HIGH-LEVEL WASTE GLASS AND OTHER DISPOSITION OPTIONS FOR ^{233}U

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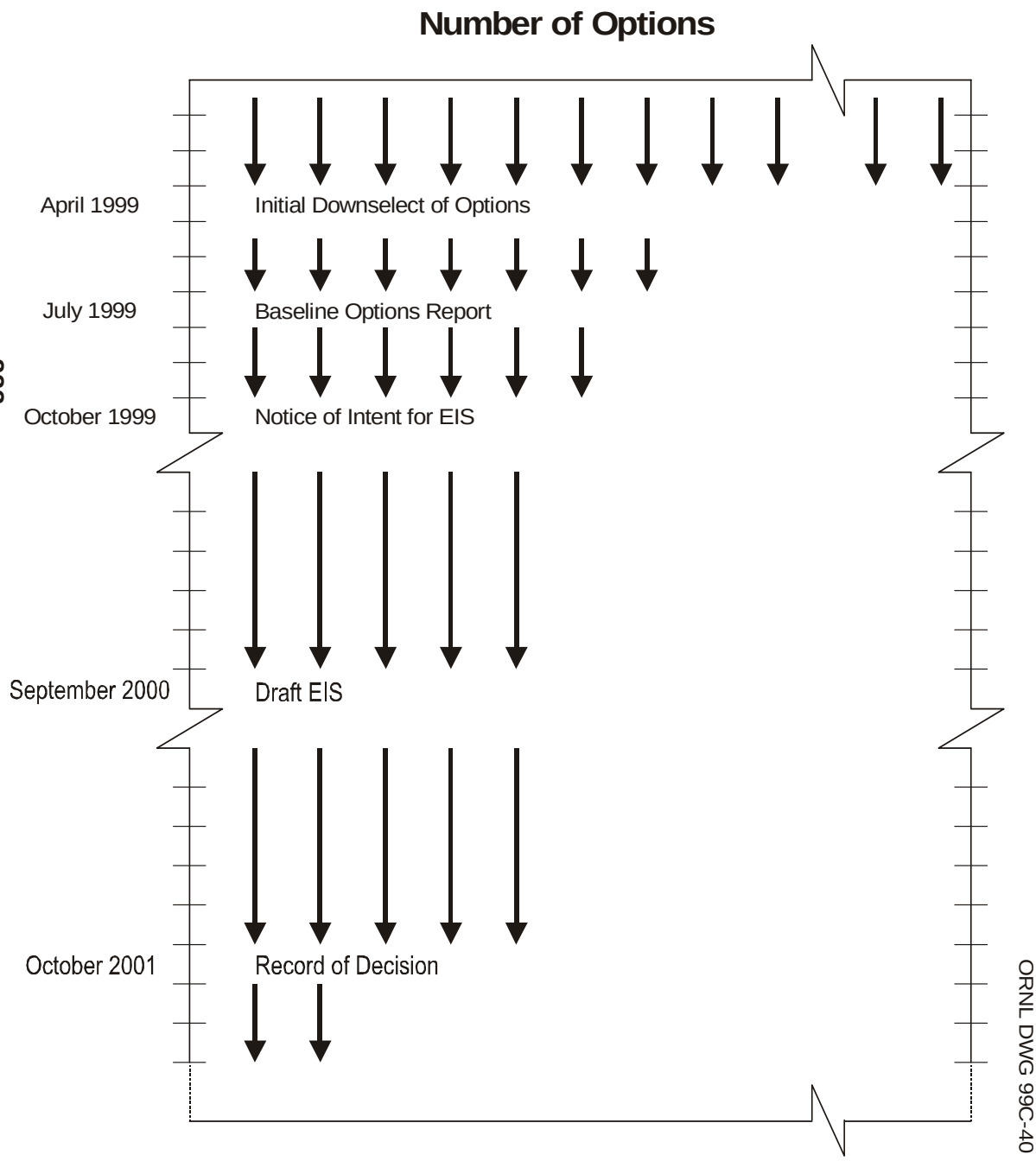
Outline

- Why relevant to the Hanford site?
- Generic issues and constraints
- Characteristics and inventory of ^{233}U
- Disposition selection criteria
- Disposition options (disposal and storage)
- Disposition in high-level waste (HLW) tanks
- Hanford ^{233}U disposition issues to be addressed

The Disposition Of ^{233}U May Impact The Hanford Site

- The U.S. Department of Energy (DOE) is examining options for disposition of ^{233}U
- For some disposition options, the Hanford HLW tanks have unique characteristics that aid ^{233}U disposition
- DOE must determine whether the use of the Hanford HLW tanks for ^{233}U disposition is realistic (technically, economically, and institutionally)
  - Hanford site input is critical for such determination
  - Issue is complex
- With the current schedule, the notice of intent for an environmental impact statement would be issued in January 2002—about 20 months from now
- The schedule could accelerate or deaccelerate



Internal ^{233}U Disposition Program Schedule

There Is Significant Schedule Uncertainty

- Factors accelerating program
  - Defense Nuclear Facility Safety Board Recommendation 97-1 (safe store ^{233}U)
  - High-cost to repackage ^{233}U
- Factors deaccelerating program
  - No decision on how much ^{233}U should be kept for future use
  - Budget limitations

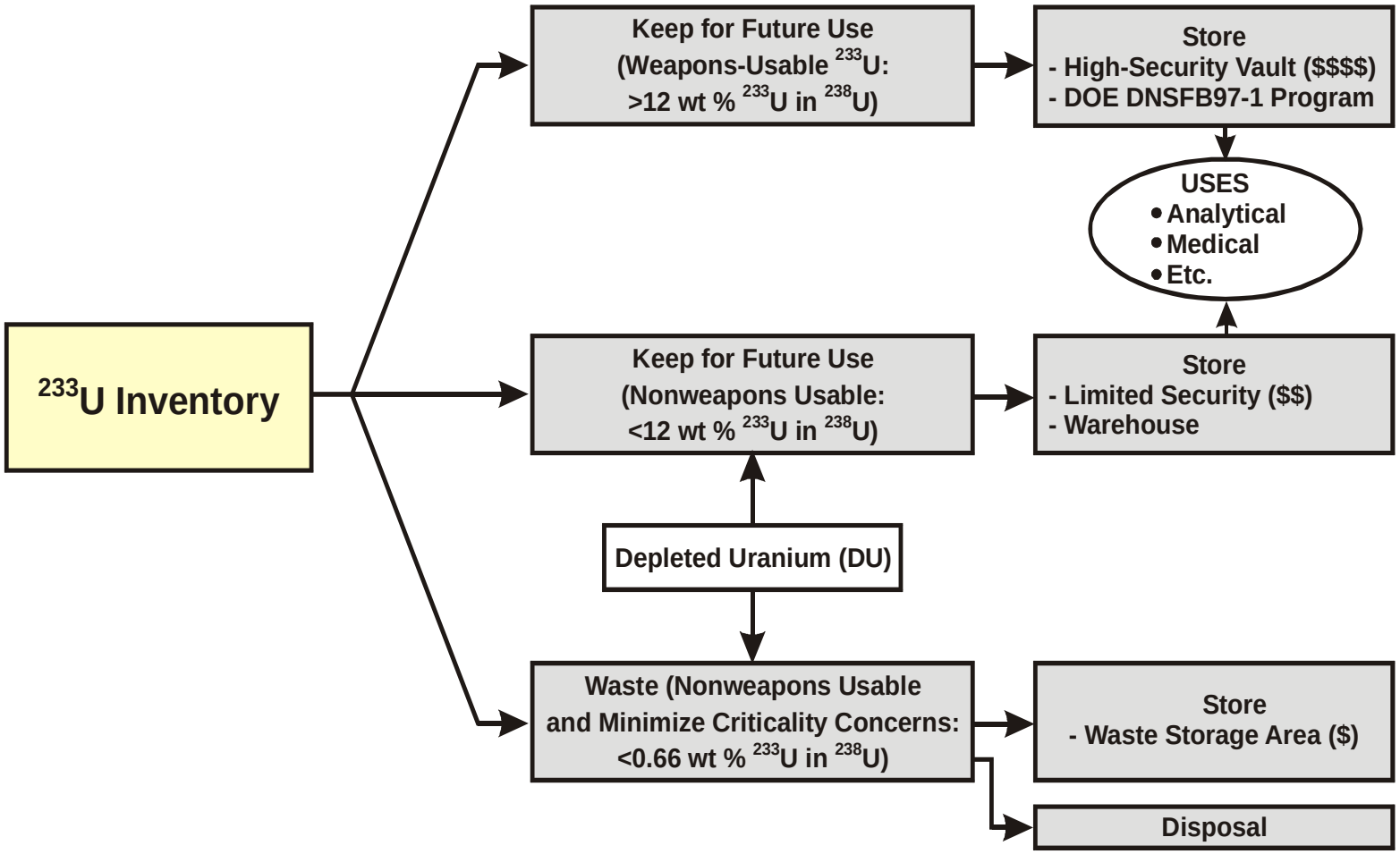
Generic Issues And Constraints

DOE's Office Of Fissile Materials Disposition (MD) Program* Has Two Objectives

- Convert excess weapons-usable fissile materials to non-weapons usable fissile materials (part of the U.S. arms control strategy)
  - Isotopic dilution to <12 wt % ^{233}U in ^{238}U meets this goal
  - Most options use isotopic dilution to convert weapons-usable ^{233}U to nonweapons-usable ^{233}U
- Manage excess fissile materials after disposition
  - Store for future use as non-weapons usable material
  - Dispose as waste

*Martin Newdorf is the headquarters DOE/MD program manager for ^{233}U disposition.

ORNL DWG 98C-23



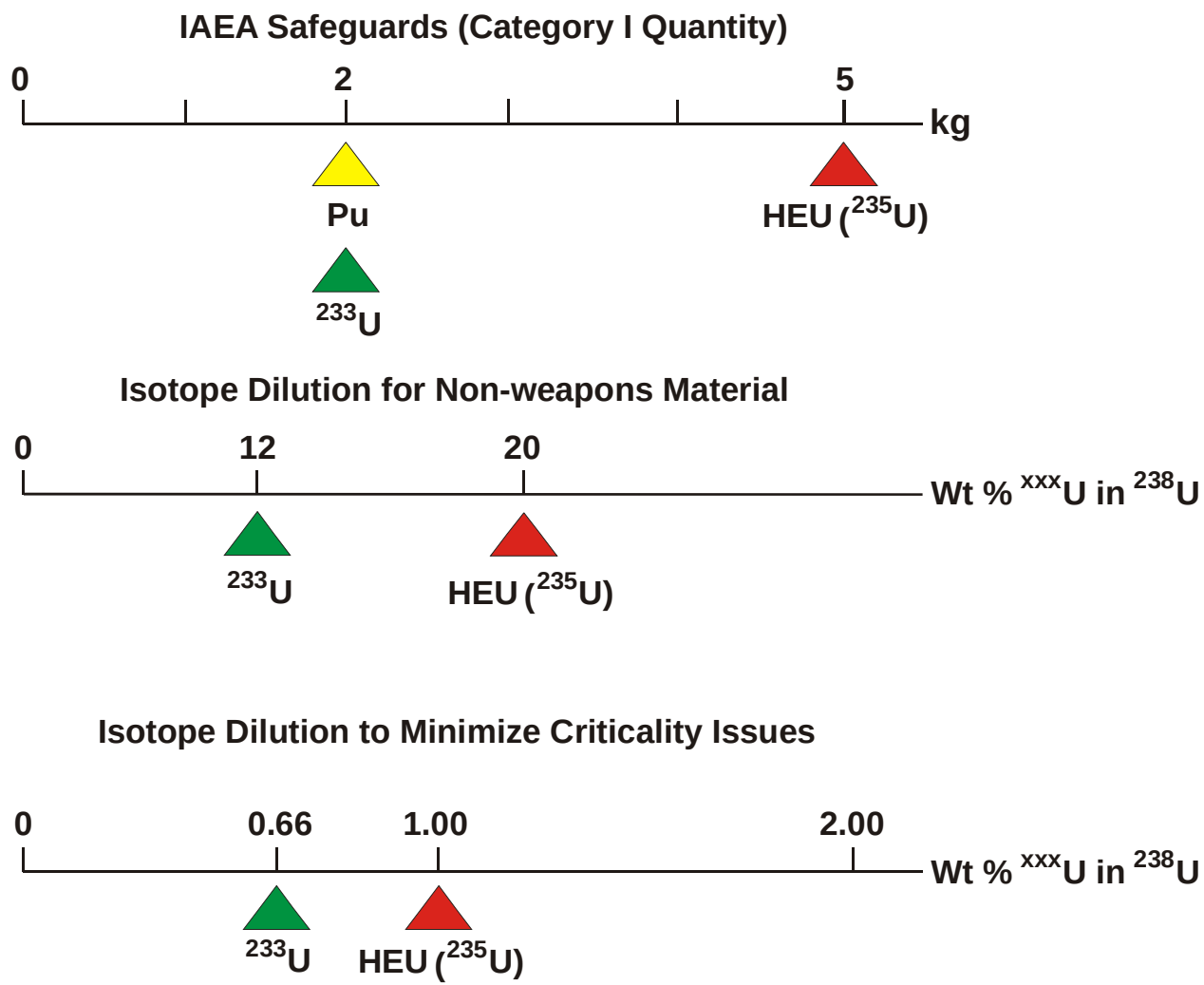
Long-Term Management Options for ^{233}U (Similar to HEU Strategy)

The Program Activities For ^{233}U Include Several Tasks

- Identify disposition options for ^{233}U
- Analyze options (17 identified) and select viable options for further evaluation
- Characterize and define down select options (economics, schedule, institutional evaluation, etc.)

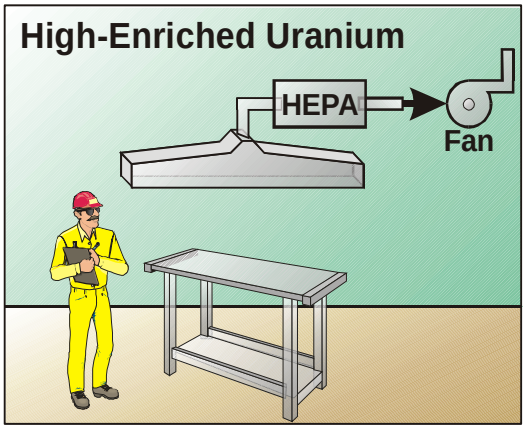
Characteristics And Inventory Of ^{233}U

ORNL DWG 98C-476

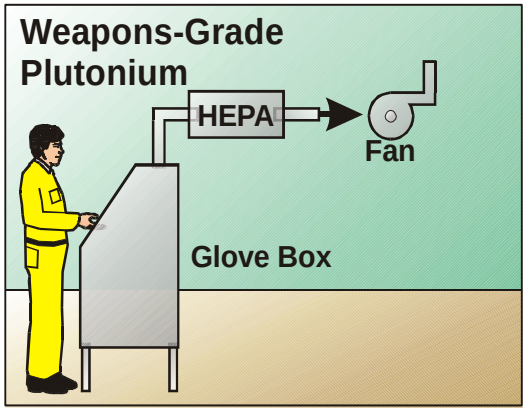


Nuclear Characteristics of Fissile Materials

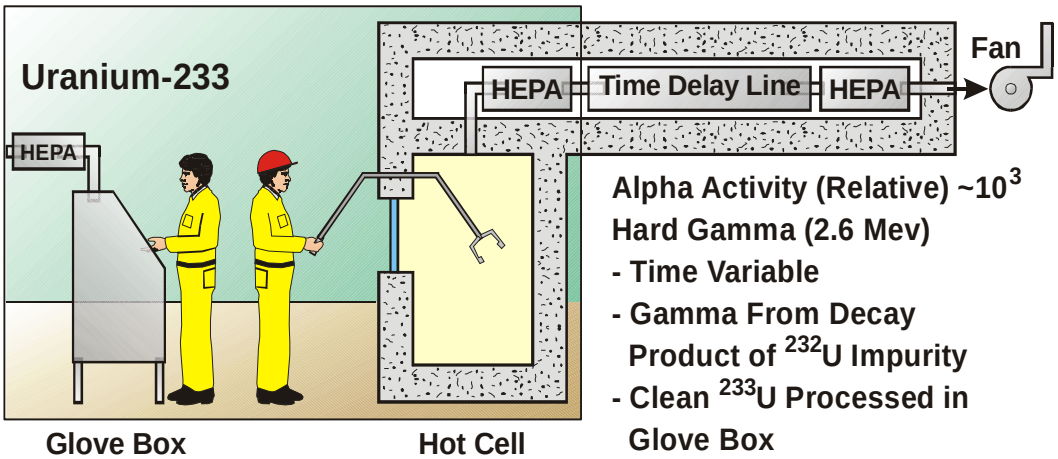
ORNL DWG 98C-488R



Alpha Activity (Relative) = 1
No Significant Gamma

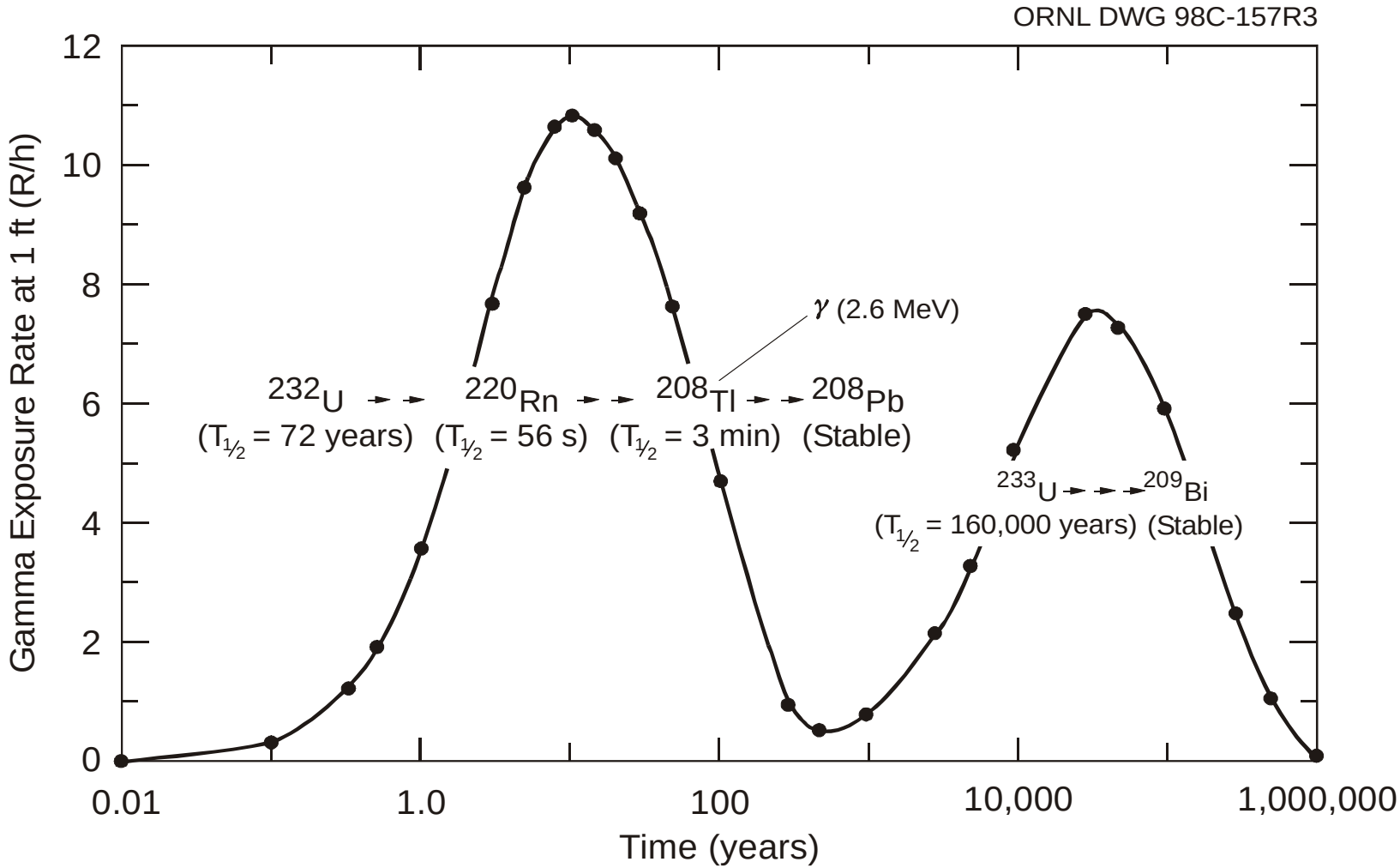


Alpha Activity (Relative) ~10^4
Soft Gamma
- Minimal Shielding
- Leaded Gloves Acceptable



Alpha Activity (Relative) ~10^3
Hard Gamma (2.6 Mev)
- Time Variable
- Gamma From Decay Product of ^{232}U Impurity
- Clean ^{233}U Processed in Glove Box

Different Fissile Materials Have Different Handling Requirements



Gamma Exposure for 1 kg ^{233}U with 100 ppm ^{232}U

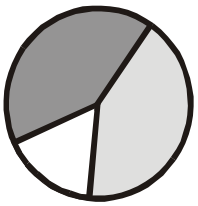
Characteristics Of Weapons-Usable Materials

Characteristic	Fissile material		
	Plutonium	High-enriched uranium (HEU)	^{233}U
Production	Neutron bombardment of ^{238}U	Separation from natural uranium	Neutron bombardment of ^{232}Th
International Atomic Energy Agency weapons Category I quantity (kg)	2	5	2
Isotopic dilution limit for nonweapons[a]	None	20 wt %	~12 wt %[a]
Isotopic criticality safety limit[b]	Not applicable	1 wt %	0.66 wt %
Chemical properties	Plutonium	Uranium	Uranium
Radiation			
Alpha (relative to HEU)	10^4	1	10^3
Gamma	Low	Low	Dependent upon ^{232}U impurity
Containment	Glovebox	Laboratory hood	Glovebox/shielded hot cell

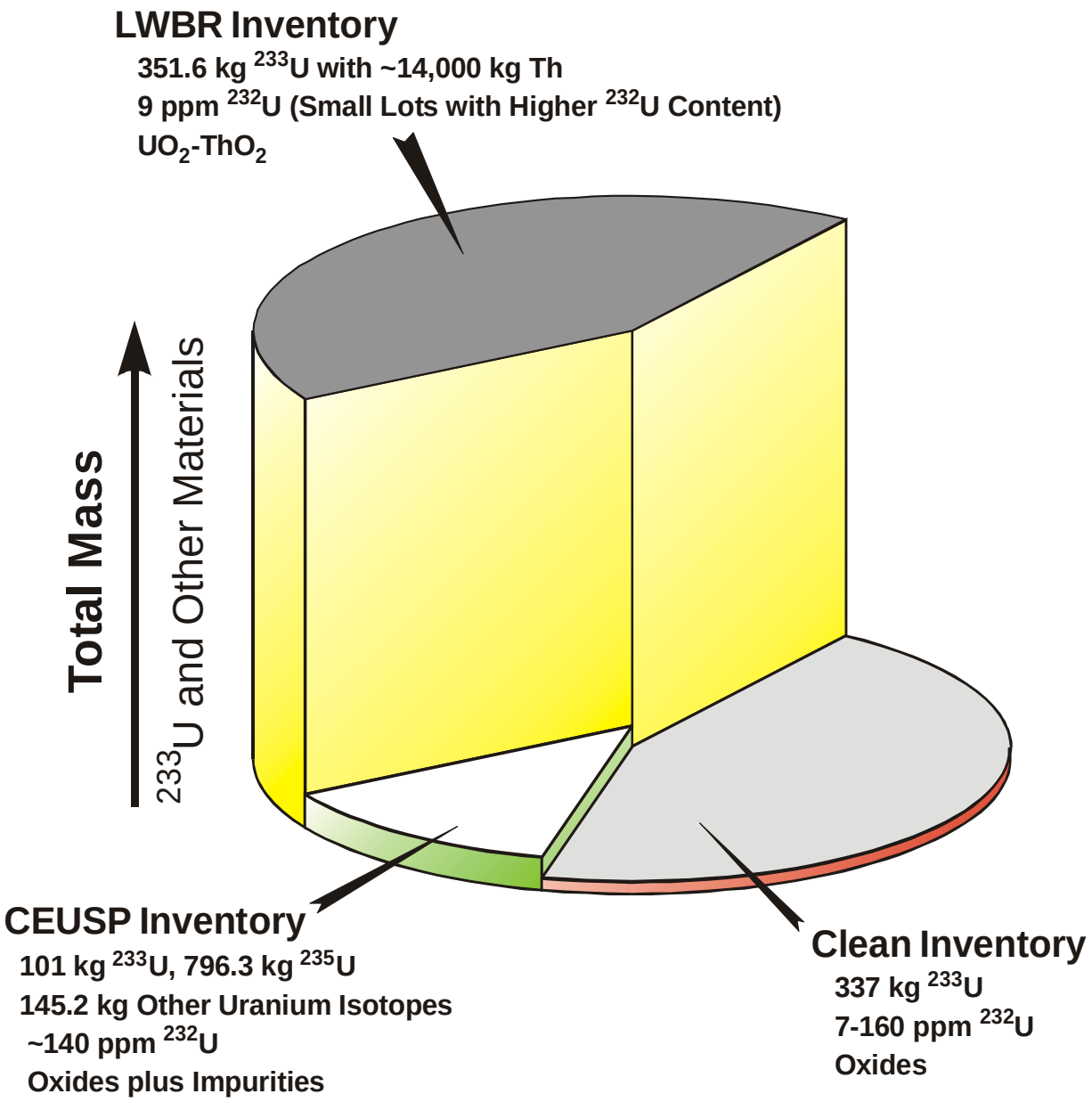
[a]The 12 wt % ^{233}U in ^{238}U is based on a technical study (Forsberg March 1998). However, neither U.S. nor international regulations explicitly address the required isotopic dilution of ^{233}U with ^{238}U to convert ^{233}U to nonweapons-usable ^{233}U.

[b]Isotopic dilution of ^{233}U and HEU with ^{238}U to these limits minimizes the potential for nuclear criticality in disposal facilities.

ORNL DWG 98C-432R



Top Area of Cylinder α ^{233}U Inventory



United States Uranium-233 Inventory

The Existing ^{233}U Inventory Can Be Divided Into Three Major Categories: Clean, Consolidated Edison Uranium Solidification Program (CEUSP), And Light-Water Breeder Reactor (LWBR) ^{233}U

- **Clean ^{233}U**
  - ~340 kg of clean ^{233}U that are primarily oxides
  - Variable-impurity levels of ^{232}U
- **CEUSP ^{233}U**
  - ~1,040 kg of uranium in oxide form
  - Unusual uranium isotopics: ~10 wt % ^{233}U, 76 wt % ^{235}U, high ^{232}U content (140 ppm), and other uranium isotopes
  - Includes the neutron poison, cadmium—A Resource Conservation and Recovery Act metal*—for criticality control
  - Uranium oxide cast as monolith integral with storage package
- **LWBR ^{233}U**
  - ~350 kg of ^{233}U oxide in ~14,000 kg of thorium oxide (ThO_2)
  - High-fired $^{233}UO_2$–ThO_2 pellets

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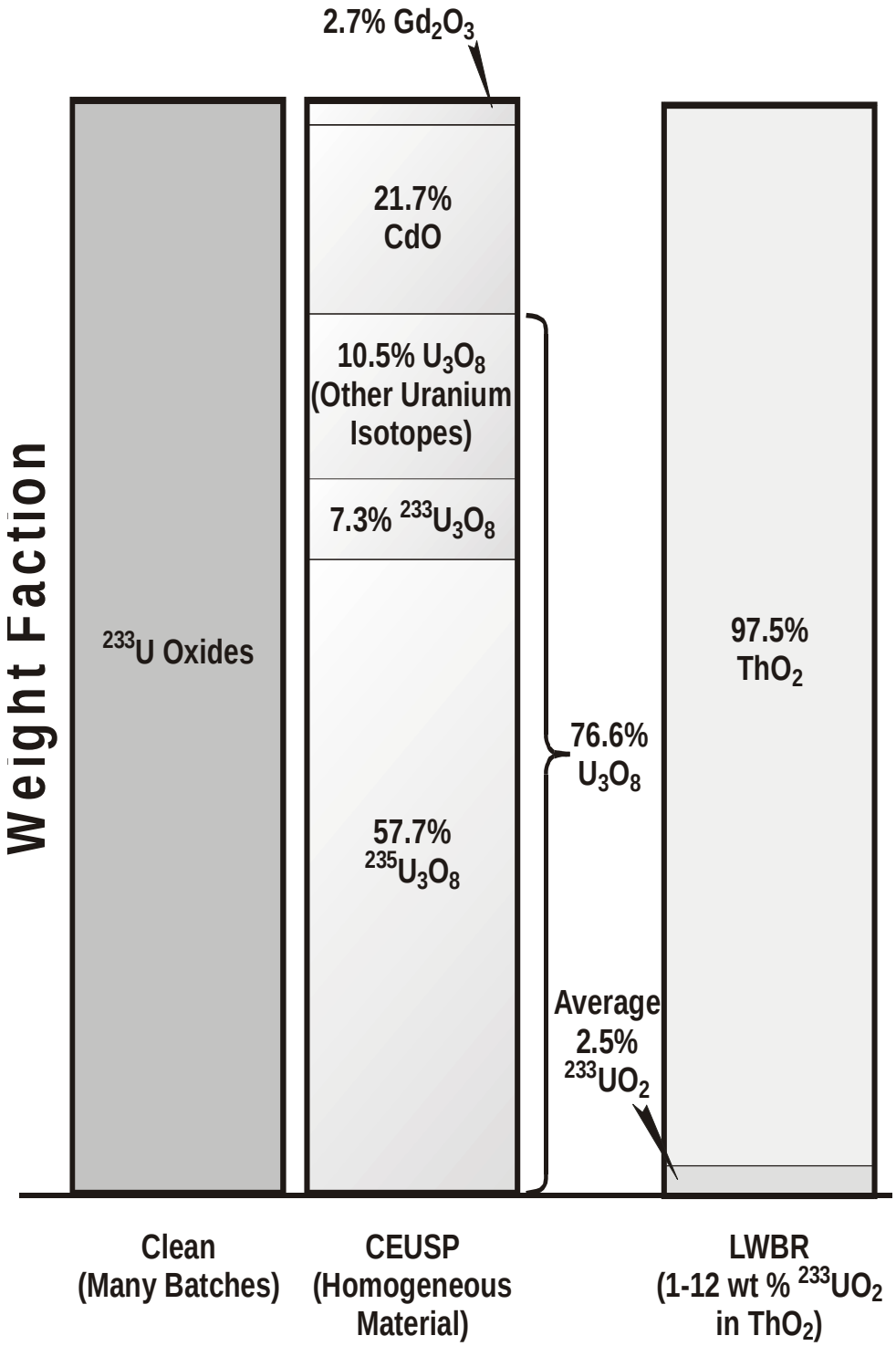
*CEUSP ^{233}U not considered hazardous because cadmium added for useful purpose (criticality control).

ORNL DWG 98C-485R3



Chemical Composition of ^{233}U Inventory

Quality Of Major Batches Of ^{233}U In Inventory[a]

Batch no.	Site	Material and packaging	Total U (kg)	Uranium isotopic composition: ^{235}U (kg)	^{233}U (kg)	^{232}U (ppm)[c]	Measures of quality[b]: Total U (kg)/ ^{233}U (kg)	^{232}U (mg)/ ^{233}U (kg)
CEUSP								
1	Oak Ridge National Laboratory (ORNL)	U_3O_8 monolith in >400 welded stainless steel cans (CEUSP material)	1042.6	796.3	101.1	140	10.3	1400
LWBR								
2	Idaho National Environmental and Engineering Laboratory (INEEL)/Radioactive Waste Management Complex	Unirradiated rods and pellets in 172 drums	35.1	0.00	34.0	21	1.03	21
3	INEEL/Idaho Chemical Processing Plant	Unirradiated LWBR fuel with 14 t natural thorium	323.5	0.00	317.4	9	1.02	8
Clean								
4	ORNL	UO_x powder in 140 welded inner aluminum cans	67.4	0.00	61.3	165	1.1	180
5	ORNL	U_3O_8 monolith in 27 welded stainless steel cans placed in tin-plate cans	65.2	0.00	60.3	15	1.08	16
6	ORNL	UO_x powder in 174 stainless steel screw-top cans	96.6	0.00	91.3	7	1.08	7
7	ORNL	UO_x powder in 1743 welded stainless steel plates	46.2	0.00	45	7	1.03	7
8	Y-12[d]	UO_x powder in 5 cans	42.6	38.70	0.8	6	53.2	6
Remainder	Various	Variety of material forms, packages, and compositions	81.5	<0.1	79.6	<10	1.04	
MSRE								
10	ORNL	Being recovered from MSRE	37.6		31.2	160		

[a]These data do not represent the entire inventory because many small batches are not listed. Estimated total quantity of such batches is <1 kg.
[b]A low number implies higher quality.
[c]Based on ^{233}U content.
[d]The Oak Ridge Y-12 Plant.

Disposition Selection Criteria

Disposition Criteria For ^{233}U

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(1)[a] Resistance to theft or diversion

(2) Resistance to national reuse

(3) Technical viability

(4) Environmental, safety, and health (ES&H)

(5) Cost effectiveness

(6) Timeliness

(7) Foreign cooperation

(8) Institutional acceptance

(9) Additional benefits[b]

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[a]Numbers in parenthesis refer to a specific criterion, from DOE/MD-0002.
[b]Thorium-229, a medically useful isotope, may be extracted from the ^{233}U in inventory.

Disposition Options (Disposal And Storage)

Disposal Options And Path Forward

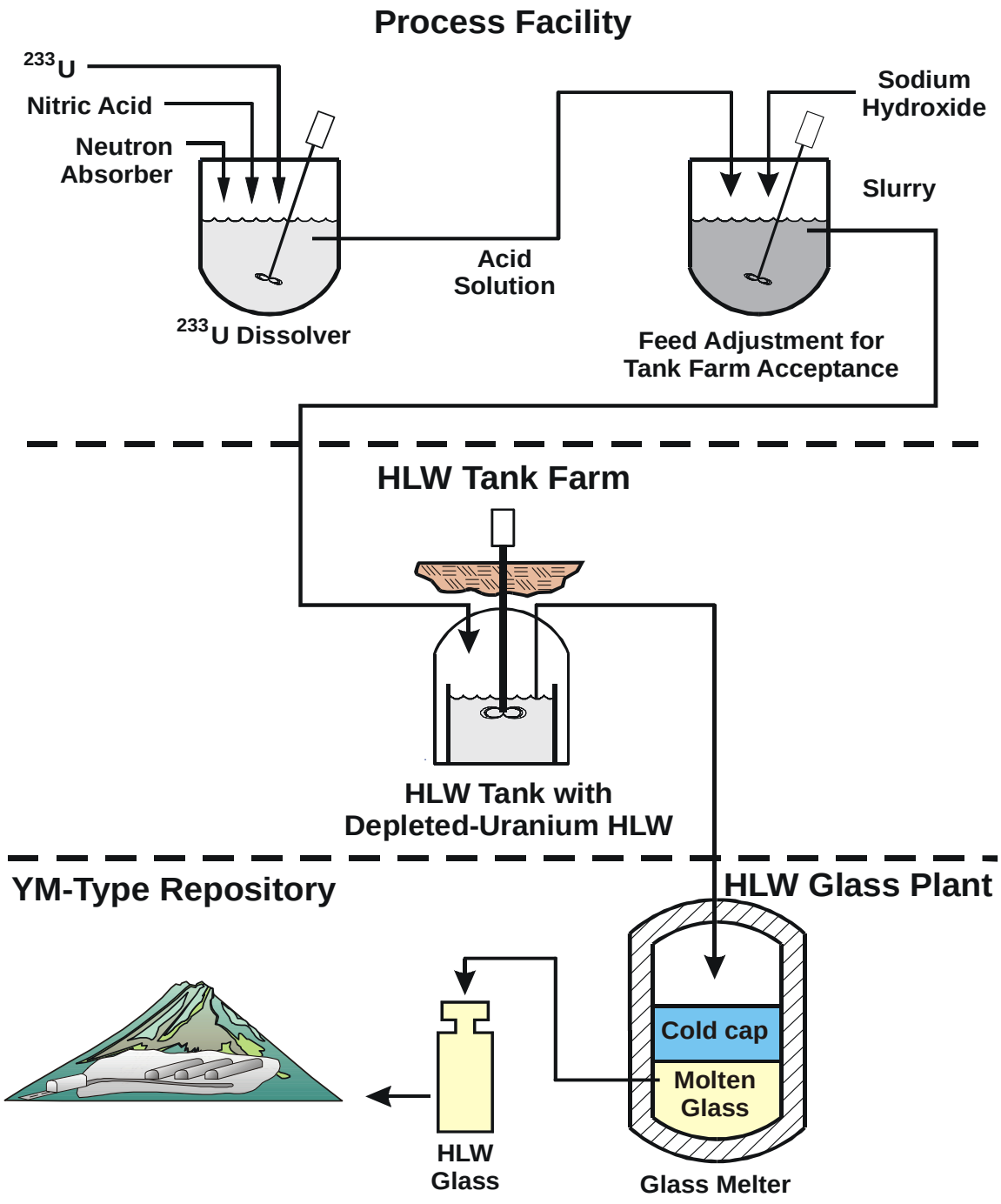
	Option	Preliminary screening
1	HLW glass	x
2a	U-Al alloy spent nuclear fuel (SNF)	x
2b	U-Al alloy (stand-alone)	
3	Can-in-canister	x
4	Aqueous	x
5a	Fusion melt (B_2O_3)	
5b	Fusion melt (glass)	x
6a	Dry blend (simple)	x
6b	Dry blend oxidation-reduction (O-R)	x
7	Chemical dilution	
8	Define as SNF	x
9	Remote-handled transuranic waste (TRUW)	
10	Contact-handled TRUW	
11	L-water reactor fuel	
12	Deep borehole	
13	Greater confinement	
14	Space	
15	Subseabed	
16	Shallow land disposal	
17	Electrometallurgical	

Storage (Downblend) Options And Path Forward

Option	Preliminary screening
Aqueous	x
U-Al metal	
Fusion melt (B_2O_3)	x
Fusion melt (glass)	
Dry blend (simple)	x
Dry blend (O-R)	x

Disposition Of ^{233}U In HLW Tanks

ORNL DWG 98C-430R



Conversion of Excess ^{233}U and High-Level Waste (Containing Depleted Uranium) to HLW Glass

The Use Of HLW Tanks For ^{233}U Disposition Has Potentially Major Advantages

- Waste volume (and maybe cost) may be minimized by beneficial use of existing depleted uranium (DU) in the HLW tanks
  - Weapons-usable ^{233}U can be converted to nonweapons-usable ^{233}U (<12 wt % ^{233}U in ^{238}U)
  - Isotopic dilution will address repository criticality control issues (<0.66 wt % ^{233}U in ^{238}U)
- HLW glass is an acceptable repository waste form (cadmium in feed is acceptable: CEUSP ^{233}U with cadmium is the most likely candidate for disposition)
- HLW tanks and vitrification facilities can accept high-gamma ^{233}U feeds

There Are Very Strong Incentives To Minimize The Amounts Of Neutron Absorbers That Must Be Added To ^{233}U. Acceptance Criteria For The Tank Farm May Determine The Feasibility Of The Option

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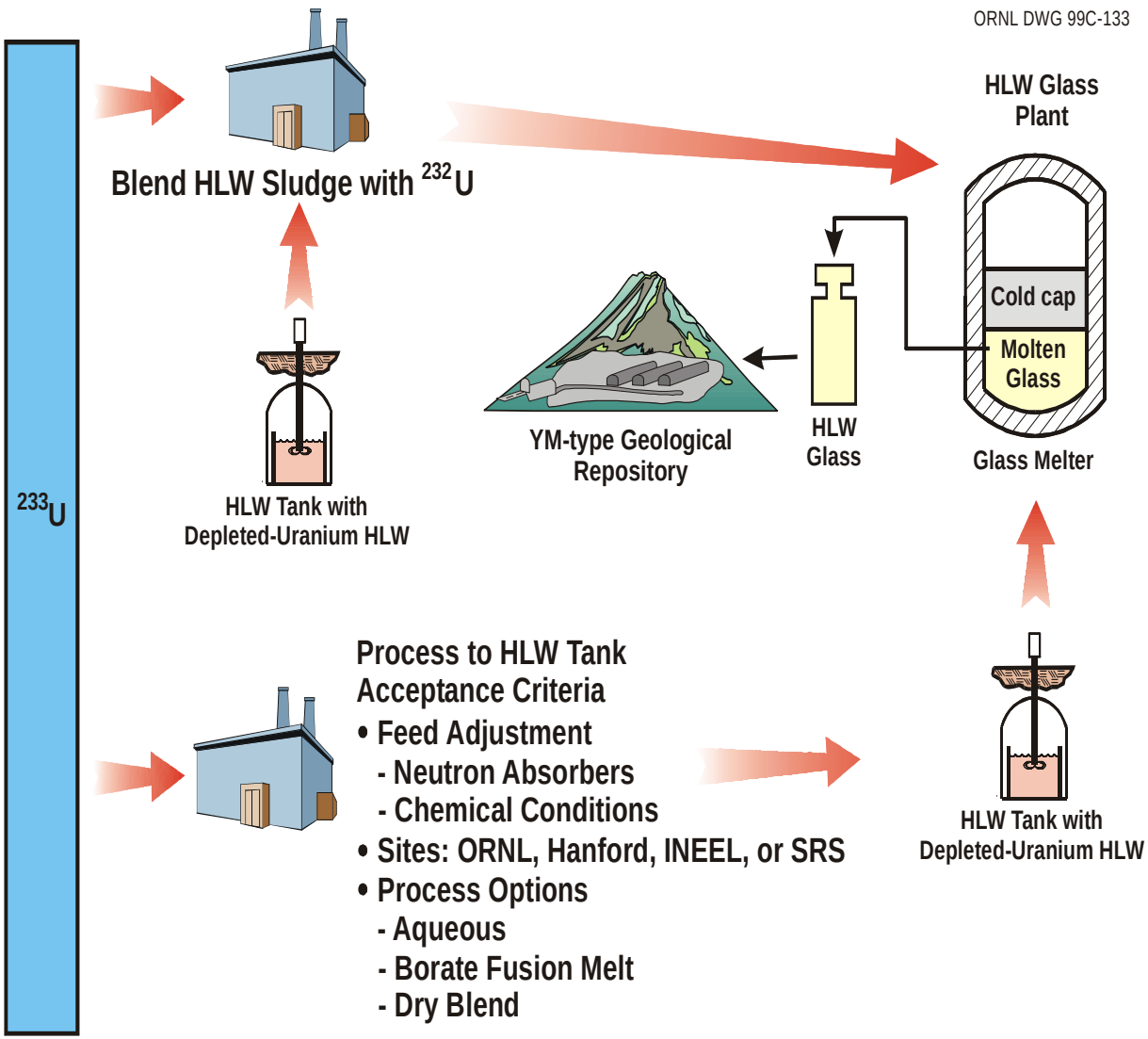
- **Costs to produce an HLW glass log vary between $0.5 to 2×10^6—depending upon assumptions [Savannah River Site (SRS) data]**

- **If isotopically diluted ^{233}U is mixed with ^{238}U to insure safety under all circumstances (0.66 wt % ^{233}U in ^{238}U), large quantities of DU are required**

  - **This process is equivalent to diluting ^{235}U to 1 wt % in ^{238}U**

  - **The ^{233}U inventory contains ~1,800 kg (but no decision has been made on how much material is to be disposed of)**

- **The Hanford HLW tanks have very large quantities of DU and thus minimize the need to add DU to the ^{233}U**



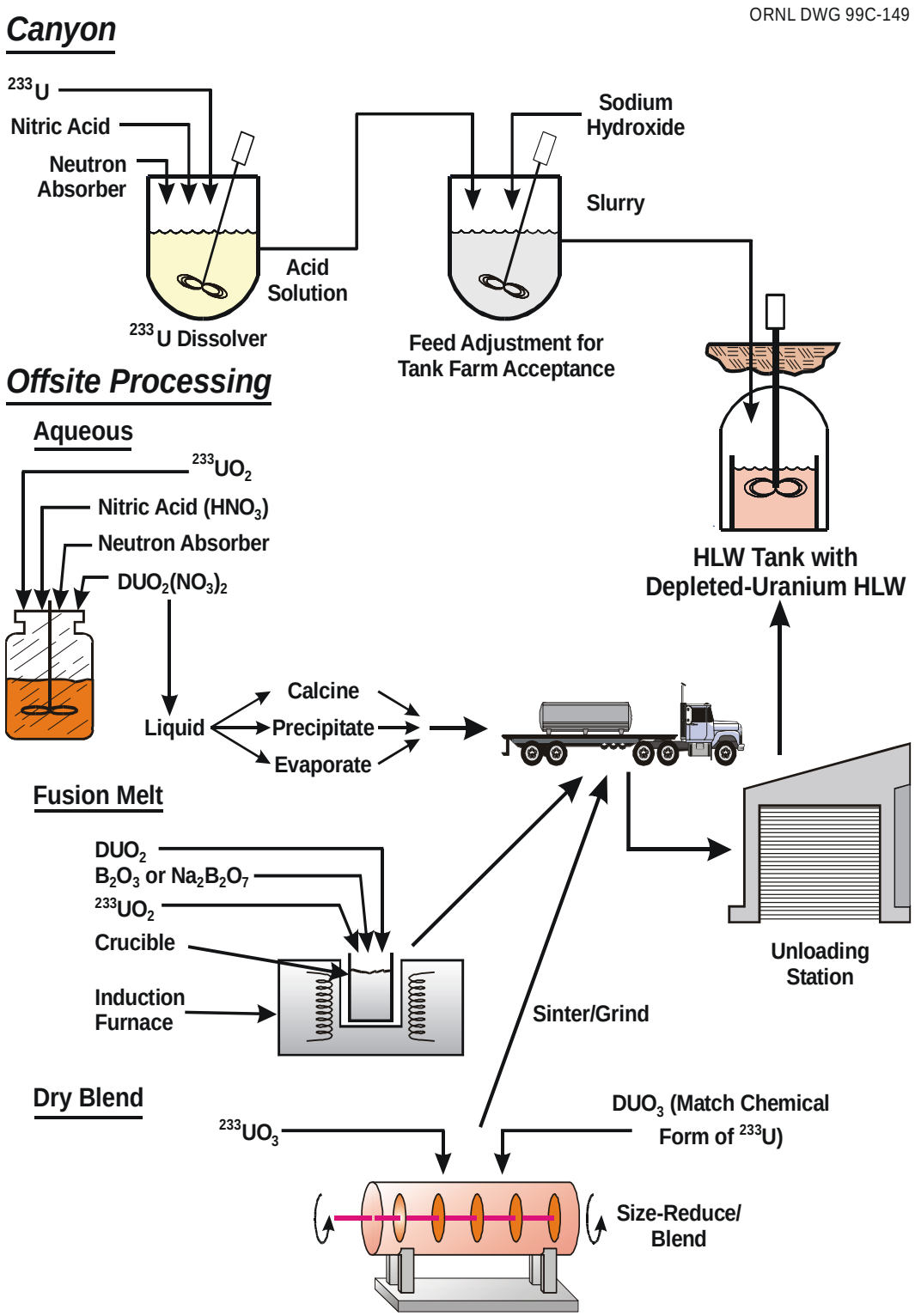
^{233}U High Level Waste Disposition Variants

There Are Several Variants Of The HLW Glass Option

- ***Pre-process*. Convert ^{233}U into a form that meets waste tank acceptance criteria, ship to the HLW tanks, and add to the HLW tanks containing DU**
  - **Add sufficient neutron absorbers (gadolinium) to eliminate operational criticality issues**
  - **Add sufficient DU to convert to non-weapons-usable ^{233}U**
  - **Convert to chemically acceptable waste form (particle size, chemical composition, etc.)**
- ***Co-process*. Mix ^{233}U with HLW containing DU <u>during</u> transfer from HLW tanks to glass melter**

Each Variant Has Specific Advantages

- ***Pre-process*. Uranium-233 is processed and shipped to HLW tanks**
  - **Preprocessing can be done at multiple sites in multiple facilities**
  - **There is no need for a coordinated ^{233}U disposition and vitrification schedule (^{233}U can be added at any time before vitrification)**
  - **Minimize safeguards during transport, storage, and operations (not weapons usable)**
- ***Co-process*. Uranium-233 and HLW are mixed just before feeding to vitrification plant**
  - **This minimizes the need to added neutron absorbers for ^{233}U (no tank farm requirements)**
  - **Minimize chemical requirements to meet tank farm acceptance criteria**



Processing For Disposition In HLW Tanks

Preprocessed ^{233}U Would Be Slurried From The Transport Package To The HLW Tanks

- ^{233}U is shipped dry
- Transfer station provides slurry water
- Several possible transport forms
  - Uranium nitrates
  - Uranium oxide powder
  - Borate solid ($Na_2 B_4 O_7$)

The Disposition Program Is Currently Conducting Joint ORNL/SRS Studies On These Options

- Flowsheets, facility options, and costs are being developed
- Limited resources dictated evaluation of one HLW site options
  - Assuming the options are attractive, other HLW sites will be considered
  - There are strong similarities between SRS and Hanford tanks, thus SRS studies should provide a “rough” perspective on the characteristics of a Hanford option
  - Preliminary data indicates this option is potentially attractive

Issues To Be Addressed

The ^{233}U Disposition Option Using Savannah River HLW Tanks Is Being Investigated. Is The Use Of Hanford HLW Tanks For ^{233}U Disposition A Viable Option?

- **Who is (are) the appropriate DOE/contractor point(s) of contact?**

- **What are the technical barriers?**

  - **What tanks have available DU?**
  - **Can ongoing tank-farm studies help define whether ^{233}U disposition is viable at Hanford?**
  - **What are the capabilities and conditions of the transfer station**

- **What are the institutional barriers?**

  - **Regulatory (Environmental Protection Agency, State of Washington, etc.)**
  - **Contractual (BNFL)**