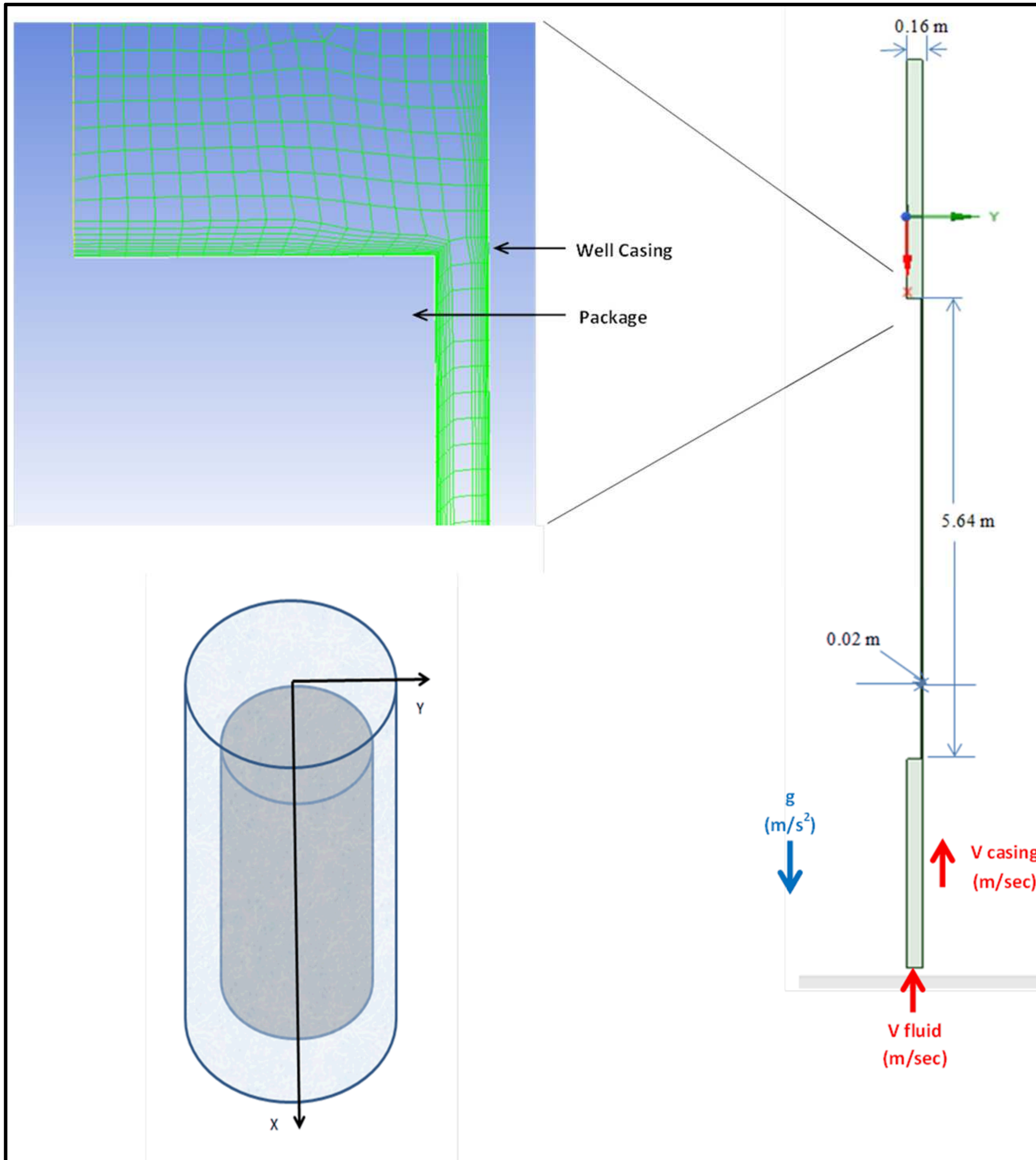
# DBFT Engineering Overview: Emplacement Zone Completion Options

- Components
  - Guidance casing
  - **Perforations** in casing
  - Emplacement fluid
  - Cement
- Options
  1. Gravity-poured cement plugs
  2. Squeezed cement plugs
  3. Fully cemented guidance casing w/ gravity-poured plugs
  4. Fully cemented emplacement



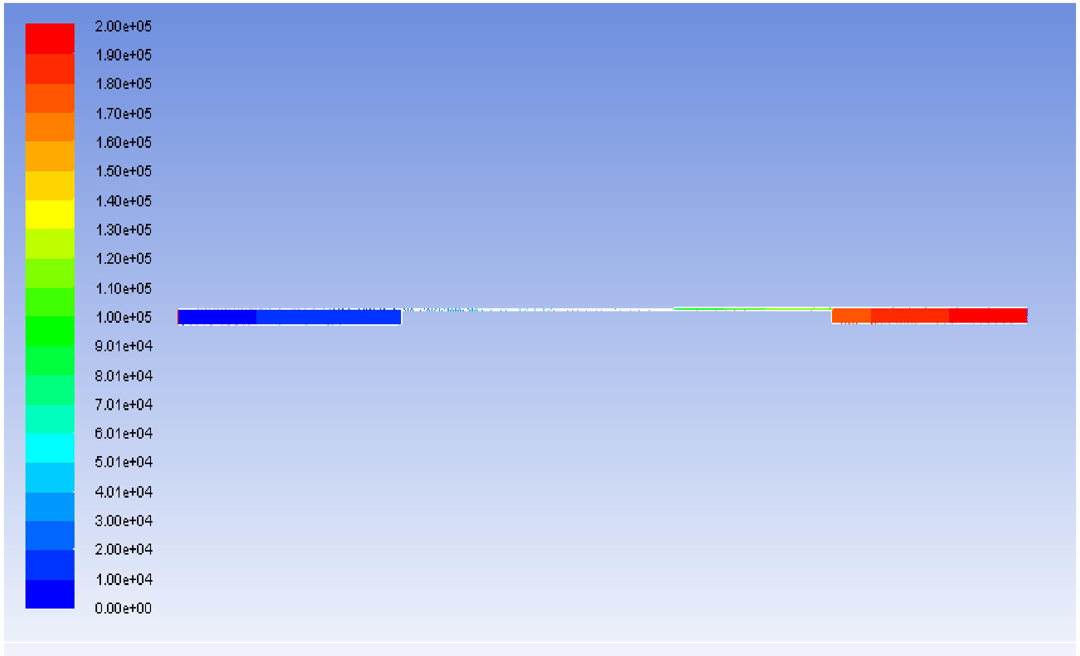
# Terminal Velocity Scoping Model Setup

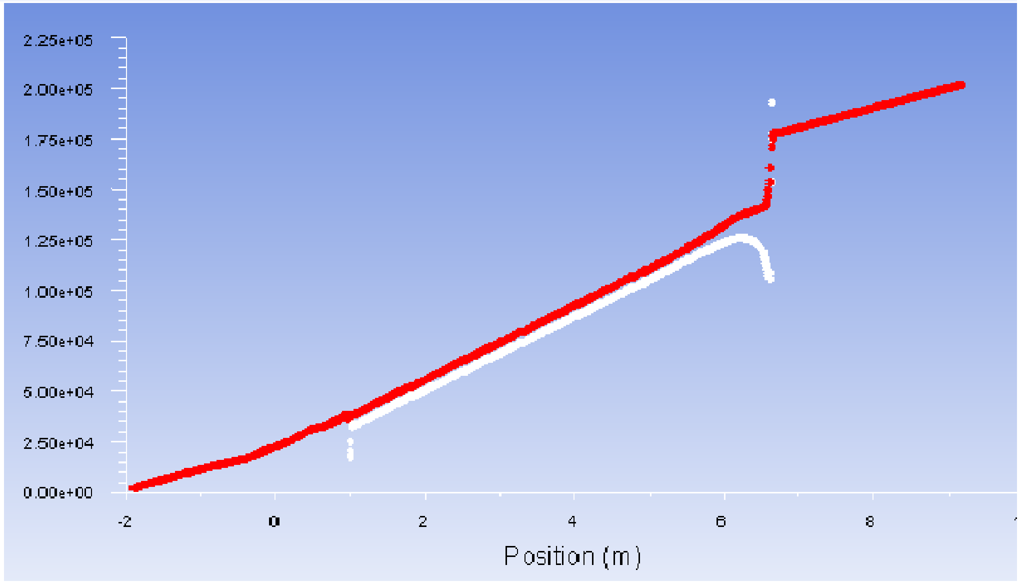
- CFD (ANSYS-Fluent®)
- Axisymmetric
- Package Centered in Casing
- Lagrangian Frame
- Reynolds Number: 300 to 5.6×104 (water @20°C)



# Terminal Velocity in Unperforated Casing

- Radial Gap 2 cm
  - Package OD 11”
- Dominated by Form Drag
  - Viscous effect ~5%
  - Sensitive to fluid density
- Uniform Dynamic Pressure
- Max. Terminal Velocity ~11 m/sec
  - Use borehole diameter (no casing)

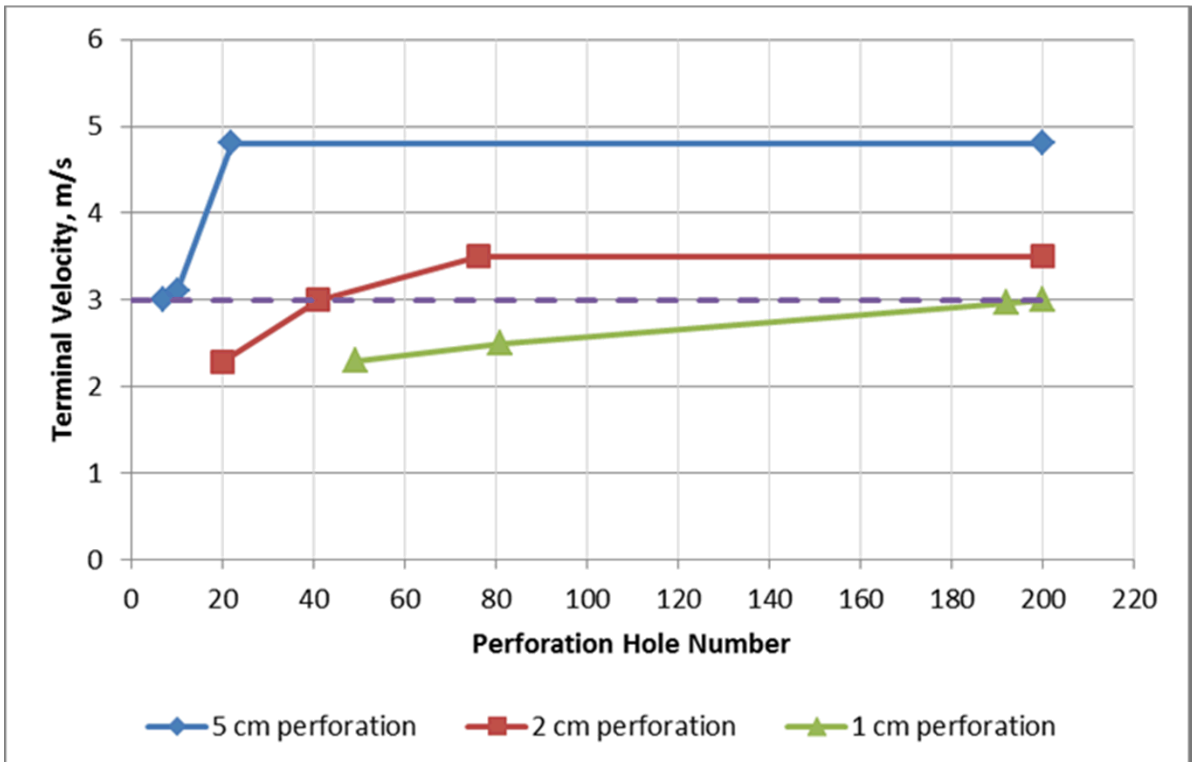


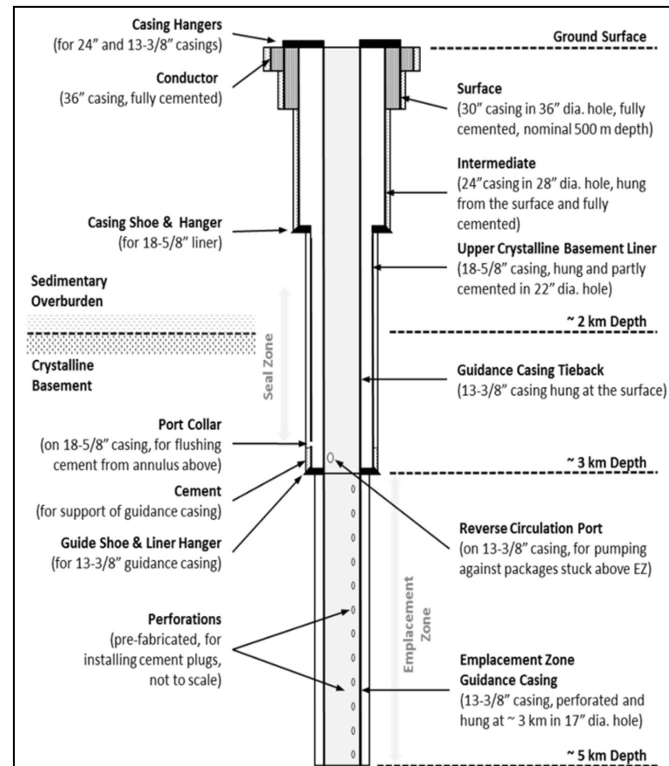



# Guidance Casing Perforation Effect and Design for DBFT Free Drop Test

- Need Small Perforations to Relieve Post-Closure Pressure, and Larger Perforations for Cementing Casing

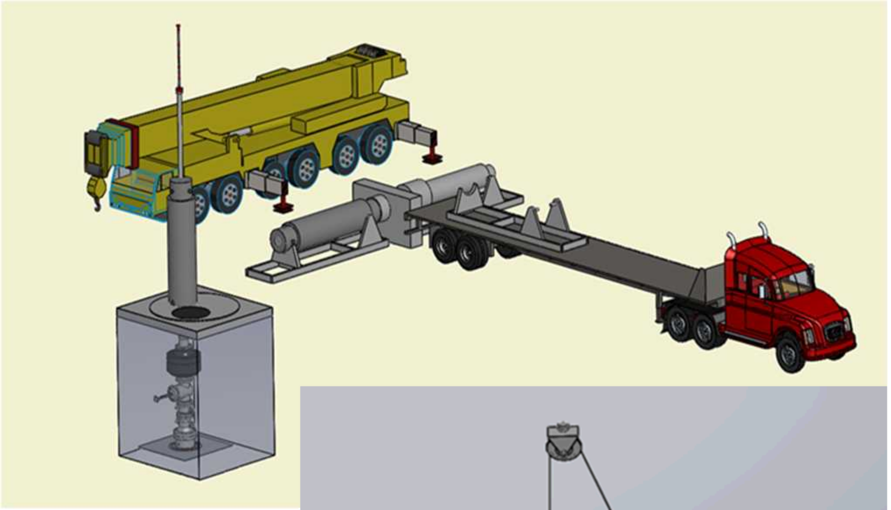
***How many, what size, and what distribution of perforations for DBFT?***

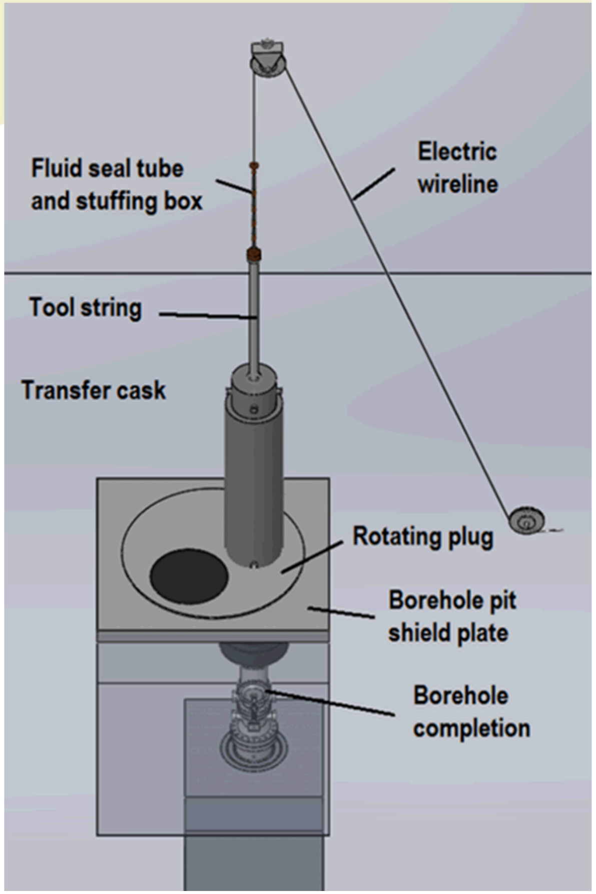


# Surface Handling/ Transfer Concept

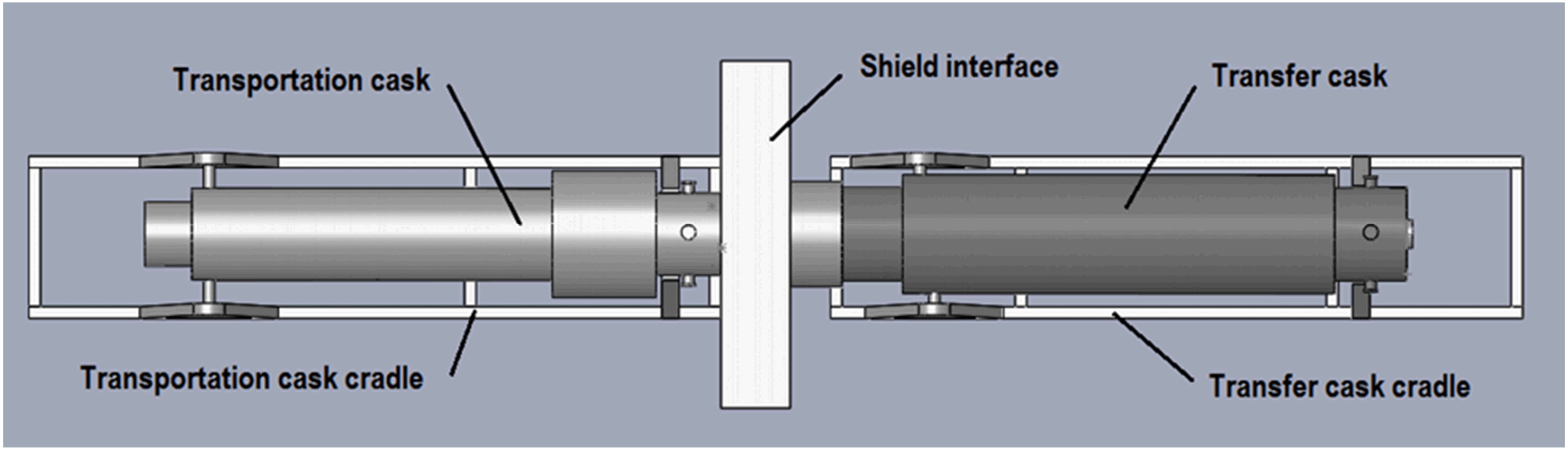
- Existing Transportation Cask (NAC Legal-Weight-Truck)
- Double-Ended Transfer Cask
- Horizontal Transfer From/To Transport Cask
- Shielded Pit Over Borehole
- Rotating Carousel Shield Over Wellhead
- Remotely Operated Mechanism for Handling Lower Shield Plug in Pit
- Remotely Operated Grayloc Flange in Pit
- Transfer Cask and Attachments Part of Well Control Pressure Envelope





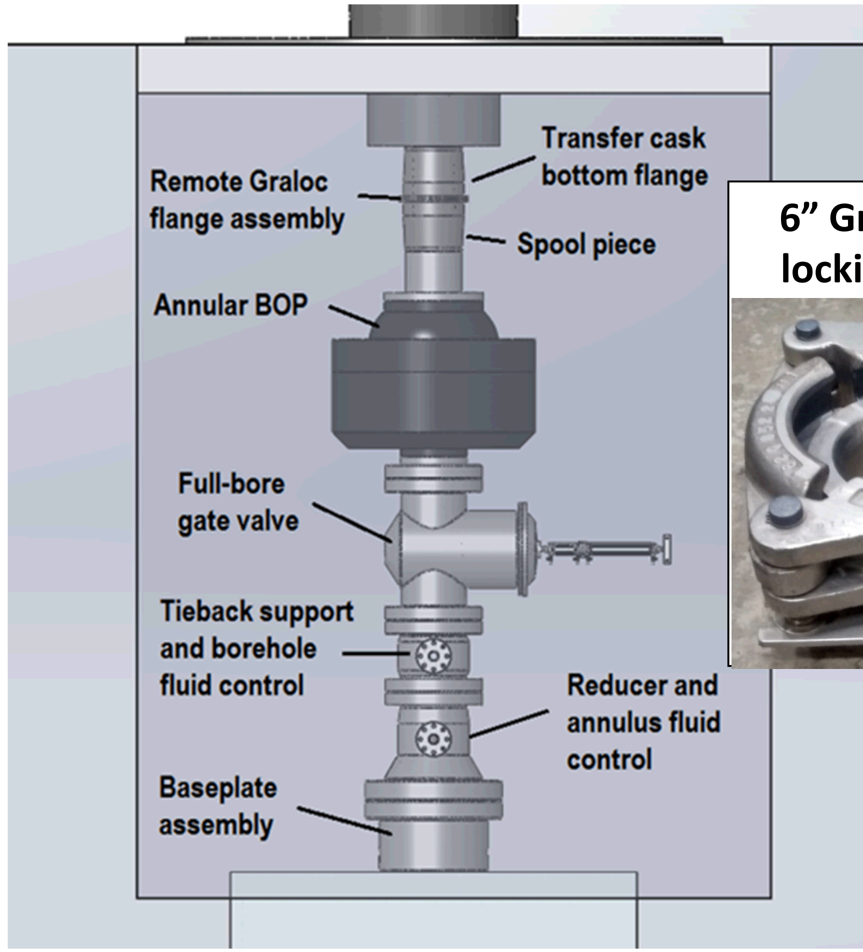
# DBFT Engineering Overview: Surface Cask-Cask Transfer Concept

- NAC Legal-Weight-Truck Transportation Cask
- Purpose-Built Double-Ended Transfer Cask
- Sliding Plate Shield Interface for Plug Removal/Replacement and Package Transfer



# DBFT Engineering Overview: Transfer Cask – Borehole Interface

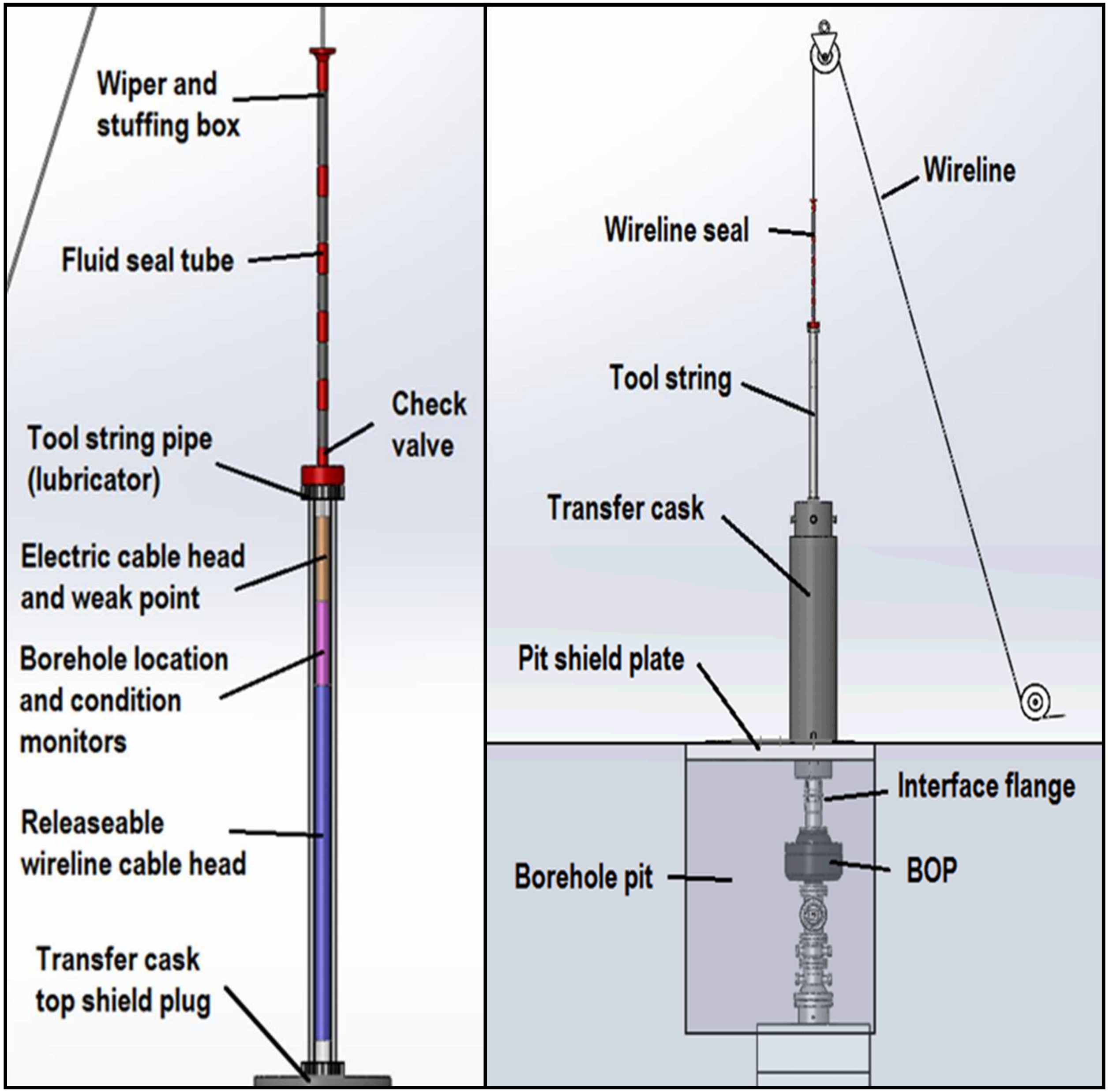
- Pressure-Rated Connection
- Grayloc Side-Clamp Flange
  - Remotely-Operated Mechanism
  - Mounted on transfer cask
  - Also used to remove or replace lower shield plug




**6” Grayloc flange & locking mechanism**

# Transfer Cask Upper and Lower Connections

- Maintain Well Control Pressure Envelope
- Lubricator and Grease Tubes Optional



# DBFT Engineering Overview: Summary and Status

- Conceptual Design Complete
  - Wireline emplacement/retrieval
  - Test packages + instrumentation package (6-axis motion)
  - Electromechanical release and impact limiters
  - Surface handling/transfer system (mockup where appropriate)
  - Well control capability
- Engineering Services Contractor
  - Preliminary and final design (FY17+)
  - Fabrication and testing (FY18)
  - Integrated Test Facility (FY19)
  - DBFT field demonstration (FY19)

***"A practical concept that will work"***