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Enhancing the Criticality Safety Analysis for the Mobile Plutonium Facility

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About the Facility

- Developed by SRNS and SRNL for NNSA
- Rapidly deploy to a host country
- Receive, assay, stabilize and package plutonium from a foreign weapons program at a remote location
- Modularized into 20-foot ISO containers
- Part of NNSA Emerging Threats Program

About the Facility

- Flexible and adaptive – extreme conditions
- Robust and flexible but simple criticality safety program required

Criticality Safety Analysis

- Hazards analysis team identified set of potential criticality event scenarios
- Examine facility and process for normal and credible abnormal conditions
  - Single unit handling
  - Storage array
  - Bounding piece of instrumentation
- Enhancements for flexibility
  - Radiation shielding
  - Non-metal receipts and limited liquid receipts
- Suite of administrative controls with simple mass and handling limits.

Process Description

- A container(s) to be received represents some inherent but acceptable risk.
- Container(s), handled one at a time
- Receive initial imaging and NDA
- If it conforms to the facility safety limits it is placed in storage
  - Otherwise it is isolated; isolated containers are dealt with on a case-by-case basis.
- Container is processed
  - Contents removed, stabilized for safe transport, repackaged, subjected to a final NDA characterization, and packaged for safe transport.

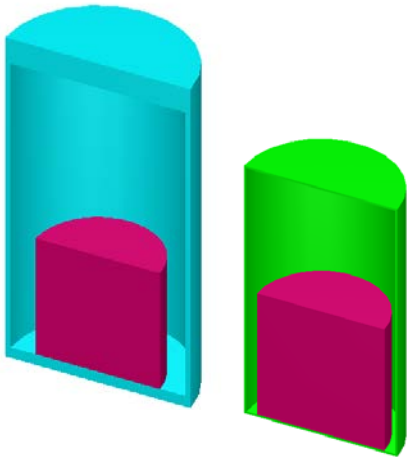
Process Description

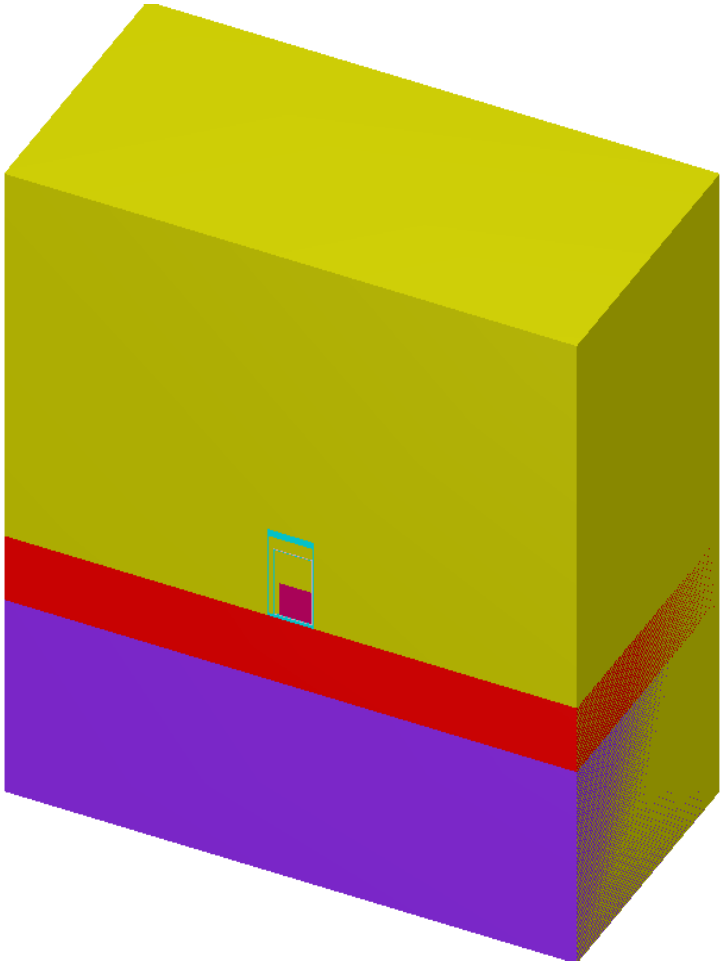
- Process is controlled from a centralized control room
  - Material accountability
  - Security
  - Observation of operations

Normal Process Conditions

- Derived from the expected flow of materials through the facility
  - Individual containers sitting in air on soil or pavement
  - Full Lead Storage Array with one addition item in transit
  - Bounding piece of instrumentation with one item inside for analysis.

Normal Process Conditions





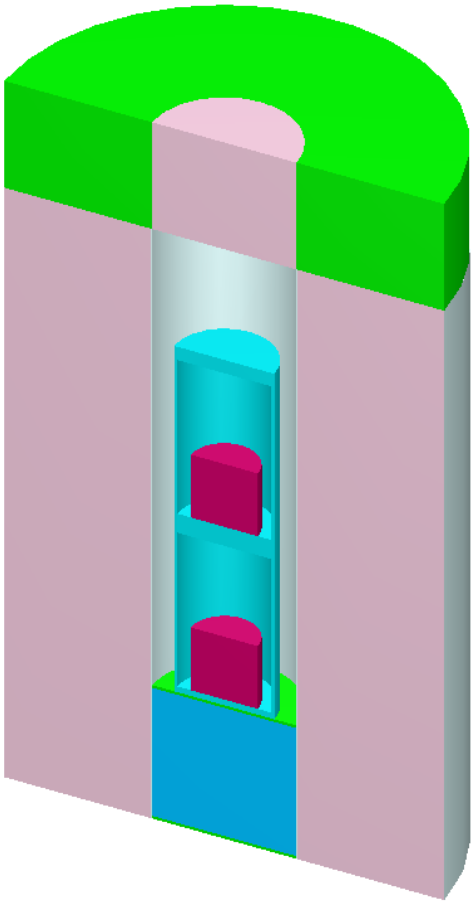
Hazards Identification

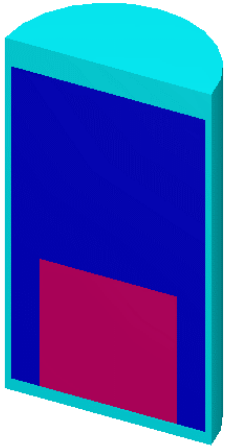
- Upsets in handling and processing
  - Inadvertent Interaction
  - Inadvertent moderation or reflection
- Not credible events due to nature of process
  - Beryllium reflection, melted shielding moderation, moderation in gloveboxes, errors in final packaging
- Natural phenomenon hazards
  - Not analyzed → accepted risk
  - Type, frequency, and severity cannot be known a priori
  - Relatively short duration of facility mission

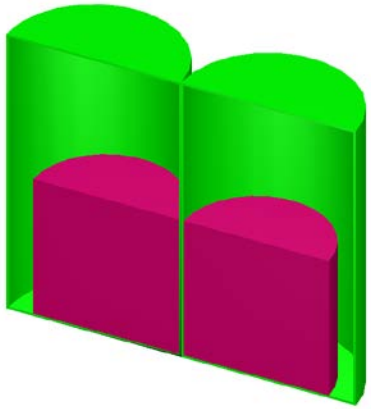
Hazards Identification

- Remaining Upsets
  - Handling and processing
  - Evaluate by bounding mass, moderation, and reflection
- Credible abnormal conditions to analyze
  - Two containers in contact with each other (interaction)
  - Container over the mass limit
  - Container fully flooded
  - Array racks fallen together
  - Two containers in the bounding piece of instrumentation

Credible Abnormal Conditions



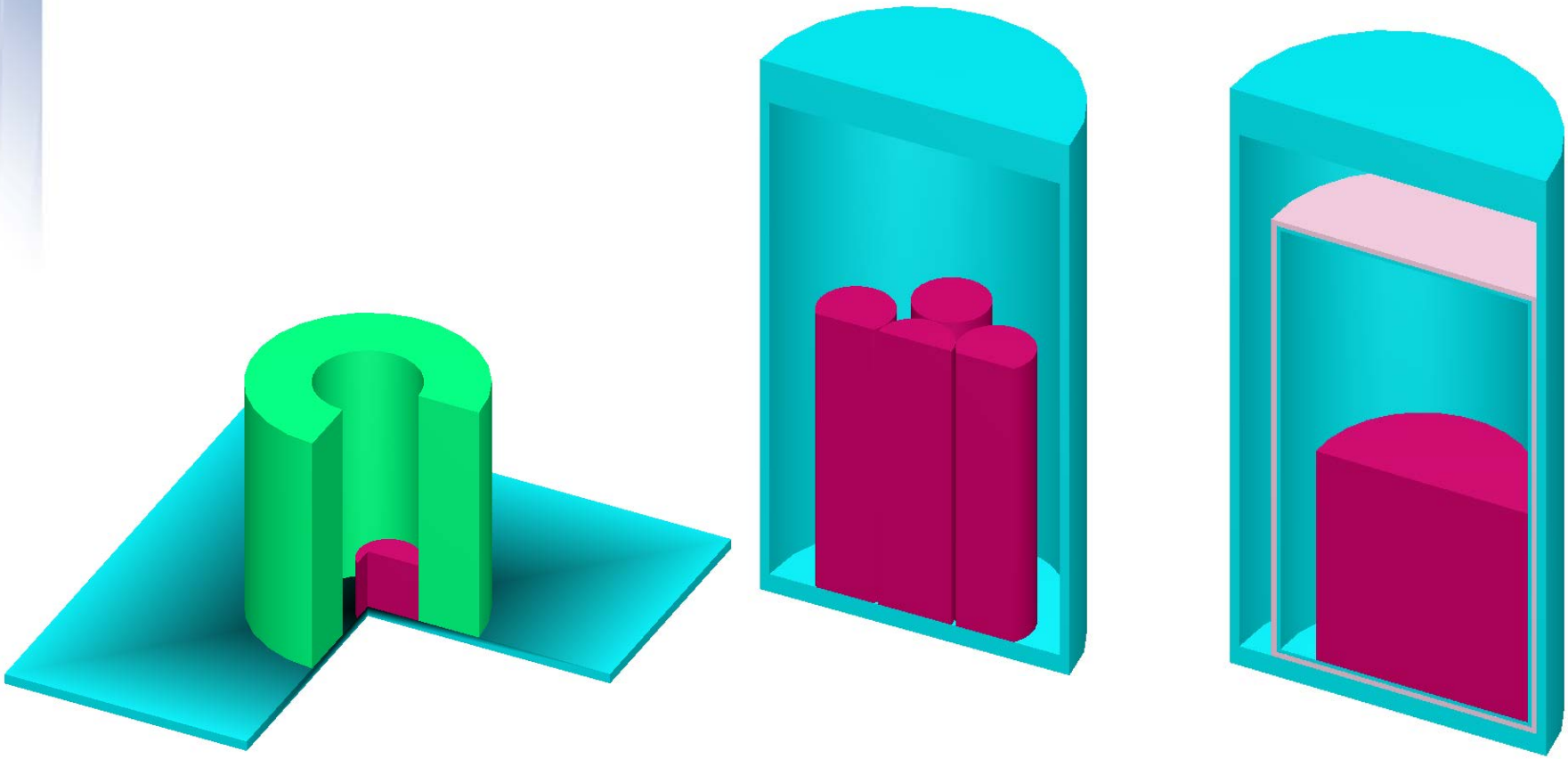




Beyond Credible Abnormal & Operational Flexibility

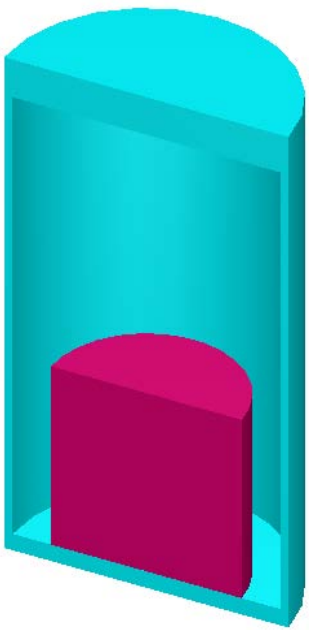
- Can-bag-can configurations
- Temporary storage of flooded container in Lead Storage array
- Inadvertent placing of flooded container into instrumentation
- Radiation shields for glovebox
  - polyethylene or W.E.P
- Radiation shields for storage array
  - Lead or polyethylene
- Subdivided pieces of metal in dry and flooded conditions
- Allow for small samples of plutonium bearing solutions
- Allow for non-metal receipts of plutonium
  - Oxide, oxalate, and fluoride

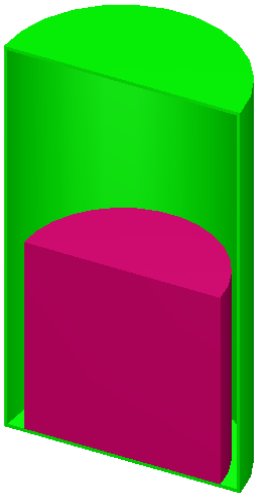
Operational Flexibility



Modeling & K-safe

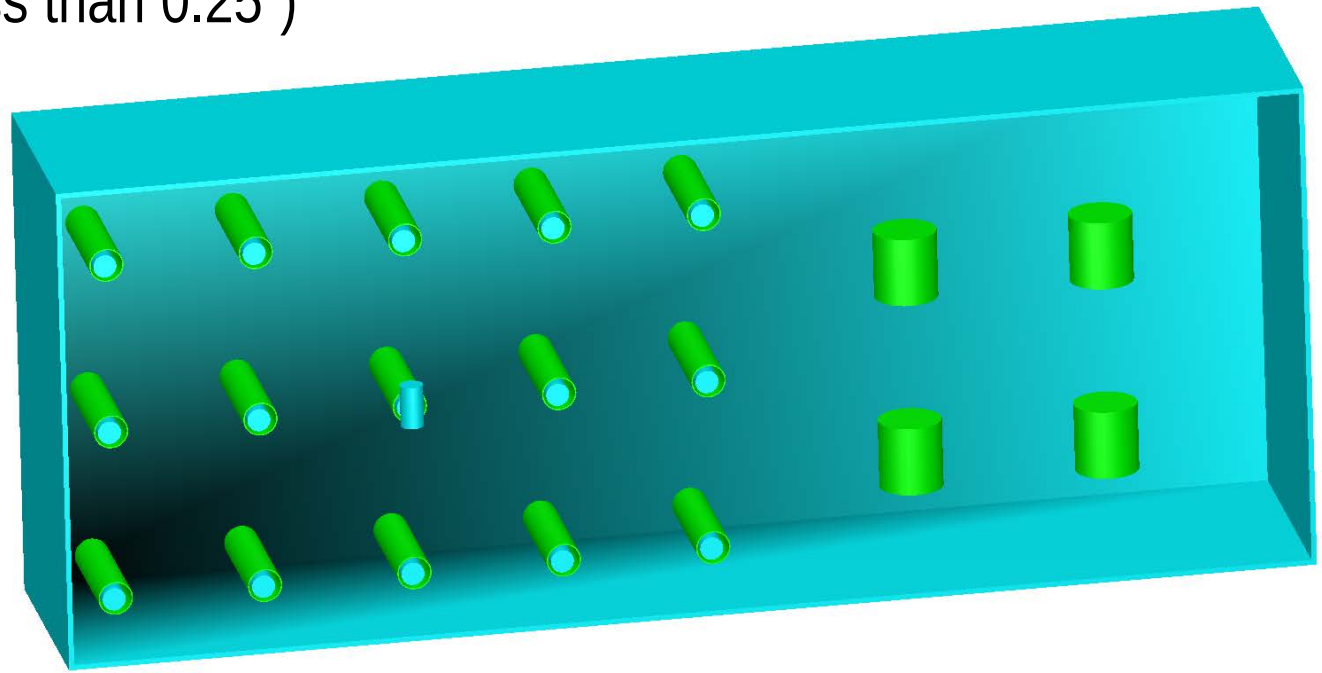
- Internal validation of SCALE 6.1 for Pu metal systems
  - k-safe= 0.9697
- Fissile
  - 6.5 kg Pu-239 alpha phase metal
  - H/D=1 cylinder
- Containers
  - Material: stainless steel, aluminum
  - Geometry: thin walled slip lid can, thick walled Hanford convenience can





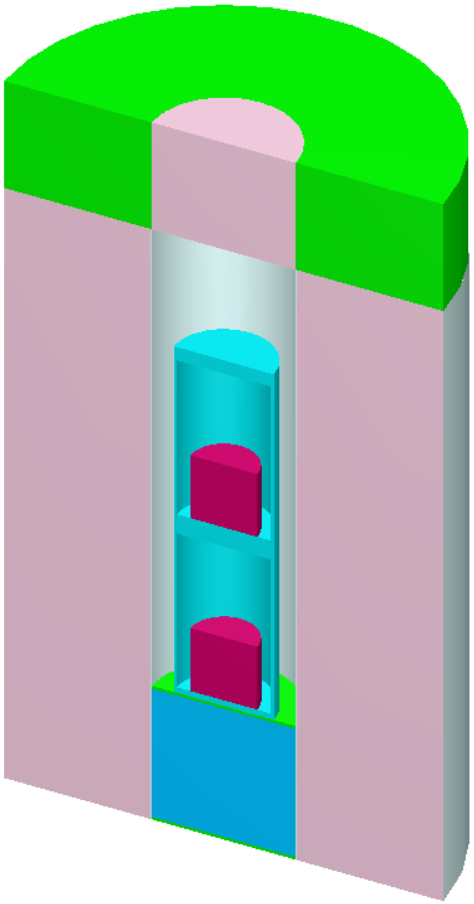
Modeling & K-safe

- Lead Storage
  - As-built with bounding separation distance between locations (minimum 63.5 cm)
  - Two adjacent racks with 15 tube and 4 pot locations per rack
  - Overly conservative stainless steel wall thickness of 6” (in reality less than 0.25”)

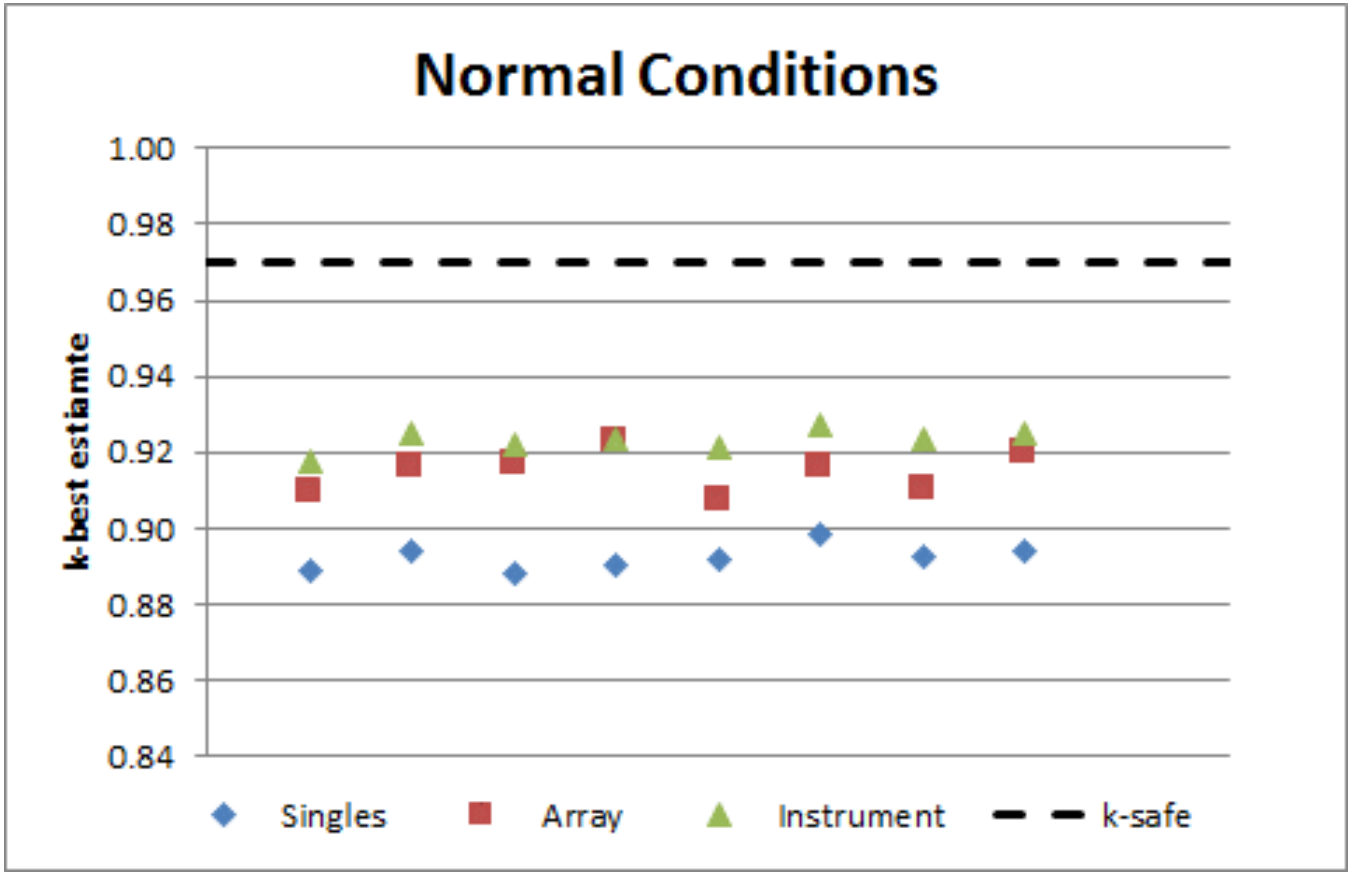


Modeling & K-safe

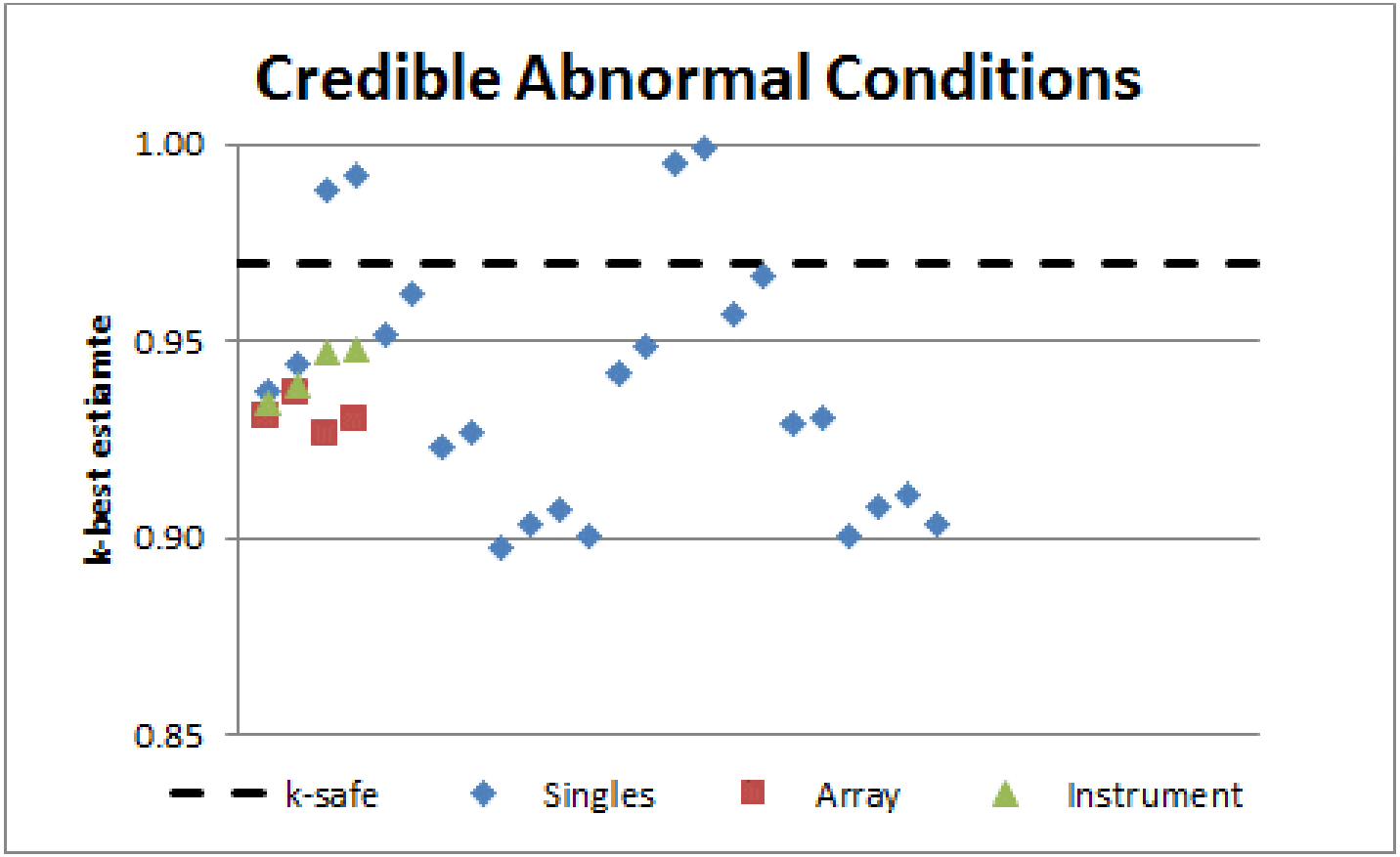
- Bounding Instrumentation
  - Epithermal Neutron Multiplicity Counter
  - Bounding moderation and reflection
    - *Simplified model*
    - *Polyethylene annulus*
    - *Inner and outer cadmium liners*
    - *Graphite and aluminum plugs*
    - *Limited vertical height of cavity*



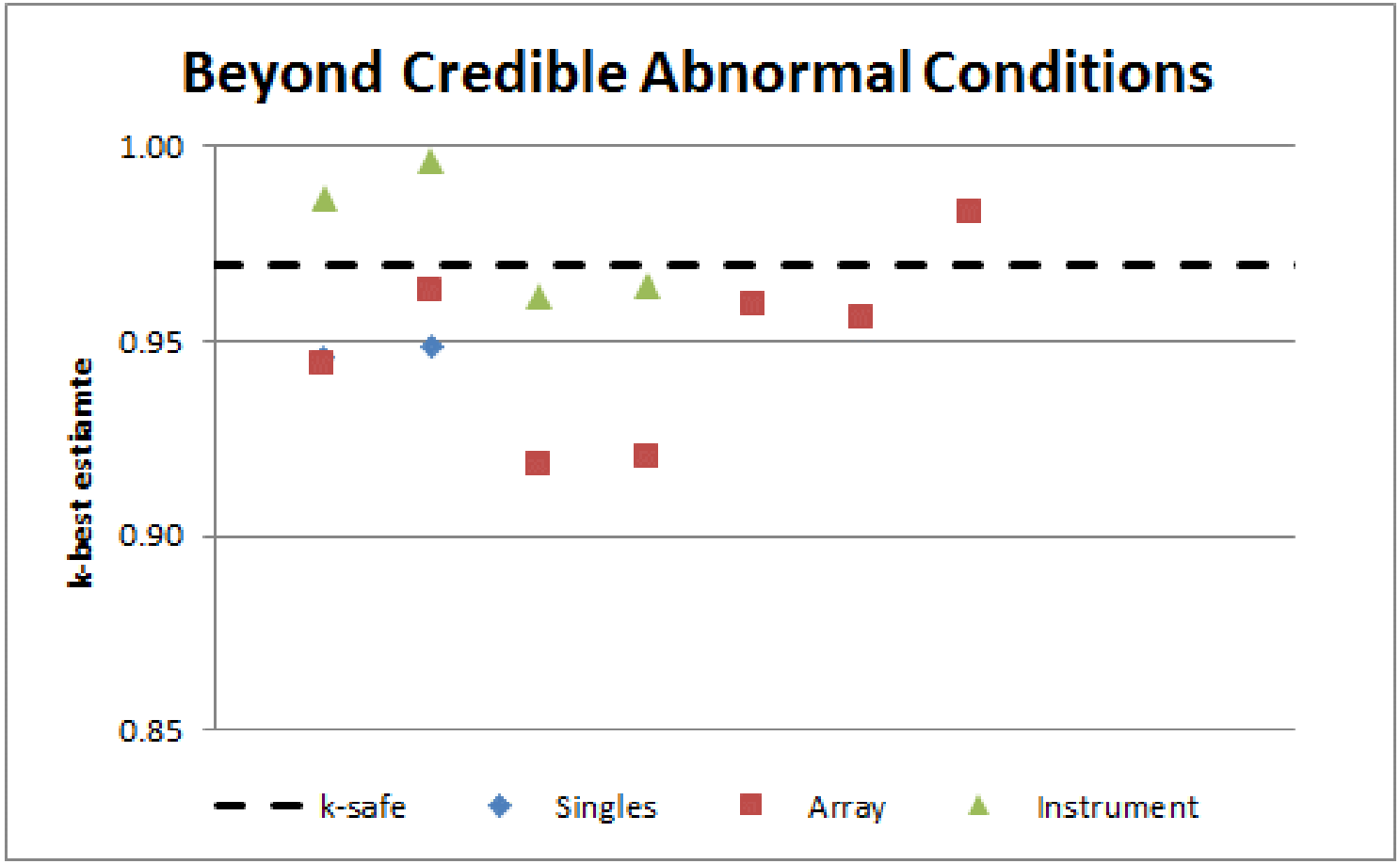
Results


Normal Conditions
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
k-best estiamte
Singles
Array
Instrument
k-safe

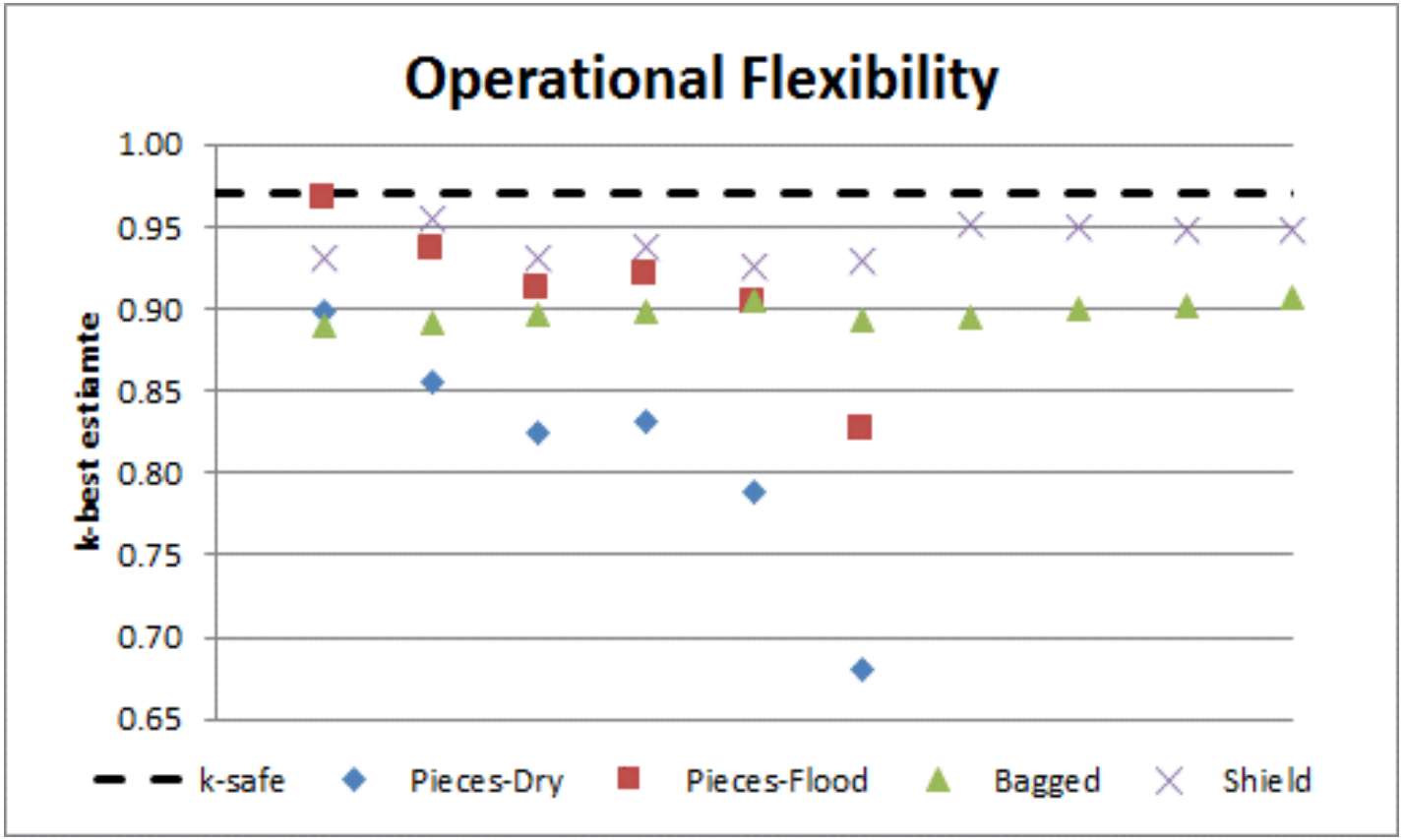
Results


Credible Abnormal Conditions
1.00
0.95
0.90
0.85
k-best estiamte
k-safe
Singles
Array
Instrument

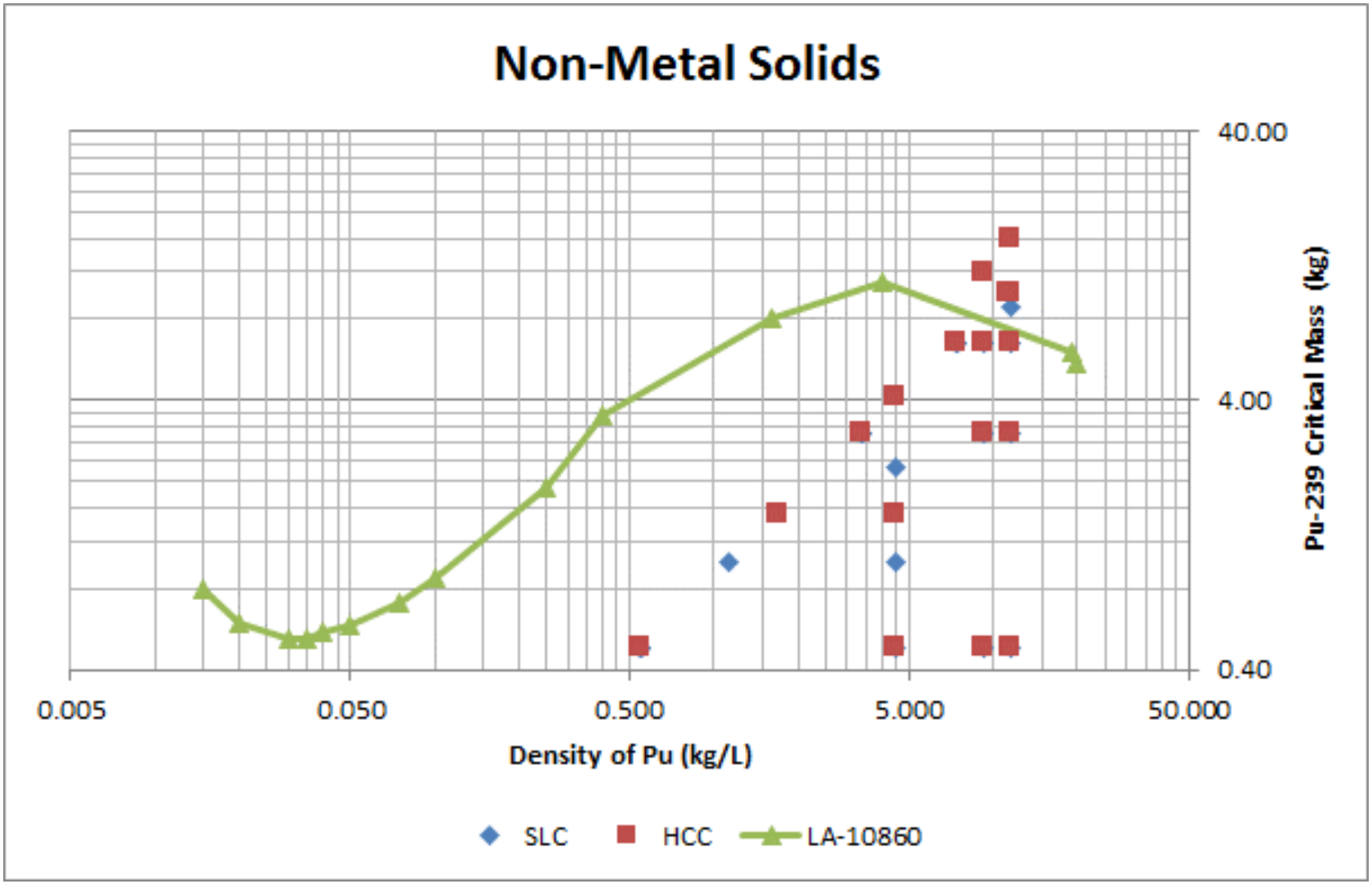
Results


Beyond Credible Abnormal Conditions
1.00
0.95
0.90
0.85
k-best estiamte
k-safe
Singles
Array
Instrument

Results


Operational Flexibility
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
k-best estimte
k-safe
Pieces-Dry
Pieces-Flood
Bagged
Shield

Non-Metal Receipts



Limited Volume Liquid Samples

- Allowance is made to permit aqueous solutions up to 3.0 L (approximately 2 Hanford cans) or up to 450 g FGE Pu-239, whichever is more limiting
  - solution container is handled individually
  - solution container is not placed in lead storage
  - solution container placed in any other mass control zone, that MCZ must be free of other fissile material
  - case-specific disposition path (e.g. drying or calcining) is executed BEFORE operations with solids resume in that MCZ

Design Features & Control Suite

- Criticality Accident Alarm System installed
  - In Solids module (i.e. near gloveboxes)
- Design Feature
  - Storage array position limiters in tube locations
- Mass control basis of 6.5 kg FGE Pu-239
  - metal and non-metal solids
- Facility divided into Mass Control Zones
  - Limit of one item at a time
  - Limit of 6.5 kg FGE Pu-239
  - Exceptions: storage, processing, final storage
- Only one container moved at a time between MCZs

Design Features & Control Suite

- Initial receipt
  - Not critical upon receipt and do not intend to do anything invasive to make it so
  - Have only sender's inventory/description until initial NDA completed
  - Considered a necessary risk for the missions
- Thin walled cans required to be placed inside more robust container
- Non-conforming containers isolated with 100 cm spacing and dealt with on a case-by-case basis

Future Work

- Removing delineation of thick and thin walled containers
  - Reflection has influence but not absorption
- Allowing variance in potential container materials
  - Zinc, tin, iron, copper
  - Steel, bronze, brass
- Allowance for temporary staging area outside of Receipt

Not All Bad Weather…

Conclusion – Highest Quality Feature of All

- Team of 24-30 plutonium experts and highly skilled operators