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Title: Nuclear Criticality Safety for the LANL Mission

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# Nuclear Criticality Safety for the LANL Mission

Bill Crooks
Division Leader
Nuclear Criticality Safety

# NCS Staff at Los Alamos National Laboratory

Norann Nell Calhoun

- B.S. Chemical Engineering **NMSU**
- 1.5 years at LANL and in NCS
- TSQP Certified Classroom Instructor at LANL

Kaelin Glover

- B.S. Nuclear Engineering **UNM**
- 1 year at LANL in NCS
- Sr. year worked satellite for NCS
- Summer Internship
- Will be an acting GB worker to further knowledge of NCS

Nadia Chisler

- B.S. Chemical Engineering **UNM**
- 4 years at LANL in NCS
- Working on masters in Nuclear Engineering through UNM

Mandy Bowles-Tomaszewski

- B.S. Nuclear Engineering **ISU**
- 4 years at LANL in NCS
- **University pipeline liaison**
- Supports regular operations
- Student intern liaison

Bill Crooks

- Ph.D. Inorganic Chemistry **FSU**
- 17 years at LANL
- 1.5 years in NCS
- Started in academics
- Transitioned to support Pu processing at Savannah River

# Nuclear Criticality Safety for the LANL Mission

- NCS for LANL – big picture
- NCS Program – purpose
- What do NCS analysts do? How? Why?
- Dec. 30, 1958 Process Accident
- What is the LANL NCS program?
- What are we looking for in NCS analysts?


**NCS Division Customers:**

Nuclear weapons
Nuclear fuels
Nuclear batteries
Nuclear waste
Accident response

Research & Dev
Science mission

# Deterrence 101

**Definition:** ***a strategy of discouraging an adversary from taking a specific action by causing doubt or fear of the consequences.***

## Three Elements of Strategic Deterrence

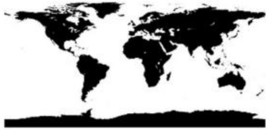
**1. Deny potential benefits an adversary would gain from taking a harmful action.**

**2. Convince an adversary you have the ability to impose significant cost against them if they take a harmful action.**

**3. Credibly inform adversaries of your readiness and capabilities so they don't underestimate your ability to protect your people, interests and allies.**

## 21st Century Strategic Deterrence

**→ Blends nuclear and non-nuclear forces with a "whole of government" approach alongside allies and partners to maintain security and stability**



**→ Accounts for a change from the Cold War world of the past to the multi-polar world of the future**

Deterrence has prevented major-power conflict since WWII.

**Deterrence saves lives.**

# The Laboratory Agenda

- The Laboratory Agenda provides a structured framework that identifies the critical outcomes, strategic initiatives and near-term R&D, and production and mission-support activities needed to accomplish our mission.

| | NUCLEAR SECURITY | MISSION-FOCUSED SCIENCE, TECHNOLOGY, AND ENGINEERING |
|---|---|---|
| Major Strategic Initiatives (1–5 years) | 1.1 Execute LANL's manufacturing mission to deliver 30 plutonium pits per year | 2.1 Refresh and refine the LANL capability pillar framework |
| | 1.2 Transform nuclear weapons warhead design and production | 2.2 Advance accelerator science, engineering, and technology to enable future stewardship capabilities |
| | 1.3 Anticipate threats to global security; develop and deploy revolutionary tools to detect, deter, and respond | 2.3 Advance the frontiers of computing to exascale and beyond |
| | 1.4 Continue to support the W88 Alt 370, the Alt 940, and the B61-12 LEP | 2.4 Assert leadership in the national quantum initiative |
| | 1.5 Assess the stockpile as it ages and project weapon system lifetimes | 2.5 Develop and implement an integrated nuclear energy and materials initiative |
| | | 2.6 Develop and implement an integrated initiative for plutonium and actinide missions |

# The Laboratory Agenda Cont.

| MISSION OPERATIONS | | COMMUNITY RELATIONS | |
|---|---|---|---|
| 3.1 | Change organizational culture with an emphasis on organizational learning | 4.1 | Continue commitment to the community with educational, economic, and philanthropic investments of time and resources |
| 3.2 | Improve integrated planning across priority mission activities and infrastructure | 4.2 | Strengthen pipelines and partnerships to build the workforce of the future |
| 3.3 | Address critical issues related to NMCA, nuclear safety, criticality safety, and classification enhancements | 4.3 | Enhance small business participation in executing LANL's scope across all directorates |
| 3.4 | Implement systematic process improvement to drive increased rigor and efficiency in work execution | | |
| 3.5 | Enhance quality of work life, workforce planning, and training and development | | |

# What do NCS analysts do … for the NCS Program

- Understand fissionable material operation = "normal conditions"
- Define upsets = *credible* abnormal conditions
- Analyze hazards
- Model the system
- <u>Implement controls</u> to provide an adequate **safety margin**

Passive **engineered controls >**

Active **engineered controls >>**

**Administrative** requirements

# What is “adequate safety margin”?

ANSI/ANS-8.1, *Nuclear Criticality Safety in Fissionable Material Operations Outside of Reactors*, Section 4.1.2. *Process Analysis*

Before an operation with fissionable material is begun, or before an existing operation is changed:

- Determine that the entire process will be **subcritical** under both normal and **credible abnormal** process condition
- ... including those initiated by earthquakes and … floods, tornados, tidal waves.

# Implement controls / limits / requirements on parameters …

## Criticality Safety Parameters

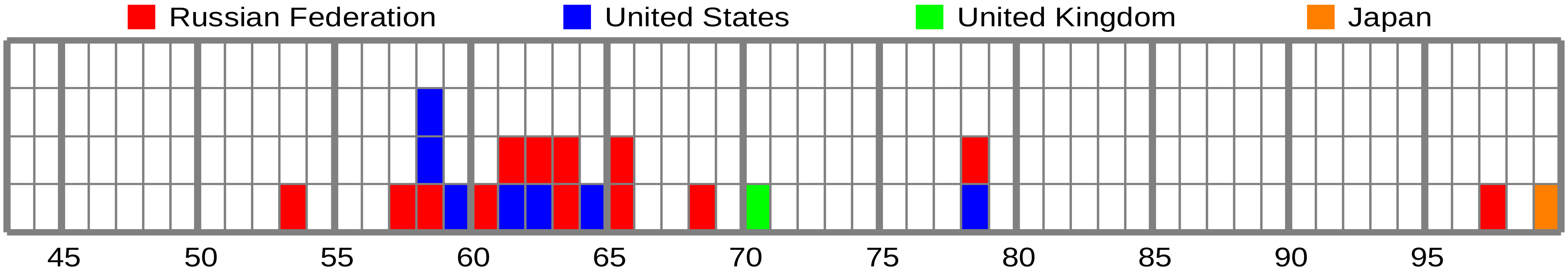
Mass
Moderation
Absorbers
Enrichment
Geometry
Reflection
Interaction
Volume
Concentration

1

# How did we learn about controlling parameters?

**Accidents.**

- 1 to 2 per year for about 10 years
- 1 per 10 years




Where did we communicate the lessons learned?

**ANS Standards.**

# Dec. 30, 1958 Process Accident

# Technical Area 21

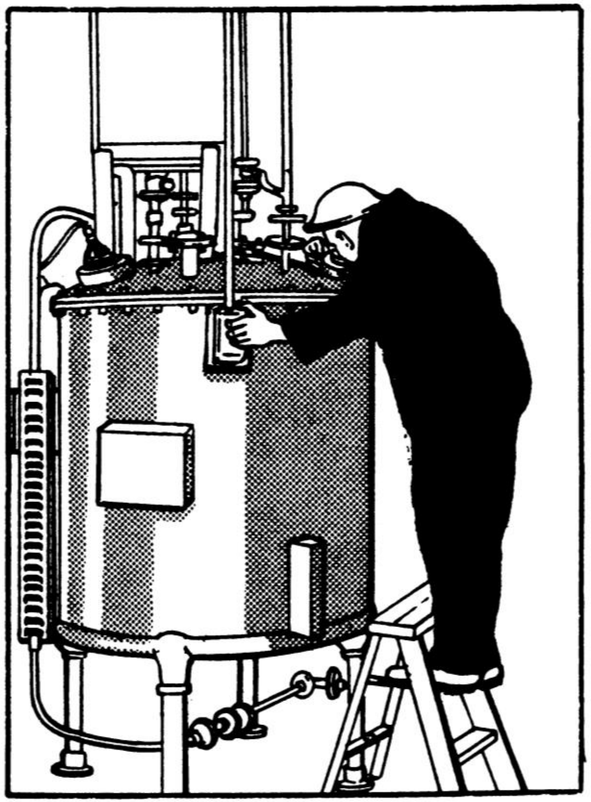
# Los Alamos



13

# Dec. 30, 1958 Process Accident

- End of year plutonium inventory in progress
- 3,100 g of plutonium in 160 L solution
  - Four tanks transferred to single tank
- Worker turned tank stirrer on
- Tank went supercritical
- 1.5 x $10^{17}$ fissions
- 3 people exposed (53, 134, 12000 rem)
- 1 fatality (36 hours)

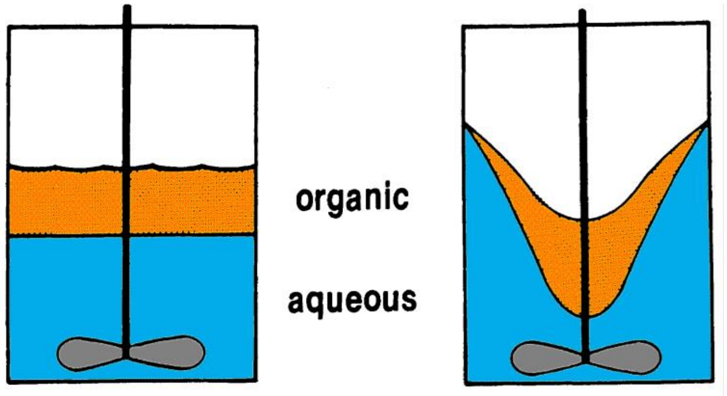


*Operator on ladder turning on stirrer*

# Dec. 30, 1958 Process Accident – 4:35 PM

- Plutonium was in two layers
  - **3100 g in top organic layer**
  - **60 grams in bottom aqueous layer**
- Stirrer caused top layer to thicken sufficiently to become supercritical within 1 second
- Stirrer agitation rendered system sub-critical within 2-3 seconds
- Tank was known to be an unsafe geometry (40-inch outside diameter)

**What happened**




*Result of Stirring*

20.3 cm = layer of organic
21 cm = critical thickness
k-eff ~ 0.985

# Event reconstruction indicates

- Several vessels were being cleaned
- Wash solution from two other vessels were fed to a third
- **Filtering was not performed**
- Vessel contained solids, solvents (organic, TBP) and lean nitric acid (aqueous)
- Sparging resulted in dissolution of Pu into the organic phase
- Lean aqueous transferred out
- Remaining 200 liters transferred to organic treatment tank

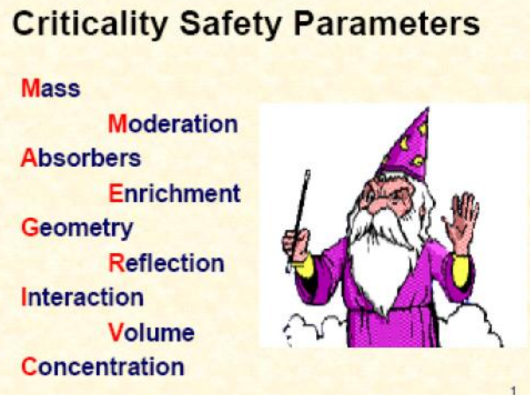
# The Consequences

- Extreme exposure
  - Operator ~12,000 ± 6000 rem
    - Died 36 hours later
  - Two others nearby
    - 134, 53 rem
    - No ill effects reported
- Tank displaced ~10mm
  - No physical damage

# Missed Opportunity

- NCS Committee reviewed operations ~1 month earlier
  - Recommended vessels be changed
  - Plans were drawn up to use banks of 6” diameters vessels
  - Budgeted for May/June of 1959
    - If accident had not occurred when it did it likely never would have
- Procurement accelerated
  - 6” diameter vessels installed prior to resumption

# Why is an array of 6” diameters vessels safer?

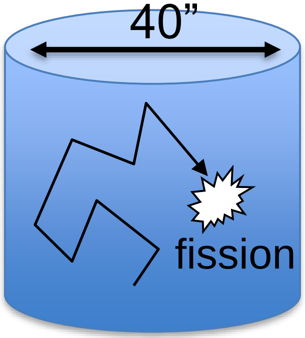



**Mass = 3100 g**
**Volume = 160 L**
**Enrichment = fixed**
**Concentration = fixed**

Principle control on parameters:
1. Geometry
2. Interaction

**Thick geometry:** less likely to leak

**Thin:** more likely to leak
Separation = **less interaction**

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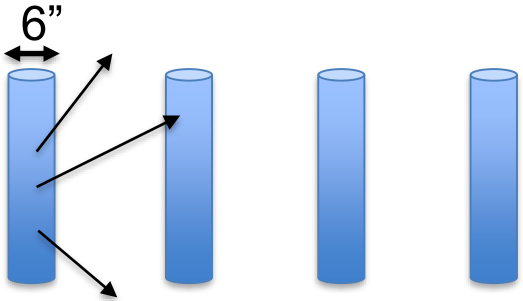
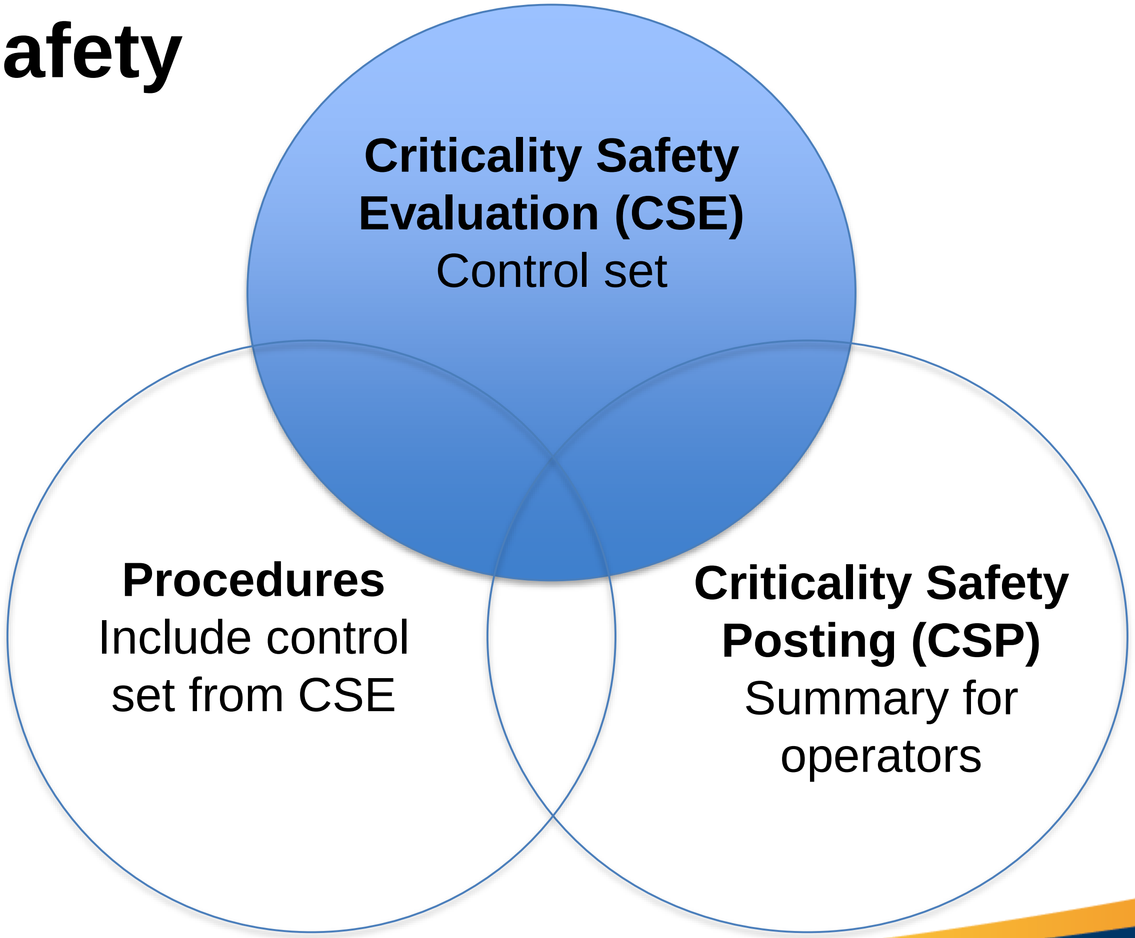


# What is the LANL's NCS program?

- **Cooperation in planning**
  – Operations staff - written operating procedure
  – NCS analyst – criticality safety evaluation derives controls

- **System of controls to minimize human error**
  – Conduct of operations, educated and trained staff, configuration control, field monitoring, learning from mistakes

# Criticality safety documents



# What is LANL NCS Looking for in NCS Analysts

- Nuclear Engineering Major
- MCNP experience
- Education/experience in nuclear criticality safety
- Need to be able to attain a security clearance

# Desired characteristics

- Technically competent, willing to learn
- Social skills for communication
- Embraces northern New Mexico
- Takes a firm stand in the in red vs. green debate

## MISSION

To solve national security challenges through simultaneous excellence

## VISION

To be trusted by our nation, emulated by our peers, and respected by the world

## CULTURE

**How** we do work is as important as **what** we do

## VALUES

### Service

Serving our nation, our partners, our community, and each other

### Integrity

Demonstrating honesty, ethical conduct, accountable stewardship, and individual responsibility

### Excellence

Ensuring safe and secure mission delivery in nuclear security; science, technology, and engineering; operations; and community relations

### Teamwork

Achieving our best by respecting diverse opinions and backgrounds, exploring alternatives, and collaborating with our colleagues and partners

## BEHAVIORS

Collaborative Problem Solving

Shared Outcome

Commitment

Continuous Learning

Trustworthy