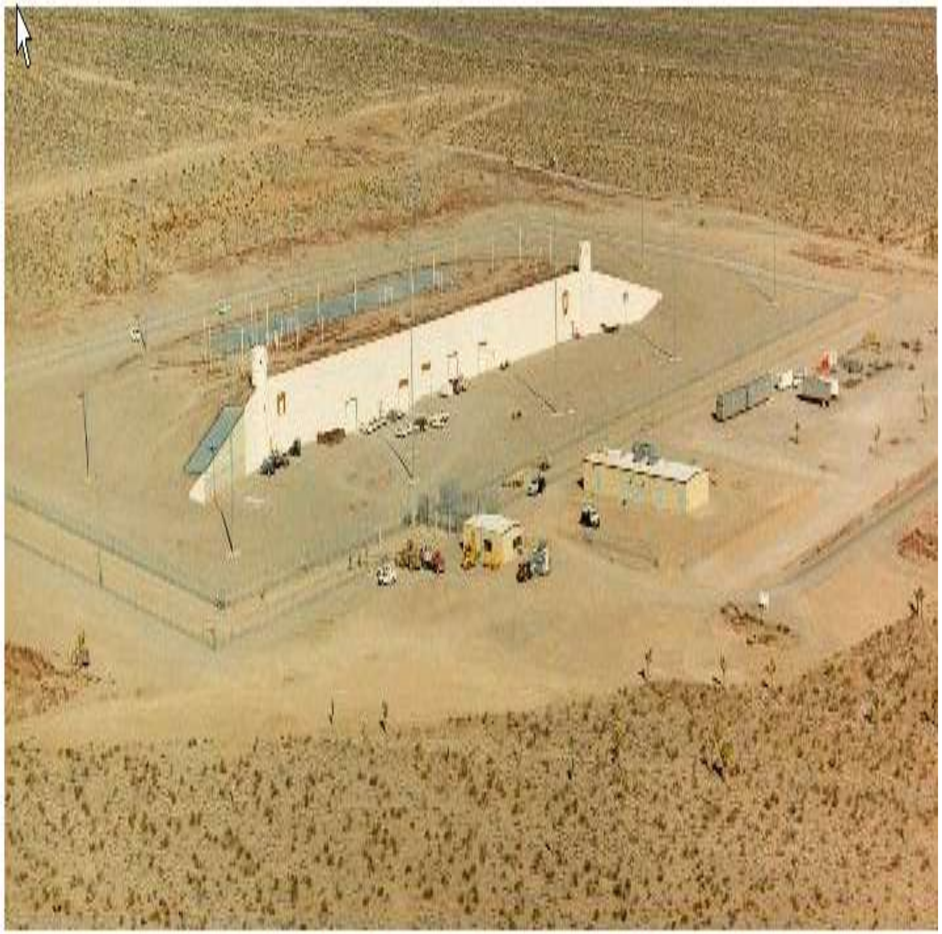


First Critical Experiment at NCERC

Rene Sanchez, David Hayes, Joetta Goda, and William Myers

Outline

- **Background**
- **Purpose**
- **Description of the Experiment (Rules, 1/M, etc.)**
- **Experimental Results**
- **Conclusions**

Background

- Cleo Byers, Memo, “Nuclear Criticality Safety Orientation,” N-2, January 1973.
- Cleo Byers and Tom McLaughlin produced the outline of the Criticality Safety Course as well as the experiments that were to be performed (1974).
- First Criticality Safety Class is given (1975).

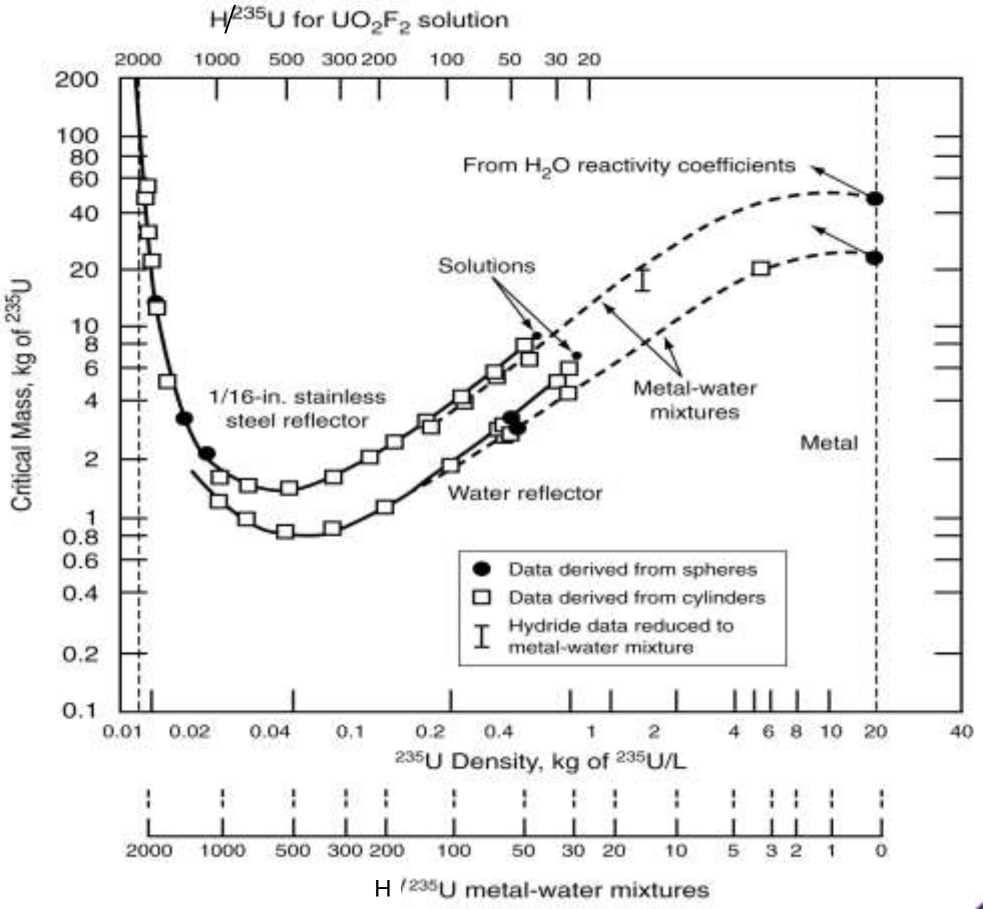
Purpose

- **Demonstration for Criticality Safety Orientation**

  - Purpose:

    To demonstrate *hand-stacking* techniques and approach to criticality by *remote operation*. The size of a well-moderated, reflected assembly and a safe size for handling will be illustrated.

Critical Masses of Homogeneous Water-Moderated U(93.2) Spheres



Approach to Critical – Safety Rules

- **Everyone is responsible for safety**
- **Initial and second fuel loadings must be safe**
- **Follow the 1/M critical approach curve**
- **Limit hand-stacking (“Three-Quarter Rule”)**
- **Limit rate of fuel addition (“Half-Way Rule”)**

Approach to Critical – Three Quarter Rule

- **No hand-assembly step shall be performed if the resulting active mass is greater than three-quarters of the estimated critical mass**

  OR

- **No hand-assembly step shall be performed if the resulting multiplication (M) will exceed 10 (k_{eff} = 0.9).**

- **Basis—For near equilateral fast-neutron systems, a central-source multiplication (M) of 10 (k_{eff} = 0.9) corresponds to about 75% of the critical mass.**

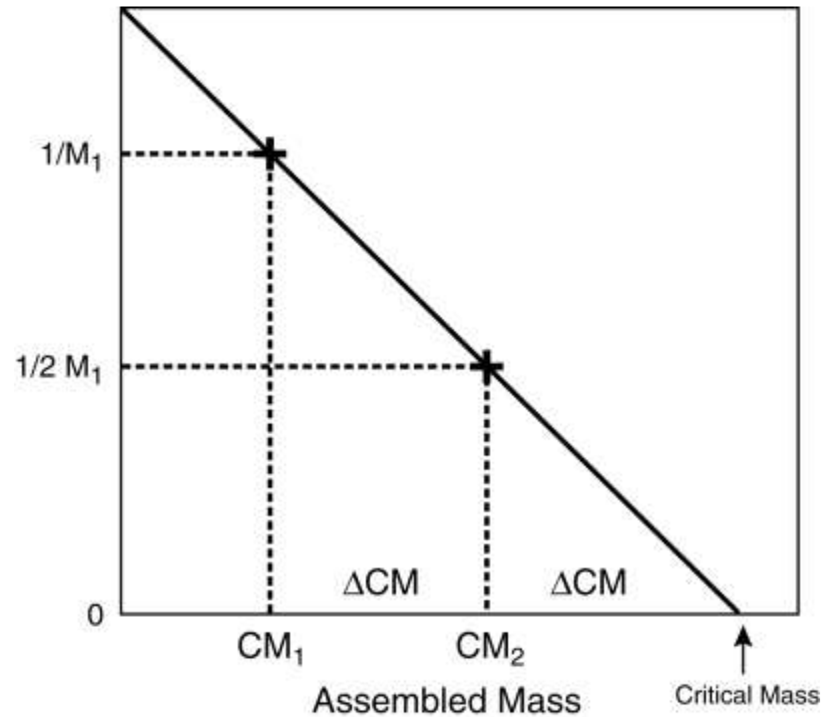
Approach to Critical – "Half-Way Rule"

- **No single-step addition goes more than half-way to critical**

  <u>OR</u>

- **No single-step addition shall double the multiplication.**

- **Basis — For a linear system, the next addition of the same size would be critical.**

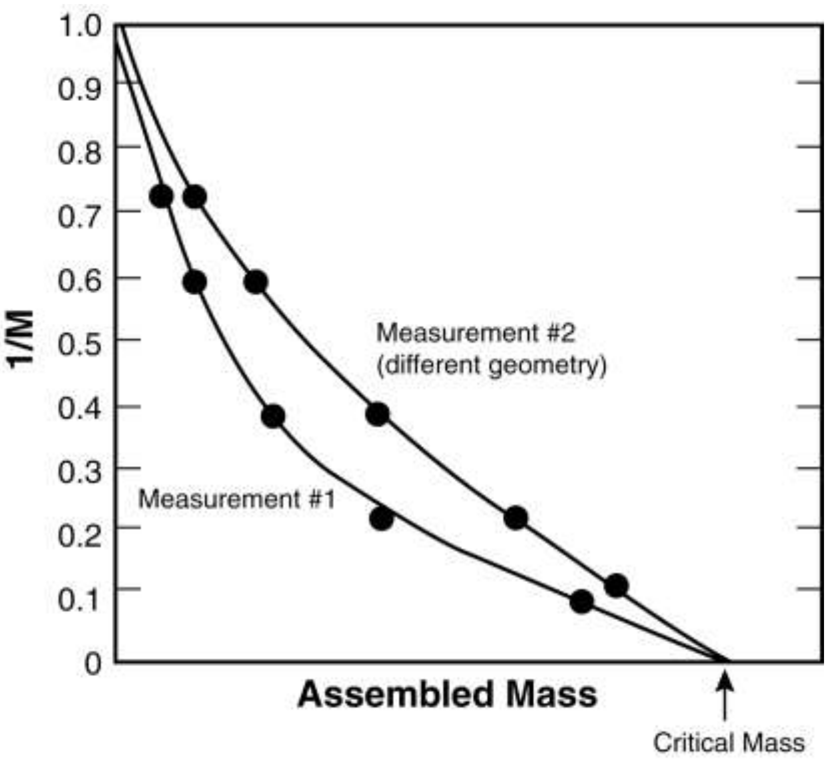


Approach to Critical – Experiment Design

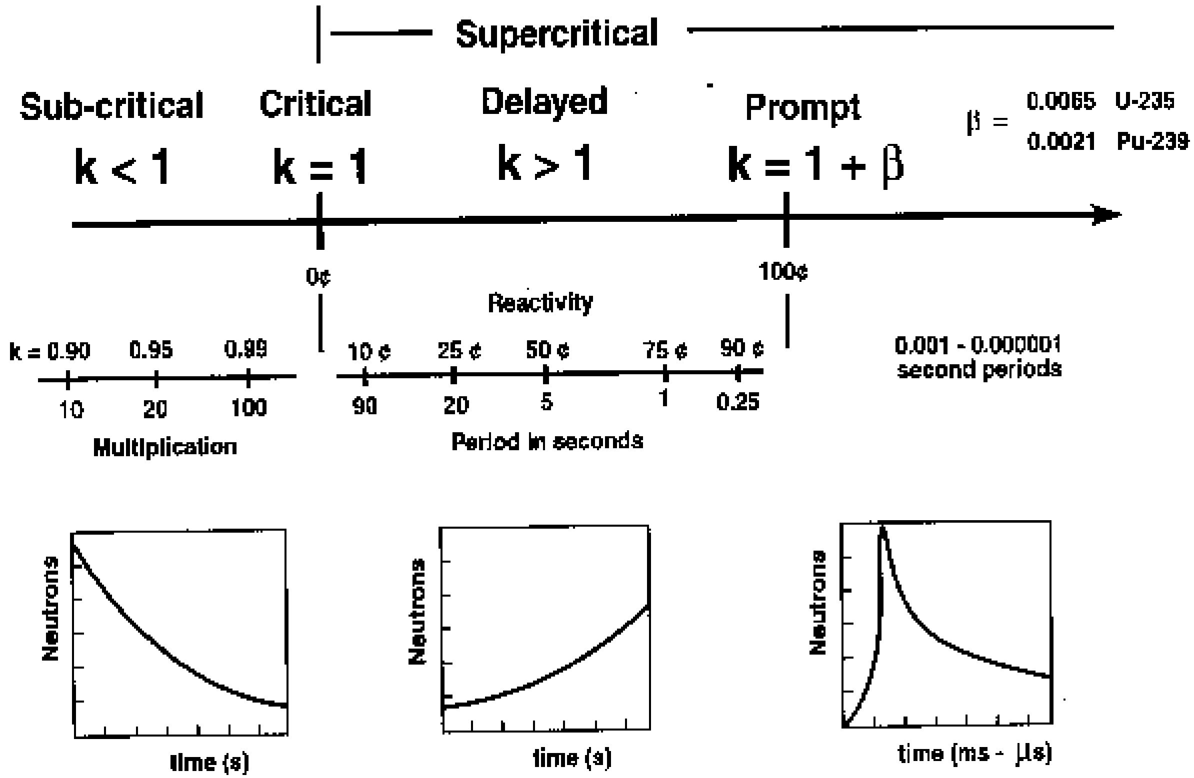
- **Use an effectively placed neutron source**
- **Use experiment design-geometry control**
- **Use remote assembly safety system**

Critical Mass Determination (1/M)

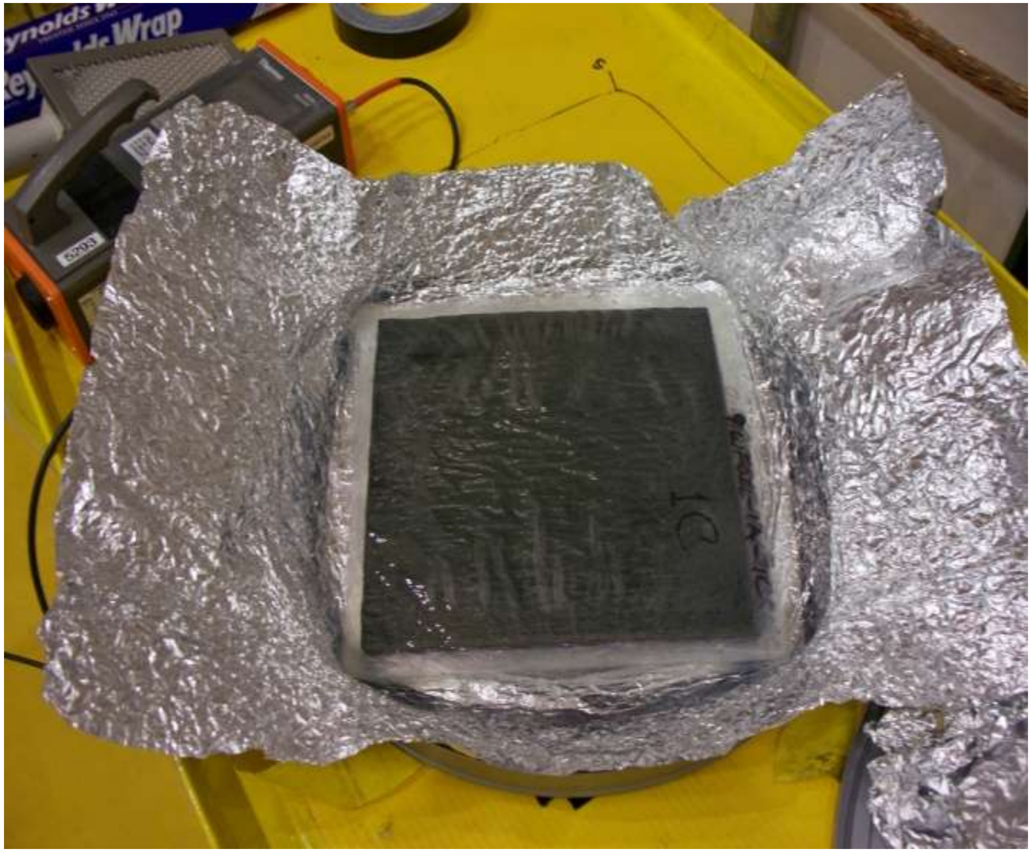
Step	Action
1	Determine base count Rate $M = \frac{\text{New count rate}}{\text{Base count rate}}$
2	Add additional material (fuel, reflector, etc.).
3	Measure new count rate and plot new 1/M.
4	Extrapolate to critical mass (1/M) = 0.
5	Determine safe addition for next step.
6	Repeat steps 2-5 to approach critical.



Behavior of Critical Systems



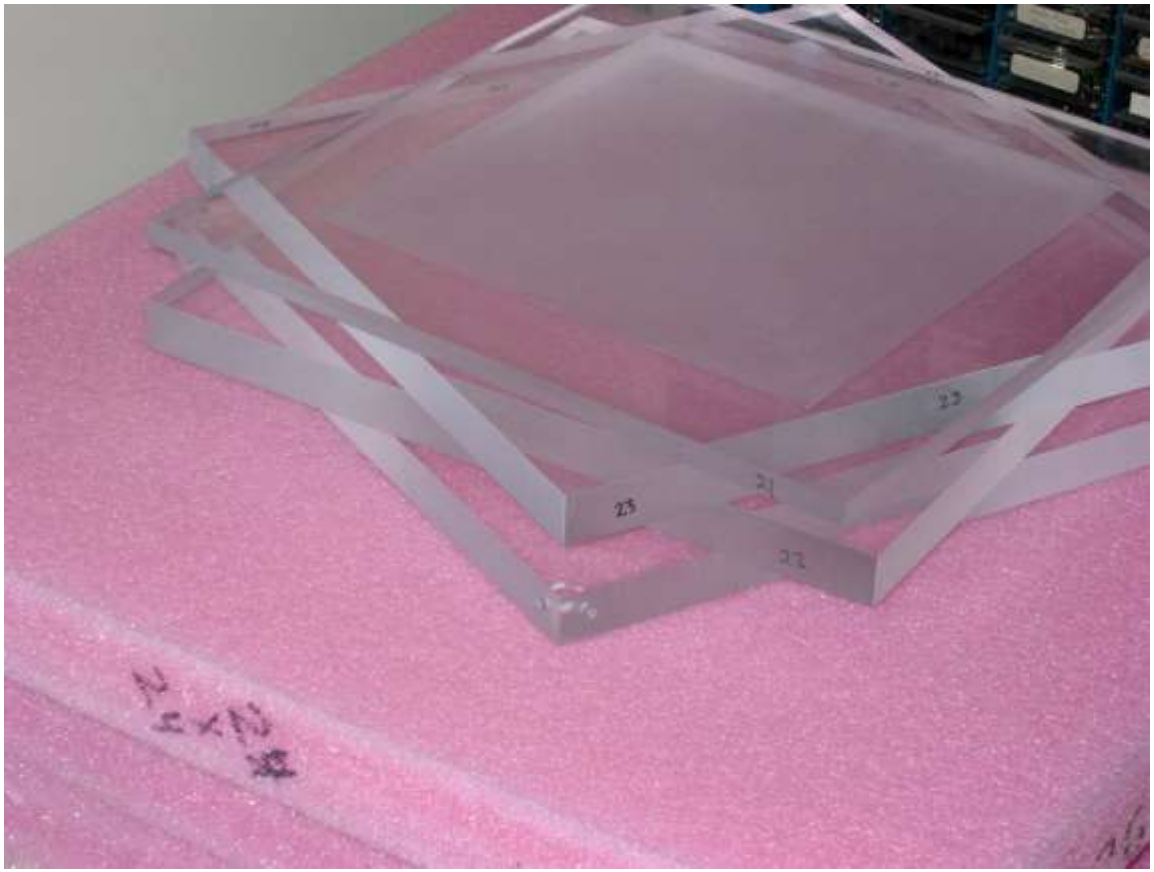
Fissile Material



Each foil weighed approximately 70 g.

Foils were 93.19 wt% ^{235}U

Lucite Plates (New)



Dimensions:

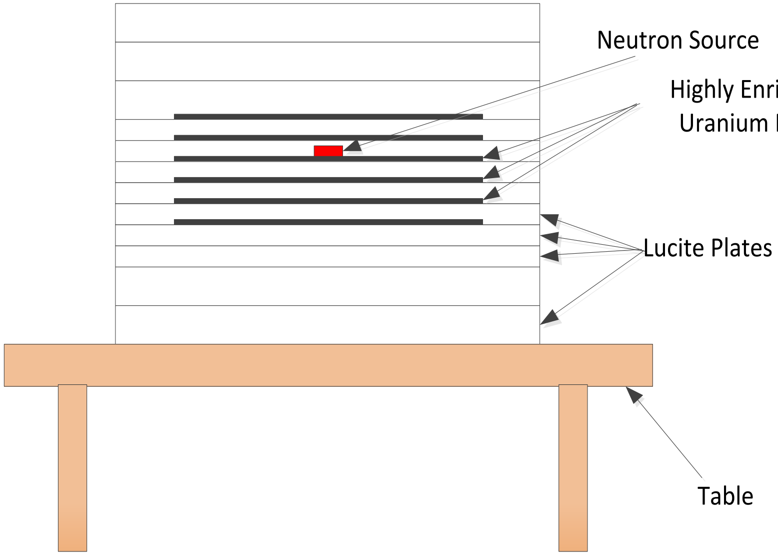
Two types
14” x 14” x 0.46”
14” x 14” x 0.92”

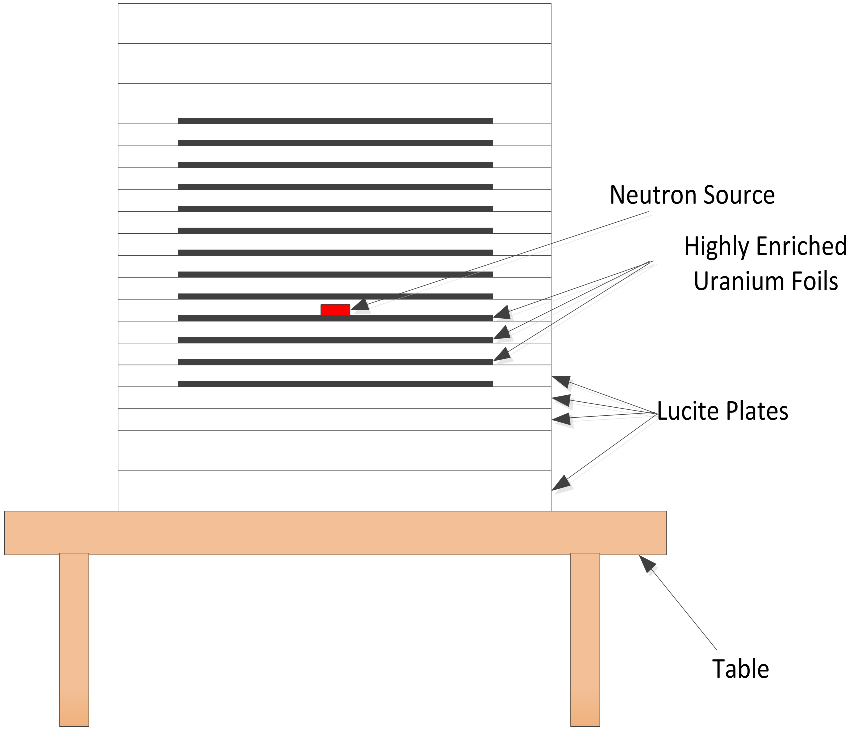
Density:

1.18 g/cc

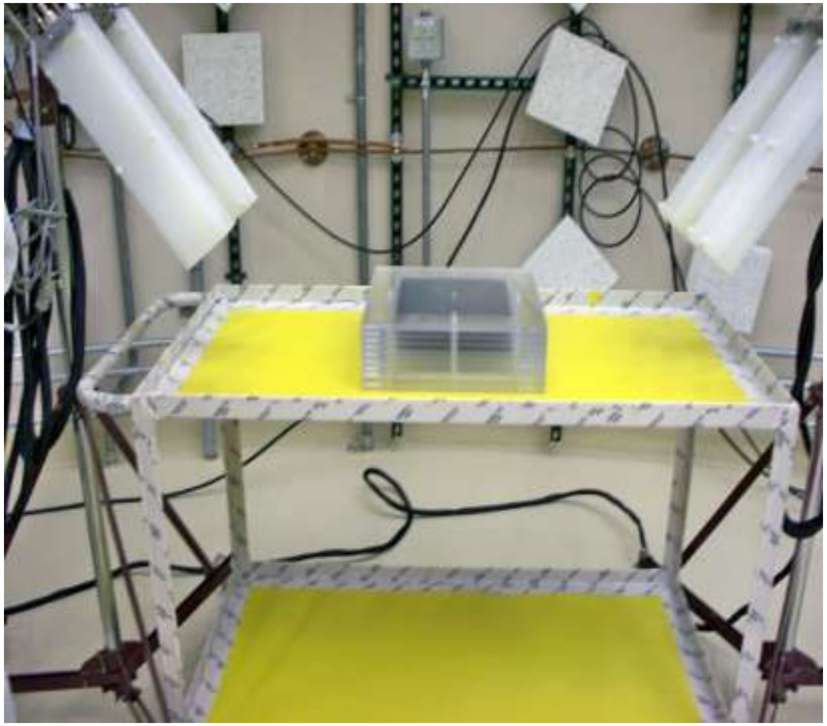
Planet Operations – Handstacking

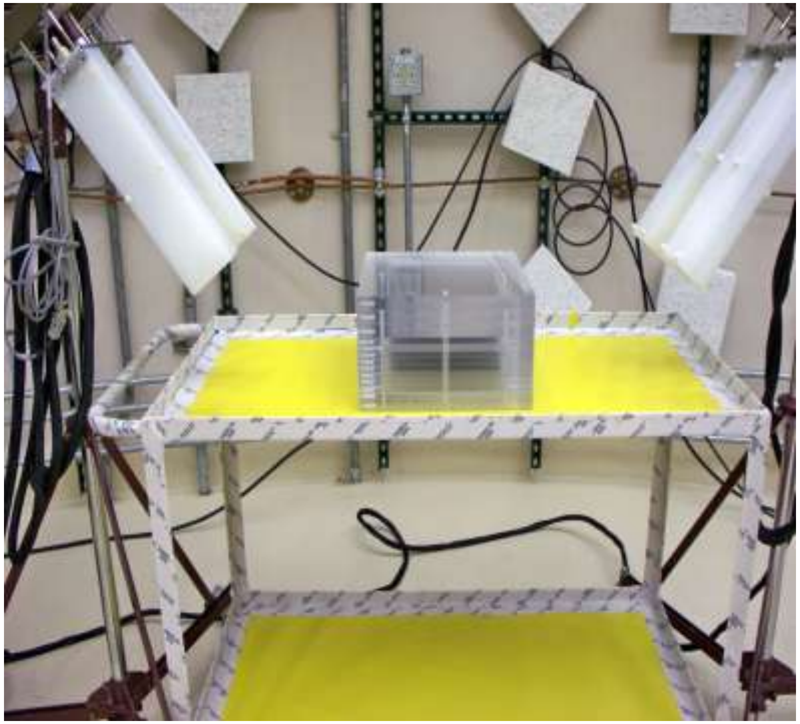
- Began Monday, June 13, 2011
- 6 units to 14 units



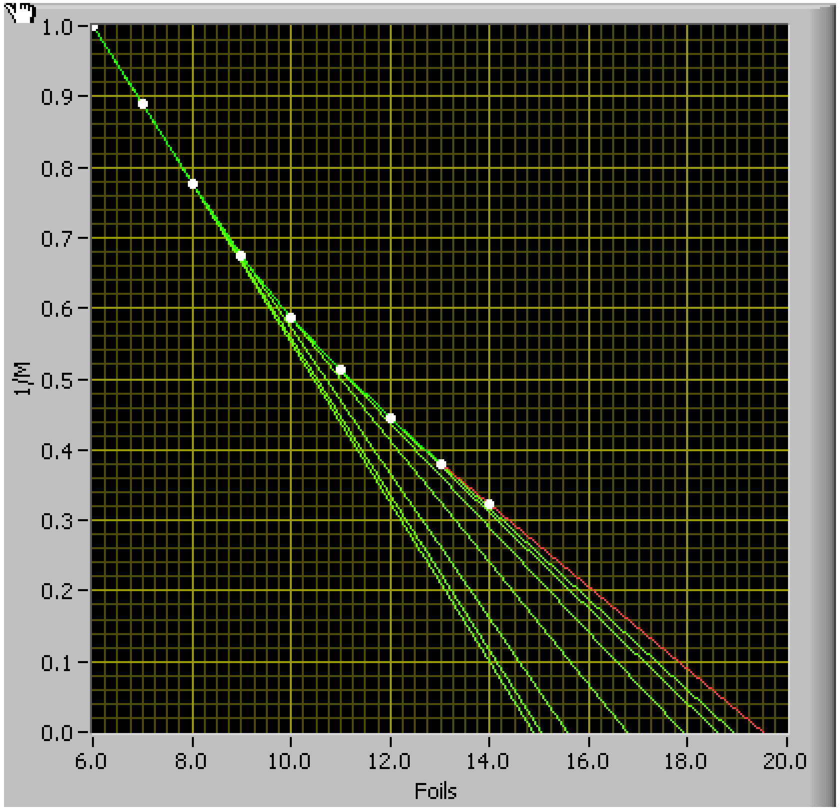


Hand-stacking Part of the Experiment





Handstacking 1/M

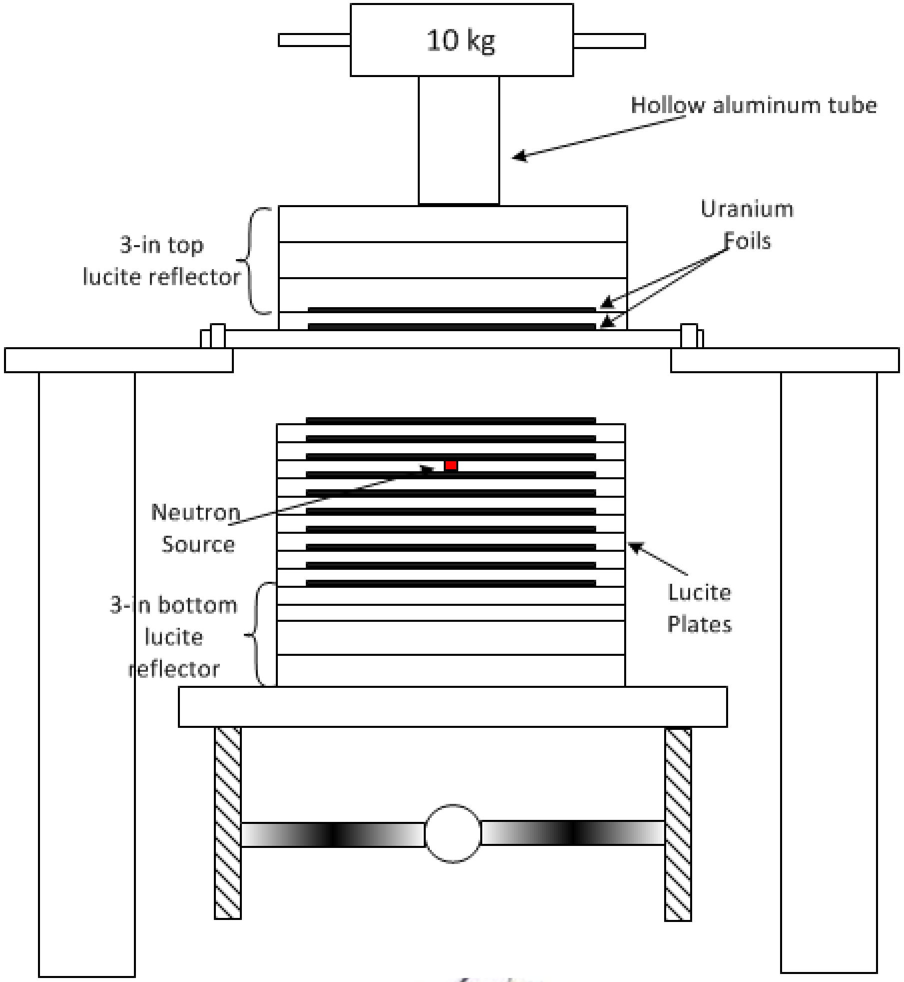


	Foils	Counts	1/M	Predicted Criticality
0	6.000	43921.000	1.000	Inf
1	7.000	49373.000	0.890	15.056
2	8.000	56563.000	0.776	14.867
3	9.000	65159.000	0.674	15.580
4	10.000	74769.000	0.587	16.780
5	11.000	85601.000	0.513	17.903
6	12.000	98567.000	0.446	18.602
7	13.000	115300.000	0.381	18.891
8	14.000	136241.000	0.322	19.506

½ Rule = 16.75

¾ Rule = 14.63

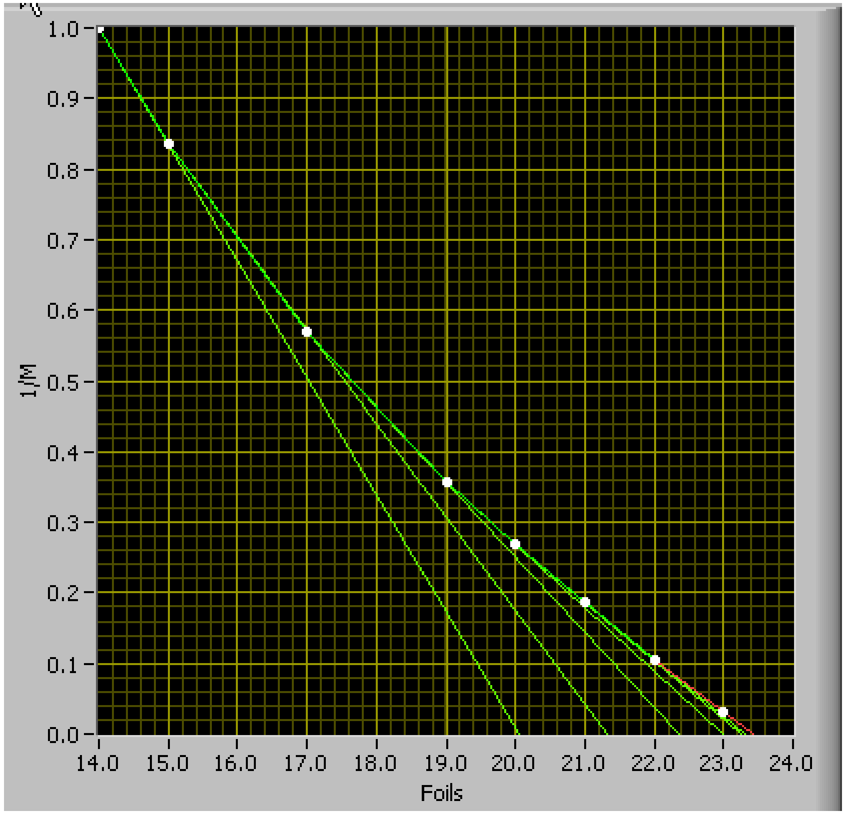
Criticality Safety Class Experiment "Split-Stack" for Remote Assembly



Planet Operations – Remote Approach-to-Critical

- **Tuesday, June 14, 2011**
- **14 units to 23 units**
- **10 units on Planet moveable platen**
- **Remainder on Planet stationary platform**

	Foils	Counts	1/M	Predicted Criticality
0	14.000	34298.000	1.000	Inf
1	15.000	41092.000	0.835	20.048
2	17.000	60098.000	0.571	21.324
3	19.000	95840.000	0.358	22.363
4	20.000	127741.000	0.268	23.004
5	21.000	184391.000	0.186	23.255
6	22.000	325201.000	0.105	23.310
7	23.000	1070016.000	0.032	23.437

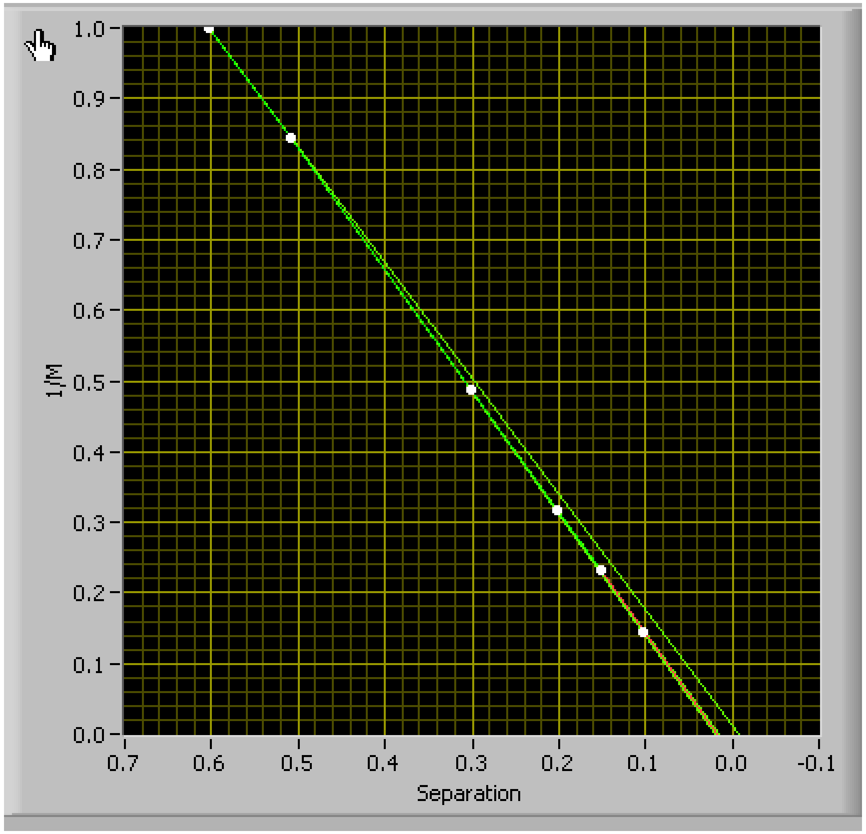


$$k_{eff} = \left(\frac{23.52}{23.437}\right)^{0.3} = 1.001061$$

$$\frac{\rho}{\beta_{eff}} = \frac{k_{eff} - 1}{k_{eff}\,\beta_{eff}} = 16.3 cents$$

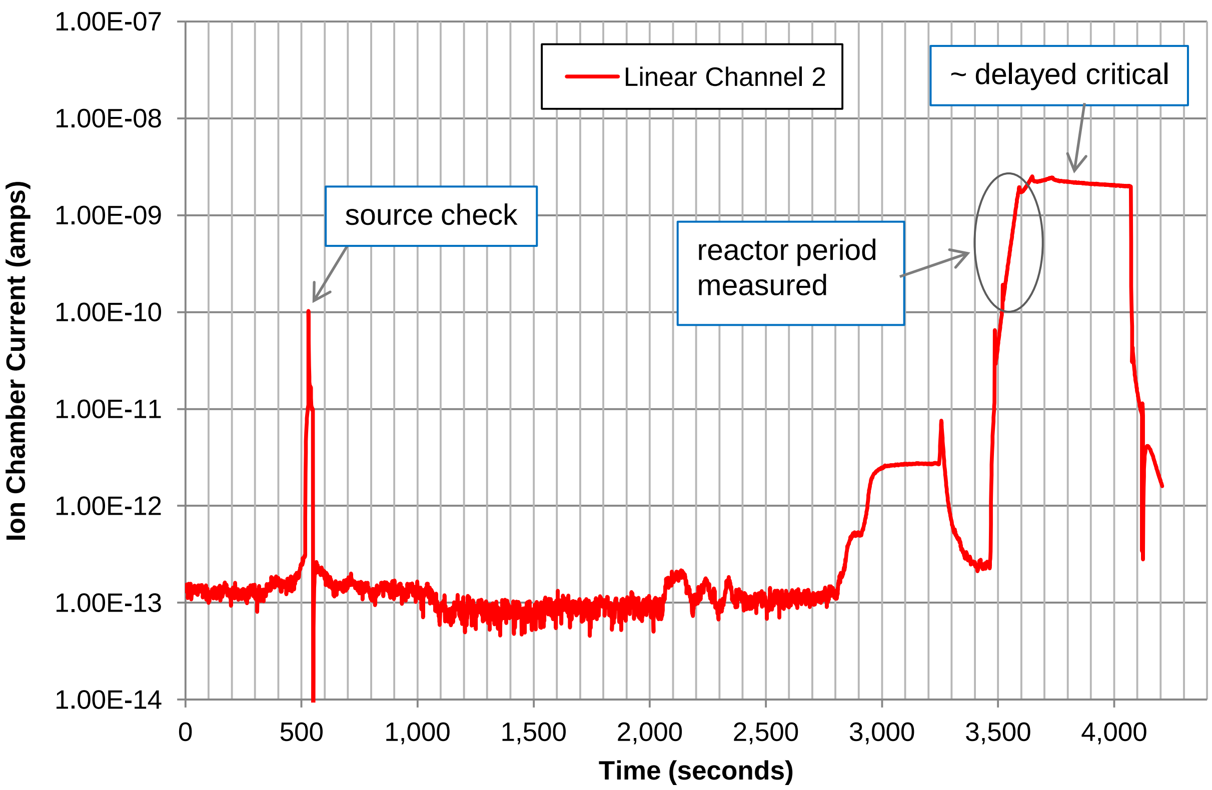
1/M versus Separation (23.52 foils)

June 15, 2011



	Separation	Counts	1/M	Predicted Criticality
0	0.604	9400.000	1.000	Inf
1	0.508	11146.000	0.843	-0.009
2	0.302	19288.000	0.487	0.020
3	0.201	29730.000	0.316	0.014
4	0.152	40700.000	0.231	0.019
5	0.102	65050.000	0.145	0.018
6				

Planet Operations



Inhour Equation

$$\rho(\$) = \frac{l}{\beta_{eff} * T} + \sum_{i=1}^{6} \frac{\beta_i / \beta_{eff}}{1 + \lambda_i T}$$

T= 23.4 sec

ρ = 26.2 cents

Experimental Results

New Plates (0.46”)	Average
Critical Mass: 1, 606 grams of Uranium (23.42 Foils)	68.68 g
Old Plates (TA-18) (0.5”) ~ 2004	
Critical Mass: 1490.35 grams of Uranium (21.7 Foils)	68.68 g
Old Plates (TA-18) (0.5”) ~1994	
Critical Mass: 1401.88 grams of Uranium (20.2 Foils)	69.40 g

Conclusions

- First critical experiment was successfully completed on June 15, 2011.
- The differences between this experiment and the one that was performed at TA-18 have been resolved.
- We repeated the TA-18 critical experiment using the old Lucite plates and there was difference.