



Deep Borehole Disposal Engineering

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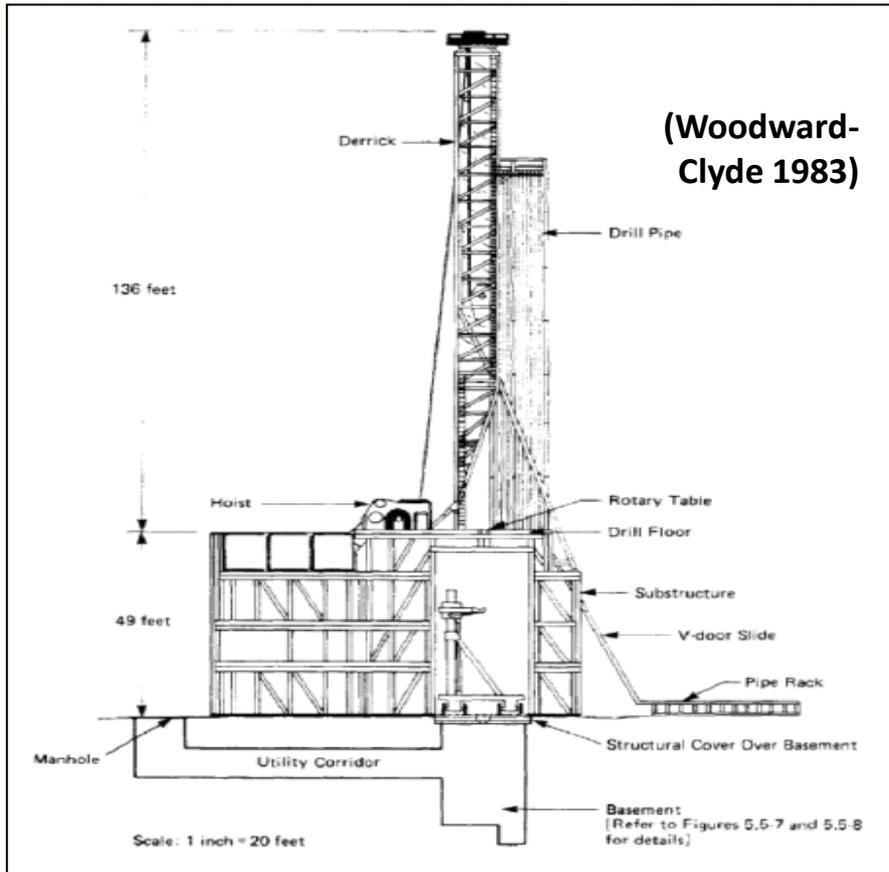
**UFD Annual Working Group Meeting – UNLV
June 10, 2015**

Outline

- **Borehole Emplacement Concepts**
- **Deep Borehole Field Test Engineering Design Study**
- **Borehole Environment**
- **Disposal Overpack/Waste Package Design Concepts**
- **Safety of Disposal Operations**
- **Disposal Borehole and Overpack Size Tradeoffs**
- **Waste Canister – Overpack Design Interface**
- **DBD Requirements Flowdown to DBFT**
- **Q&A**

Deep Borehole Disposal Alternative Emplacement Concepts*

Drill-String Emplacement



Wireline Emplacement

Coiled Tubing

(www.stewartandstevenson.com)



Electric Wireline

(www.wellservicingmagazine.com)



* Workover rig needed for borehole sealing and plugging

Deep Borehole Field Test Engineering Design

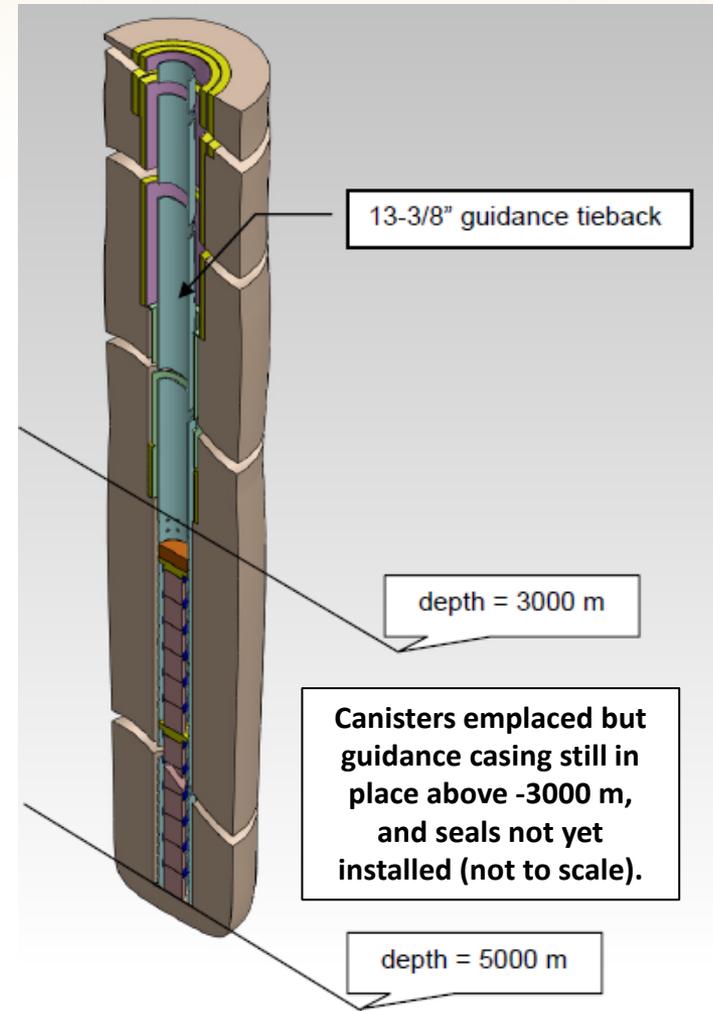
- **Conceptual Design FY15**
 - Conceptual Design Report
 - Placement Option Description
 - Hazard/Risk Analysis
 - Costing
 - Overpack/Package Concepts
 - Placement Mode Selection
- **Final Design FY16**
 - Design Package
 - Design, Fabrication Specs.
 - Safety Manual, Procedures, Testing
 - Transport Cask Integration
- **Fabrication/Testing FY17**
- **Field Implementation FY18-19**

**Engineering Services
Contractor Support**

**Additional
Procurement**

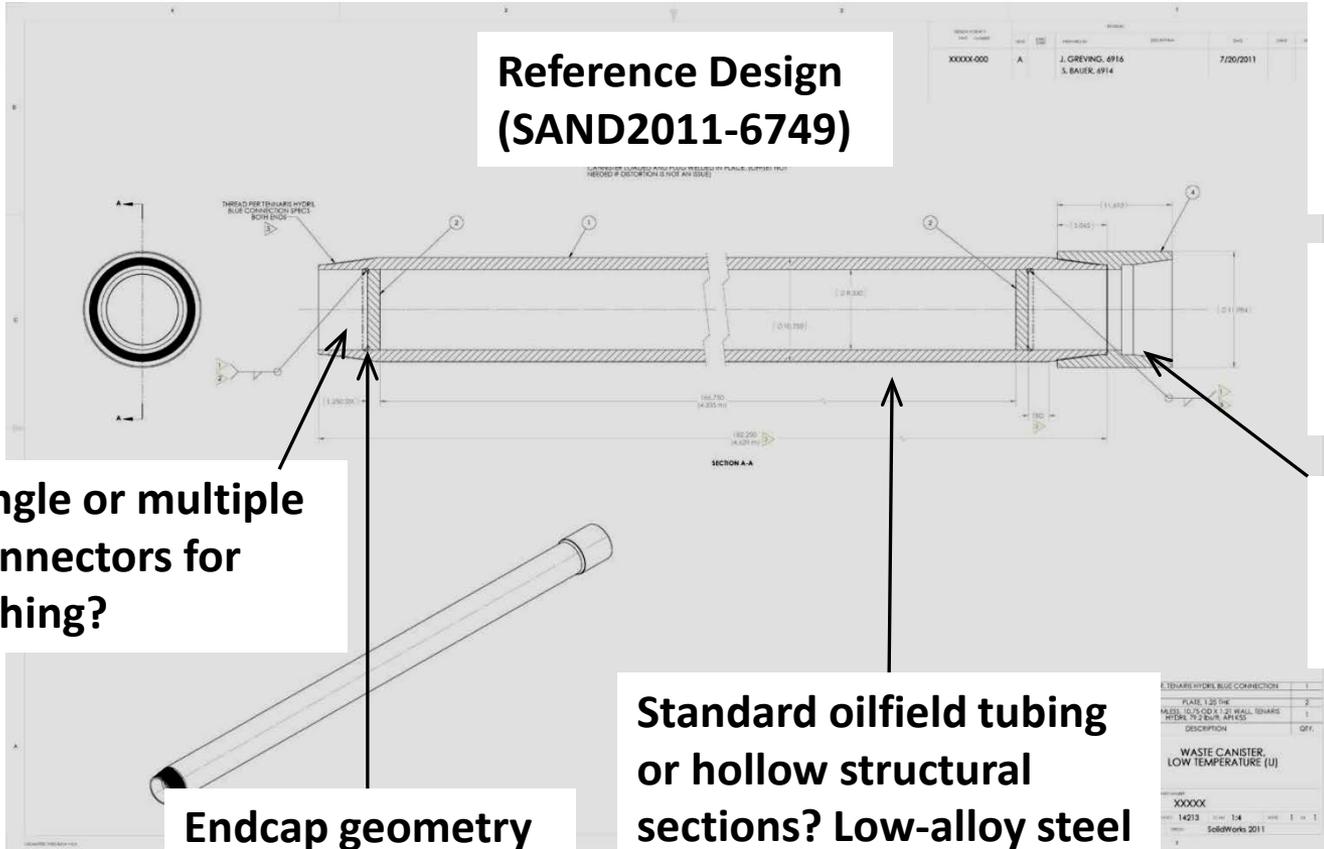
Borehole Environment

- **Thermal**
 - 170°C background (+/-)
- **Hydrologic**
 - 9.6 ksi downhole pressure with 1.3× borehole fluid
- **Mechanical**
 - Steel liner from surface
- **Chemical**
 - Chloride brine
- **Longevity of Construction and Packaging Materials**
 - Nominally ≤ 10 years



Deep Borehole Disposal Disposal Overpack Design Questions

Reference Design
(SAND2011-6749)



Factor of safety?
Oilfield tubulars ≤ 1.66
Gas pipelines ≤ 2.0
(49CFR192)
Hydraulics = up to ~ 4

Post-emplacment
containment
lifetime?

Separate connectors
or welded box/pin
ends?

Standard oilfield tubing
or hollow structural
sections? Low-alloy steel
or higher strength (e.g.,
forged, smaller t/D) for
more disposal volume?

Endcap geometry
pressure rating?
Credit threaded
connections?

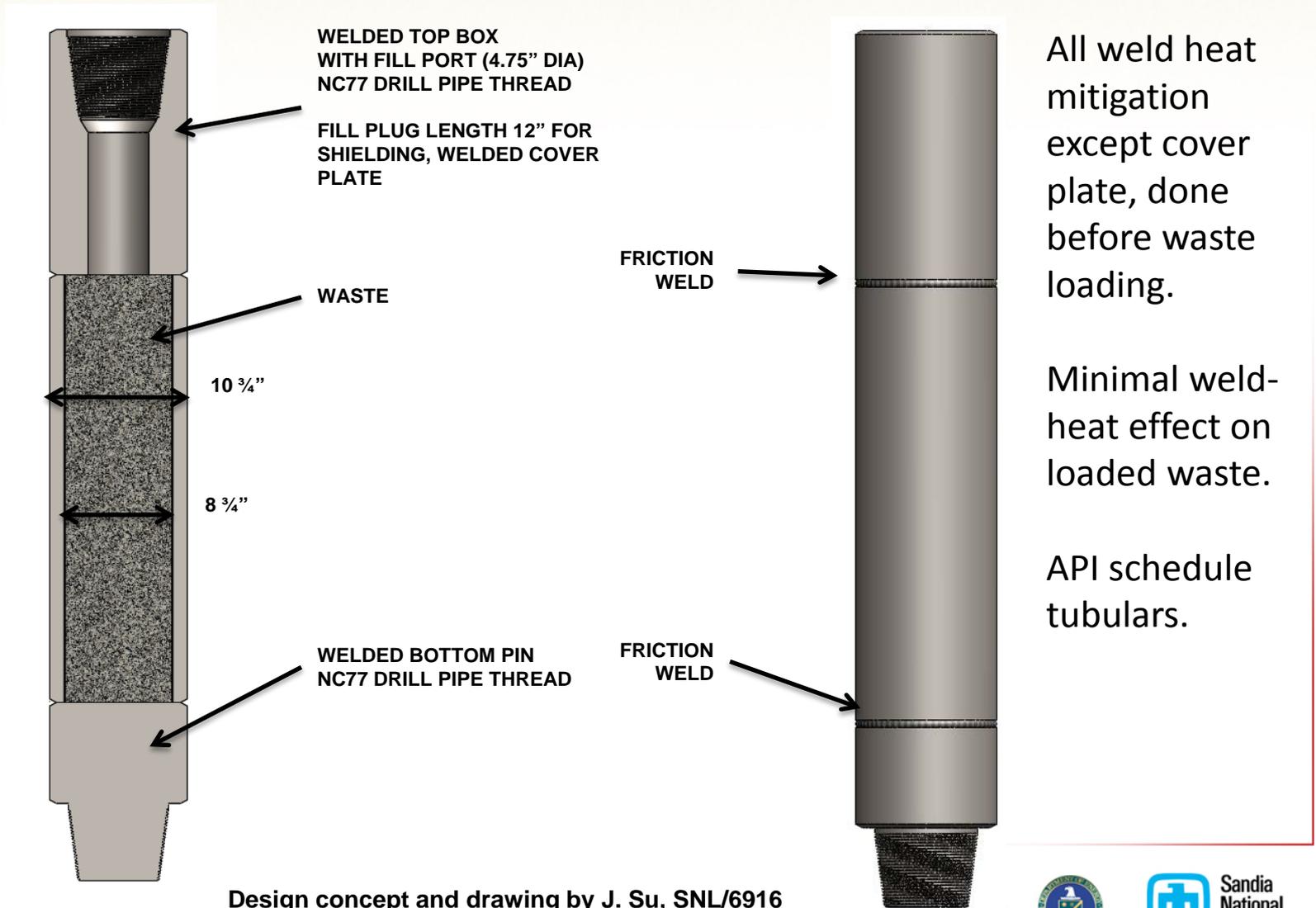
Single or multiple
connectors for
fishing?

Overpack/Package Conceptual Design

- **Same concepts for wireline and drill-string emplacement**
- **Axial load ~150,000 lb (tensile, compressive)**
- **Bending stresses**
- **Provision for fishing**
- **Requirement: factor of safety ≥ 2.0**
- **Terminology**
 - Canister – Thin-wall sealed (stainless) vessel
 - Disposal Overpack – Heavy container for canistered wastes
 - Waste Package – Heavy container for bulk wastes
 - Examples (Cs/Sr capsules, DOE/EM bulk wastes, SNF)

Option #1 Waste Package – Flask Type

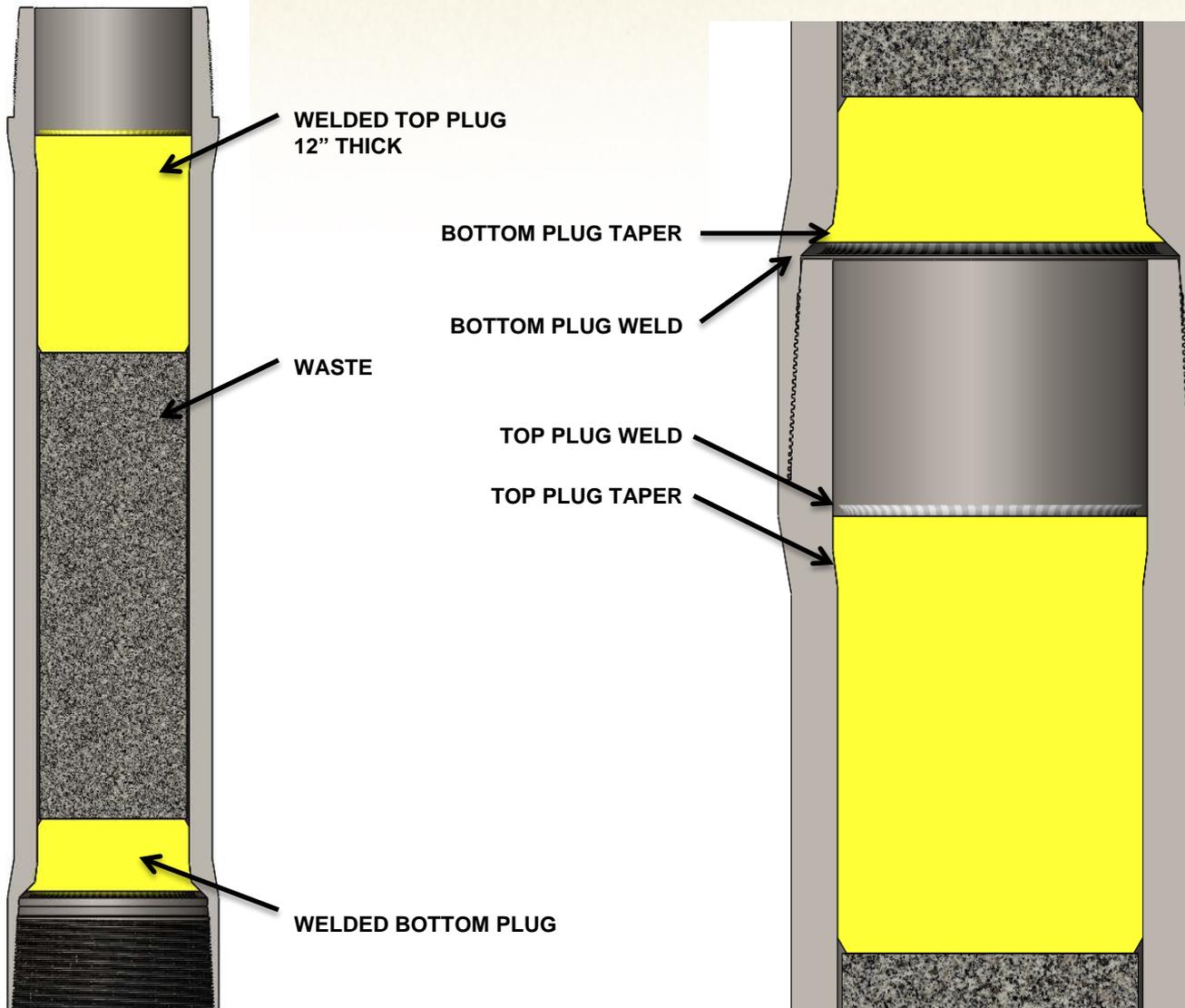
Reference size 10.75" max. OD



Design concept and drawing by J. Su, SNL/6916

Option #2 – Bulk Waste Overpack

Reference size 11" max. OD



Internal-flush design for canistered waste forms.

No fabrication welds in axial load path.

External upset (forged) connections.

Possible weld-heat effect on loaded waste.

Novel taper/weld sealing design.

API schedule tubulars.

Design concept and drawing by J. Su, SNL/6916

Option #4 Cs/Sr Capsule Overpack

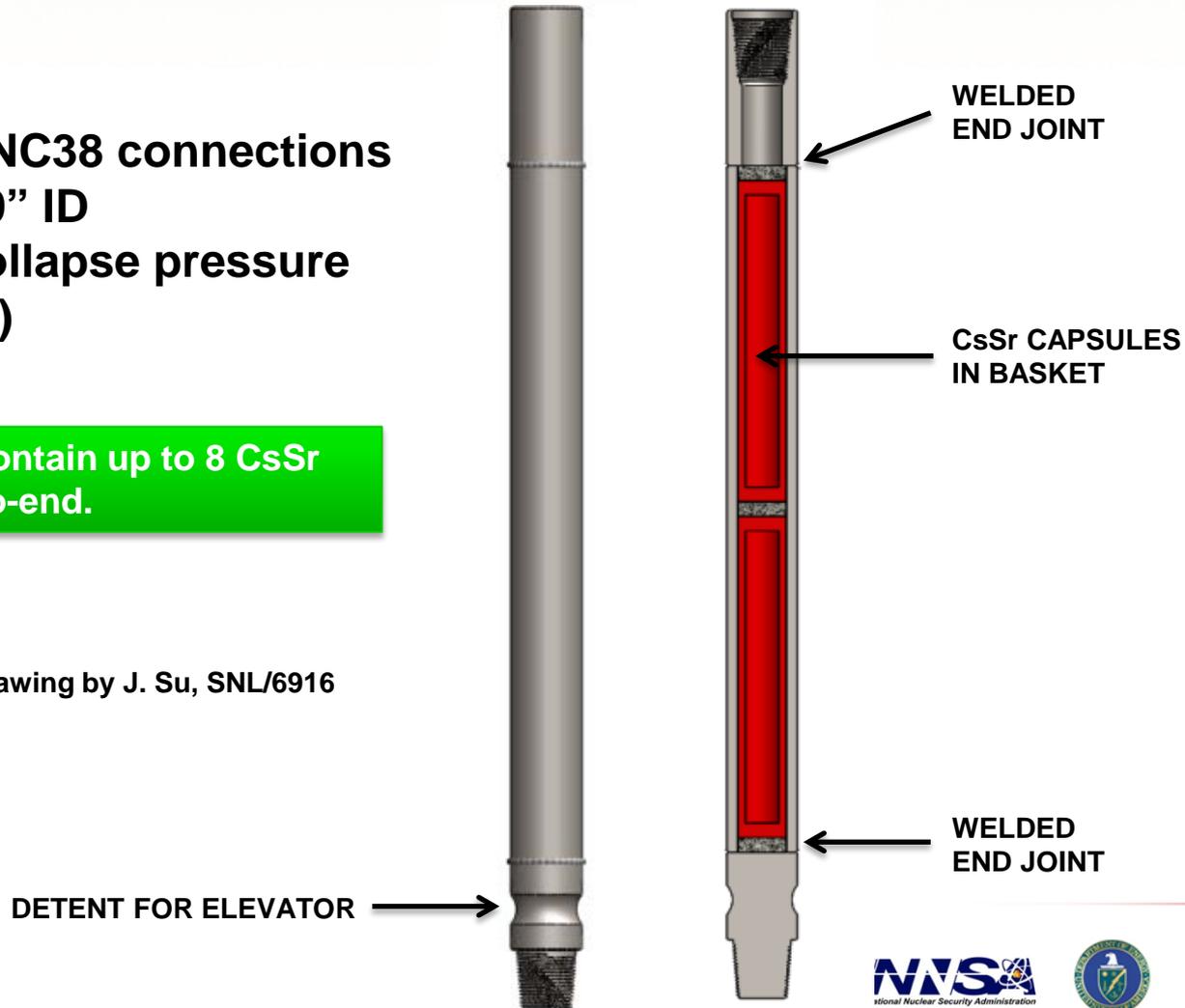
Reference size ~5" OD

Flask-type for loading the majority of capsules (2.6" OD)

- Welded API NC38 connections
- 5.0" OD x 4.0" ID
- 19,800 psi collapse pressure
- (Not to scale)

Canister may contain up to 8 CsSr capsules end-to-end.

Design concept and drawing by J. Su, SNL/6916



Overpack/Package Design Concepts Summary

#	Application	Cost	Pros	Cons
1	Large canister bulk waste (smaller version for 3-capsule bundles)	~\$10k for body	External flush Standard API thread Post-weld heat treatment	Welds in axial load path Flask-type waste loading limitations
2	Large canister bulk waste (smaller version for 3-capsule bundles)	TBD	External upset (strong) No welds in axial load path	External upset tubing hard to find (Tenaris) Sealing weld after waste loading
3	Large canister bulk waste/3 capsule groups	TBD	External semi-flush No welds in axial load path	Lower collapse pressure Smaller OD, less waste volume Custom mill run Sealing weld after waste loading
4	Stacked Cs/Sr capsules (2.6" OD) in canister or basket	TBD	External flush Standard API thread Post-weld heat treatment	Welds in axial load path Flask-type waste loading limitations
5	Stacked Cs/Sr capsules (2.6" or 3.3" OD) in canister or basket	TBD	External flush No welds in axial load path	Custom mill run Sealing weld after waste loading

Deep Borehole Disposal Waste Canister – Overpack Design Interface

- **Physical Environment for Waste Canisters (size, weight, temperature)**
- **Shielding Requirements for Waste Forms**
- **Transportation Effects (remote disposal locations)**
- **Overpack Closure Welding**
- **Other Possible Interface Specs.**
 - Canister handling features (e.g., grapple for loading)
 - Material compatibility
 - Waste heat generation
 - Canister fillers
- **Waste and Environment Data for Postclosure PA**

Safety of Disposal Operations

- **DB Field Test vs. Potential Future Disposal System**
 - DBFT will have zero radiological risk
- **Accident Prevention During Emplacement Operations**
 - DBFT engineering: safety analysis of emplacement that discriminates between alternative emplacement concepts
- **Downhole Failure Modes/Accidents (disposal system)**
 - Single canister drop in borehole (zero consequence?)
 - Pipe string + waste packages drop in borehole
 - Pipe string drop onto canister(s)
 - Canister leak/crush
 - Fishing operations (pipe string or wireline)
 - External hazards (seismic, extreme weather; potentially significant to selection of emplacement mode?)

Disposal Borehole and Overpack Size Tradeoffs

Borehole and Canister Sizes >>>>	Small	Medium	Reference	Large
Waste per Canister >>>>	2 to 8 capsules end-to-end	3-capsule groups stacked ≤ 8 high	Bulk	Bulk
Disposal Zone Hole Diameter	8.5"	12.3"	17"	22"
Disposal Zone Casing ID	6.4"	9.8"	12.6"	17.4"
Disposal Overpack OD	5"	8.5"	11"	16"
Disposal Overpack ID	4"	6.5"	8.5"	12"
Avail. Disposal Volume/Borehole (ft ³)	460	1220	2,090	4,170
Disposal Canister Length (ft)	3.9 to 15.6	3.9 to 15.6	16.7	16.7
Canister Capacity	2 to 8 capsules	6 to 24 capsules	5.2 ft. ³	10.4 ft. ³
# Waste Packages/Disposal Zone	968 to 242	323 to 81	400	400
Capsule Disposal Interval Height	~4,500 ft *	~1,500 ft *		
Drilling/Completion Costs (\$M)	< 20 *	< 25 *	40	60
Borehole Cost/Disposal Vol. (\$k/ft ³)	< 40 *	< 26 *	19	15
	(\$/in ³)	< 23 *	11	8

* Capsule disposal intervals are less than the length of 2 km (6,560 ft) used for borehole cost estimation, so borehole costs would be less.

DBD Flowdown to DBFT Requirements (1/6)

Waste Disposal Requirement	Deep Borehole Field Test Requirement
1.1 Industrial Safety and Health	
1.2 Radiological Protection	
<p>Radiation Exposure to Workers and the Public – Waste package loading, welding/sealing, handling, transport, emplacement, and retrieval equipment and operations shall comply with applicable radiological dose standards (e.g., 10CFR20). Engineered systems shall maintain exposures ALARA.</p>	<p>Radioactive Materials – Radioactive sealed sources used for well logging shall be removed from the site. No other designated radioactive materials or wastes will be used in the DBFT.</p> <p>Test Design to Demonstrate Radiological Protection Capability – DBFT waste package handling, emplacement, and retrieval shall demonstrate that radiation exposure to workers could be effectively limited.</p>
1.3 Safeguards and Security Requirements	
1.4 Quality Assurance Requirements	

DBD Flowdown to DBFT Requirements (2/6)

Waste Disposal Requirement	Deep Borehole Field Test Requirement
1.5 Other Statutory and Regulatory Requirements	
1.6 Functional Requirements	
1.7 Operating Requirements	
	...
	<p>Material Control – Materials used in the Characterization and Field Test Boreholes shall be restricted to those on a list maintained by the Project Manager.</p>
	<p>Material Inventory – Materials used in the boreholes shall be logged, recording type, quantity, date of use, location of use, and manner of introduction.</p>
	<p>Water Tracer – All water (including makeup water for mud or cement) that is used in subsurface operations or otherwise introduced to the DBFT boreholes, will be tagged with a conservative tracer that is selected so that the presence of such water can be appropriately quantified in any fluid samples recovered for analysis.</p>
	...

DBD Flowdown to DBFT Requirements (3/6)

Waste Disposal Requirement	Deep Borehole Field Test Requirement
1.8 Performance Criteria	
...	...
Disposal Borehole Service Life – Borehole construction and completion shall be designed with service lifetime of 10 years, for safe disposal operations and sealing.	Field Test Borehole Service Life – Design service lifetime of the Characterization and Field Test Boreholes shall be 10 years, considering casing corrosion, creep, and other significant degradation processes.
...	...
1.9 Borehole Design and Construction	
...	...
Borehole Deviation – Waste disposal borehole(s) shall be constructed so that: 1) horizontal lineal deviation does not exceed 50 m; and 2) maximum dogleg severity specifications are met (Table 2).	Borehole Deviation – The Characterization Borehole and Field Test Borehole shall be constructed so that: 1) horizontal lineal deviation does not exceed 50 m; and 2) maximum dogleg severity specifications are met (Table 2).
...	...

DBD Flowdown to DBFT Requirements (4/6)

Waste Disposal Requirement	Deep Borehole Field Test Requirement
1.10 Waste Packaging Requirements	
...	...
<p>Disposal Zone Pressure – Waste packages shall perform in borehole fluid with minimum pressure from pure water and borehole depth, and maximum pressure TBD.</p>	<p>Test Disposal Zone Pressure – Test waste packages shall perform in borehole fluid with minimum pressure from pure water and borehole depth and maximum pressure for with maximum fluid density (Table 2).</p>
<p>Waste Package Factor of Safety – Minimum FoS for mechanical integrity calculations will be based in part on DBFT results and is TBD.</p>	<p>Test Waste Package Factor of Safety – Minimum FoS for mechanical analysis shall be 2.0 with respect to elastic/plastic analysis with idealized geometry.</p>
...	...

DBD Flowdown to DBFT Requirements (5/6)

1.11 Waste Package Emplacement and Retrieval	
...	...
(The need for wellhead blowout prevention equipment in waste disposal boreholes is TBD.)	Field Test Wellhead Preventer – Test waste package emplacement and retrieval shall be configured so these operations can be performed with a blowout preventer stack.
Emplacement System Redundancy – Emplacement system shall have redundant means for holding packages and/or drill pipe so that single-point failures cannot result in drops.	Emplacement System Redundancy – Emplacement system shall have redundant means for holding packages and/or drill pipe so that single-point failures cannot result in drops.
...	...

DBD Flowdown to DBFT Requirements (6/6)

1.12 Borehole Sealing	
1.13 Characterization Testing	
...	...
<p>(Testing, logging, sampling, and other data collection requirements for disposal boreholes are TBD.)</p>	<p>Safety Basis for Testing – Testing, logging, sampling, and other data collection shall be directly linked to the deep borehole disposal safety case.</p>
	<p>Testing Baseline – Testing, logging, sampling, and other data collection, and the disposition of samples, shall be specified in a testing baseline.</p>
	<p>Test Interference – Surface and subsurface testing activities shall be evaluated prior to deployment to determine whether they may significantly interfere with other testing activities.</p>

DBD Flowdown to DBFT Requirements (6/6)

Controlled Design Assumptions	
...	...
(Leakage control requirements for waste packages during operations are TBD.)	Test Waste Package Failure – For testing, package failure is defined as loss of control (e.g., dropping) of package(s) in the borehole, or dropping of drill pipe on one or more packages in the borehole.
(The need for directional drilling for disposal boreholes is TBD, and could be based on experience with drilling and construction of characterization borehole(s) at a future disposal site.	Dogleg Severity/Directional Drilling – Dogleg severity will be limited to 2°/100 ft in the top 1,000 m of the Characterization and Field Test Boreholes, and to 3°/100 ft below that (see deviation requirement).
(Maximum density of borehole fluid when loaded waste packages are present is TBD.)	Borehole Fluid Maximum Density – Borehole fluid density is assumed to be less than or equal to 1.3 of the pure water at in situ conditions.
...	...

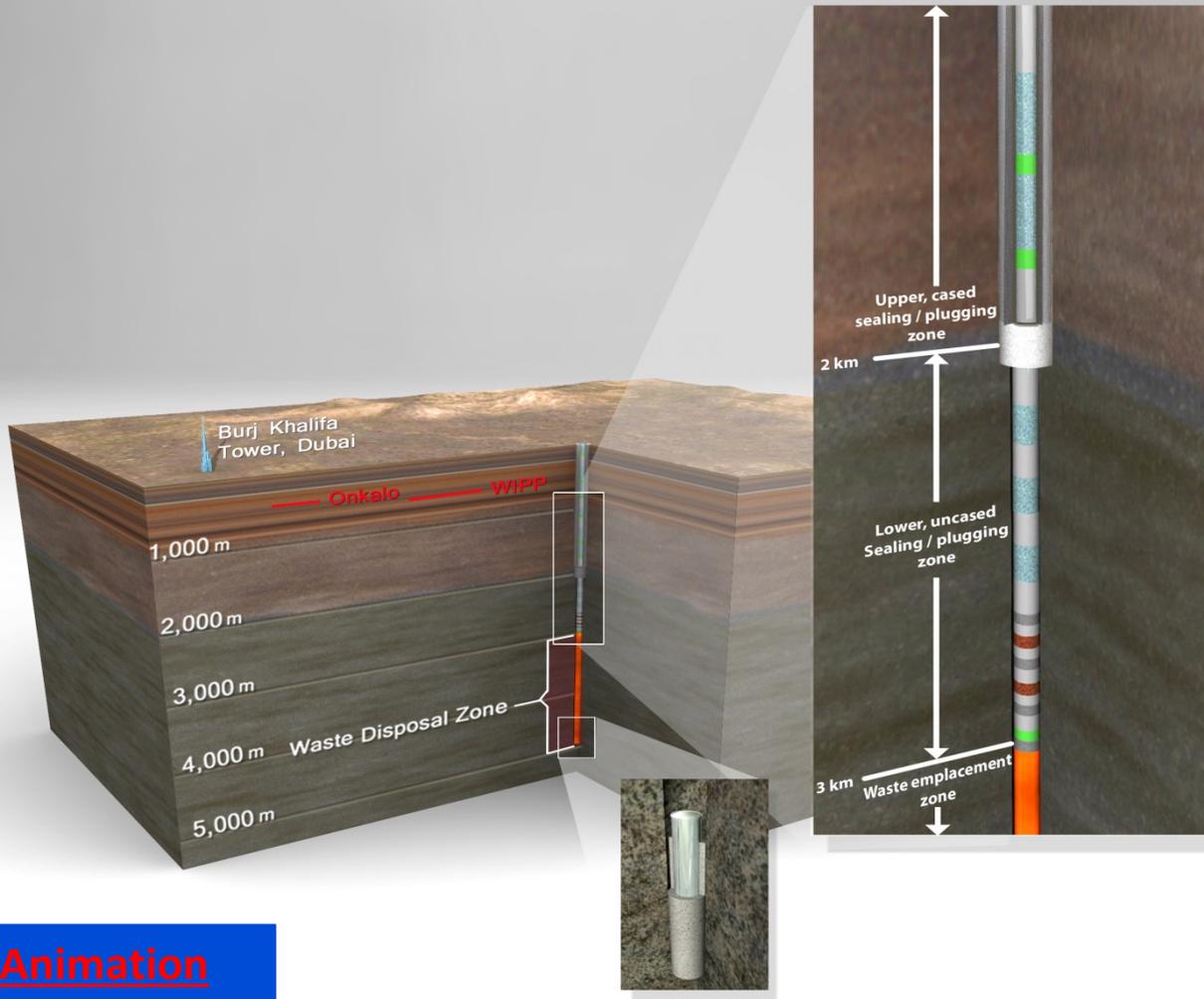


Backup

Cs/Sr Capsules

	Count	Outer Dia. (in.)	Length (in.)	Outer Matl.	Capsule heat (2025)	
					Avg. (W)	Max. (W)
Cs Capsules	1312	2.6	20.8	316L SS	95	129
Cs Capsules (overpacked)	23	3.3	21.8	316L SS	78	105
Sr Capsules	600	2.6	20.1	316L SS or C-276	127	333

Deep Borehole Disposal Concept



Animation

