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NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

New Hands-On Training and Research with the LLNL Training Assembly for Criticality Safety

Lawrence Livermore National Laboratory Training and Education FY2011 Accomplishments

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LLNL 4 Day NCS Training Overview

- First class in August of 2006
- Curriculum designed to satisfy DOE-STD-1135-99 requirements for hands-on NCS Training and reviewed by CSSG in 2006
- Lecture topics follow DOE-STD-1135 and include:
  - Criticality Safety Fundamentals
  - DOE NCS Regulations
  - Hand Calculations and Computational Methods
  - NCS Evaluations
  - Nuclear Instrumentation and Physics of Multiplying Systems
  - Criticality Accidents, including an in-class exercise with the ORNL Criticality Accident Slide Rule

Training Assembly for Criticality Safety (TACS)

- Eight Nimbus HEU Shells
- Vertical lift machine with lower, moveable platform driven by a hand crank
- 1-D, spherical assembly
- ^{252}Cf neutron source
- Subcritical with a peak multiplication of 10

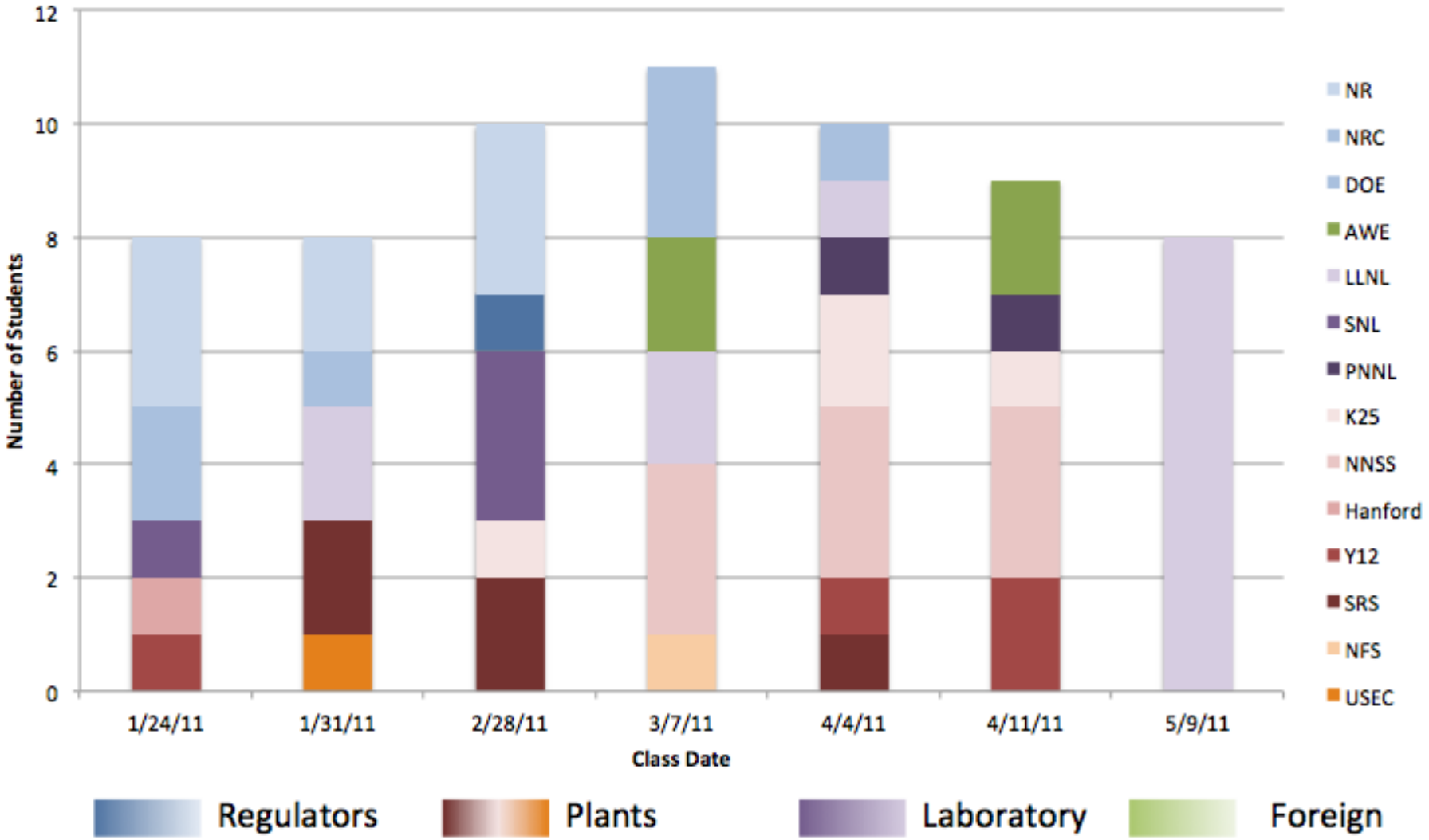
FY2011 Accomplishments Overview

- 7 classes conducted at LLNL with 64 students (student demographic information on next slide)

- Started up TACS in DAF as part of the new NCSP T&EP Nuclear Criticality Safety Engineer Hands-on Training and participated in the first pilot course

- Best poster award at ICNC 2011
  - Poster quantifying the effectiveness of operator hands as reflectors based on data gathered during LLNL classes

FY2011 Student Demographic Information



Transition to DAF

- LLNL shipped all TACS materials to DAF in July 2011
- Extensive effort over the summer to stand up TACS operations
  - Safety plans, work packages, radiation work permits
  - Workstation set-up (temporary location)
- Readiness Assessment (RA) for TACS
  - Management Requirements Certification Board (MRCB)
  - LLNL passed with no findings or areas for improvement
  - Start up approval in early August 2011

First Pilot NCSP T&EP Class

- TACS debuted in DAF during the first pilot for the new NCSP T&EP Nuclear Criticality Safety Engineer Hands-on Training Course, August 29-September 2, 2011

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ICNC 2011 Paper

An Experimental Study of the Effect of Operator Hands on the Reactivity of a Fast Metal System, C. Percher and D. Heinrichs

- Effect of hand reflection on multiplication experimentally measured during classes
- In 2008, we began measuring hand surface area and volume to try and correlate to multiplication increase
- Multiplication effects of 52 people's hands were quantified using the fissile/surrogate multiplication measurement technique

Experimental Method: Two Experiments

Experiment 1: Conduct experiment with neutron source and depleted Uranium (D38) shells and use ^{3}He neutron detectors to take count rate, C_o.

Experiment 2: Conduct experiment exactly the same as Experiment 1, including same detector placement, but instead of D38 use HEU shells. Measure count rate, C.

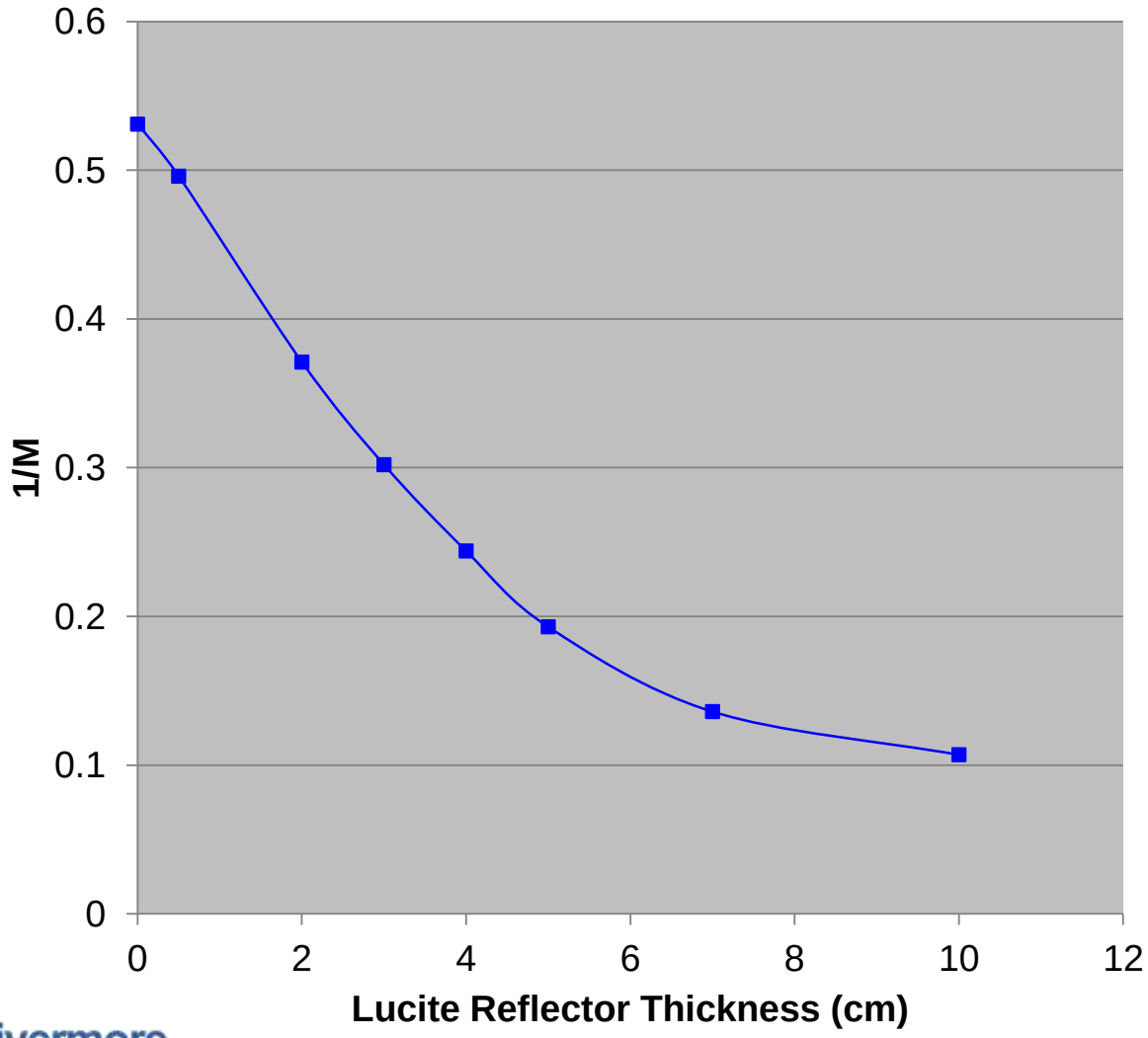
Use data collected from experiments to determine *observed* M

$$M_{obs} = \frac{C}{C_o}$$

Experimental Method: Approach to Critical

- Approach to Critical by Reflection
  - (1) Assemble TACS with bare D38 shells, determine neutron count rate, C_0
  - (2) Assemble TACS with bare HEU shells determine neutron count rate, C_1. Determine M_{obs1} ($=C_1/C_0$). Plot 1/M versus reflector thickness.
  - (3) Measure D38 shells (C_{02})and HEU shells (C_2) with thin reflector, determine M_{obs2} ($=C_2/C_{02}$). Plot 1/M versus reflector.
  - (4) Add progressively thicker reflectors and continue to plot 1/M versus reflector

Class Data: Approach to Critical by Reflector



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Hand Reflection Methodology

- For each class, one student with “small” hands and one student with “large” hands was selected

- Measurements with bare TACS assembly (no other reflectors)
  - One small hand
  - Two small hands
  - One large hand
  - Two large hands
  - 3 hands (two large, one small)
  - 4 hands

Hand Reflection Methodology

1 Small Hand

Hand Reflection Methodology

2 Small Hands

Hand Reflection Methodology

1 Large Hand

Hand Reflection Methodology

2 Large Hands

Hand Reflection Methodology

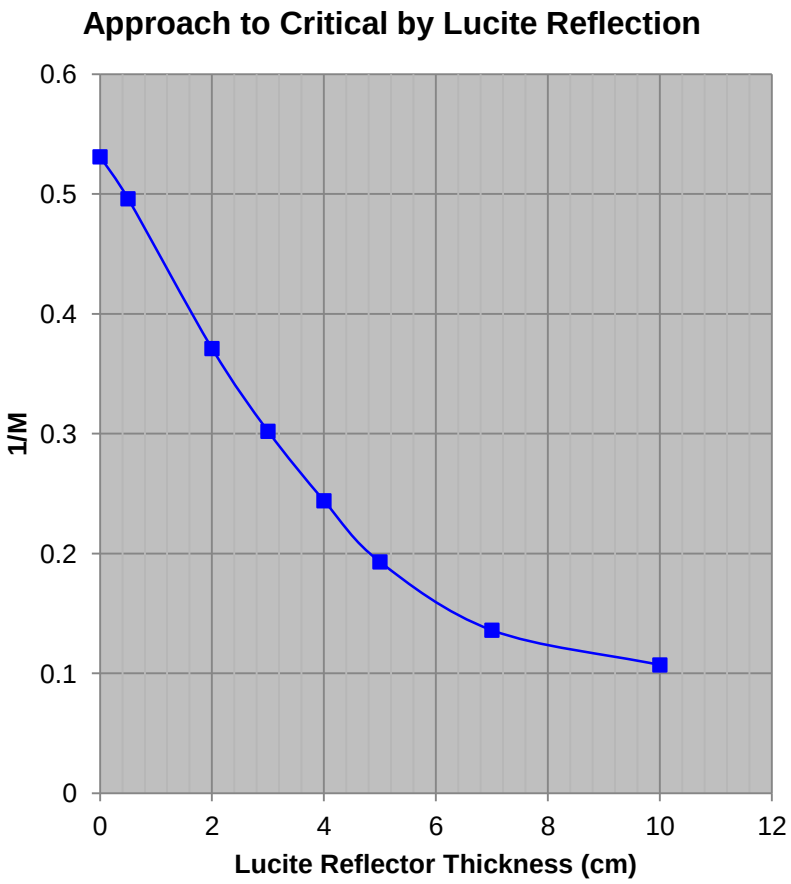
3 Hands

Hand Reflection Methodology

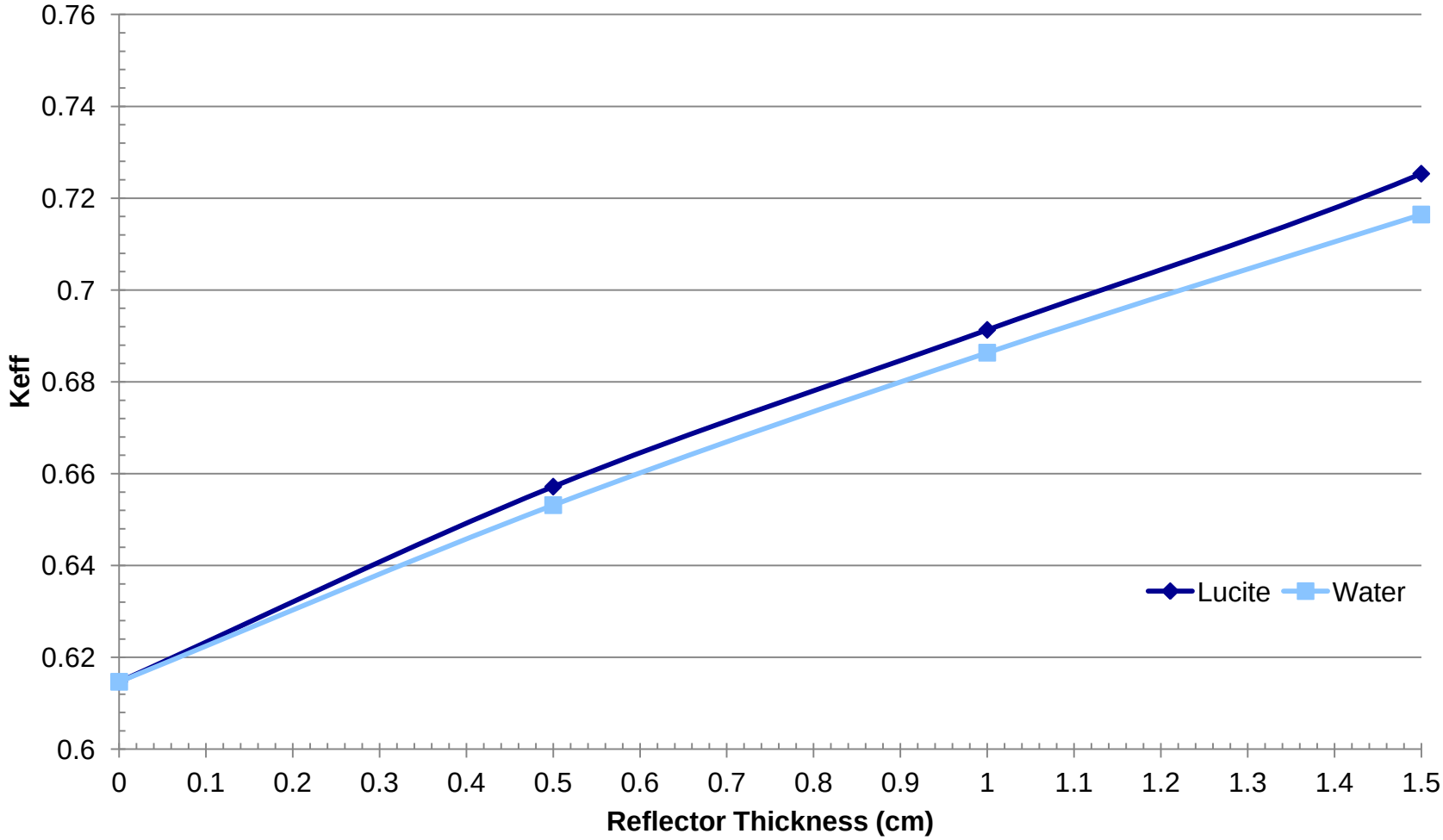
4 Hands

Relating Measured M values to Water Thickness

- For each hand configuration, determine 1/M
- Use 1/M data to determine an equivalent thickness of full Lucite reflection, based on data collected in class
- Use equivalent Lucite thickness to determine equivalent water thickness, based on a Monte Carlo calculation



Monte Carlo Comparison of Lucite to Water



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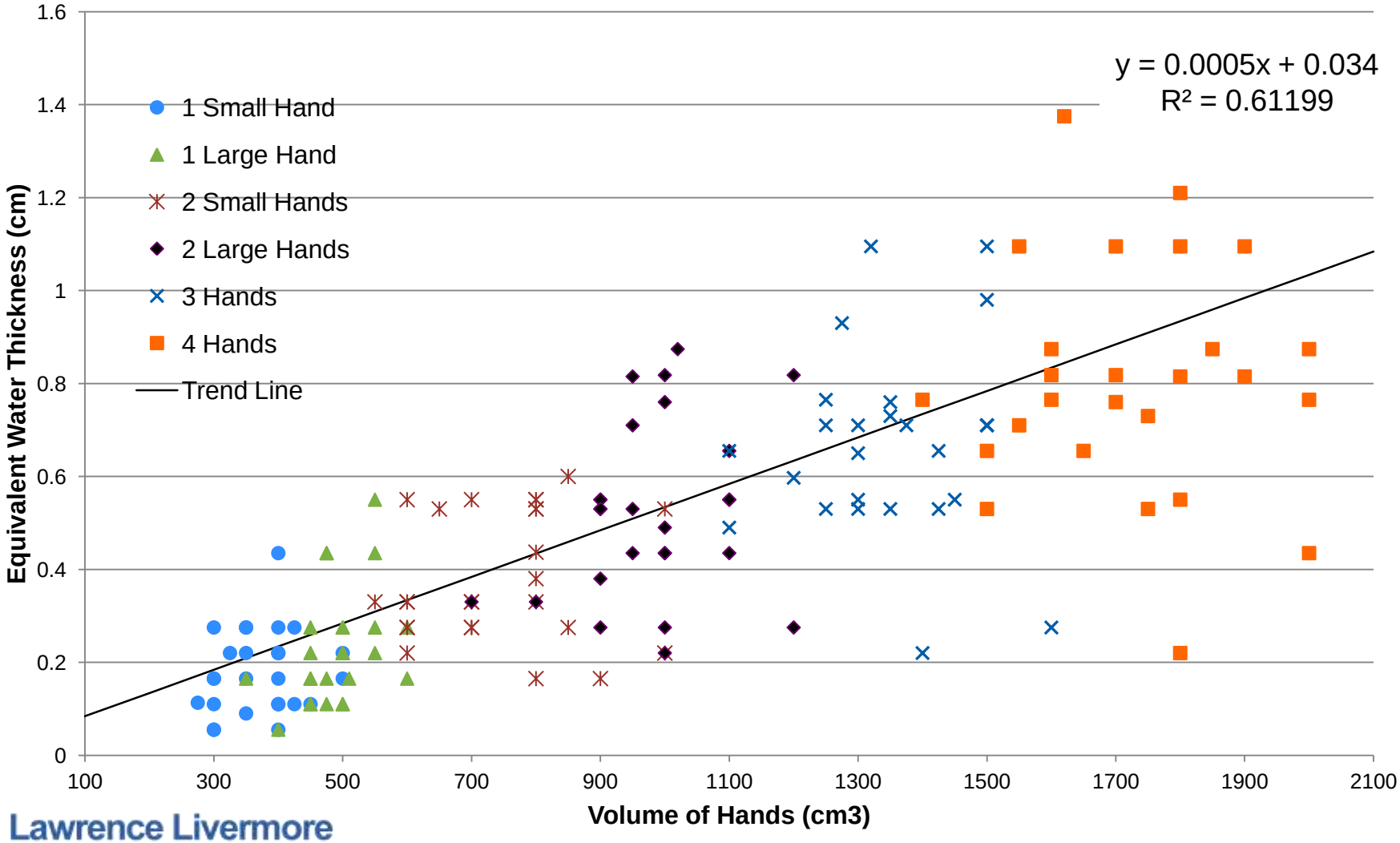
Hand Reflection Measurements

- 52 people's hands were measured, 26 "small" and 26 "large"
- Total of 156 individual measurements
- Hands were measured for surface area using graph paper
- The volume of hands was determined using water displacement in a graduated cylinder

Equivalent Water Reflection as a Function of Hand Volume



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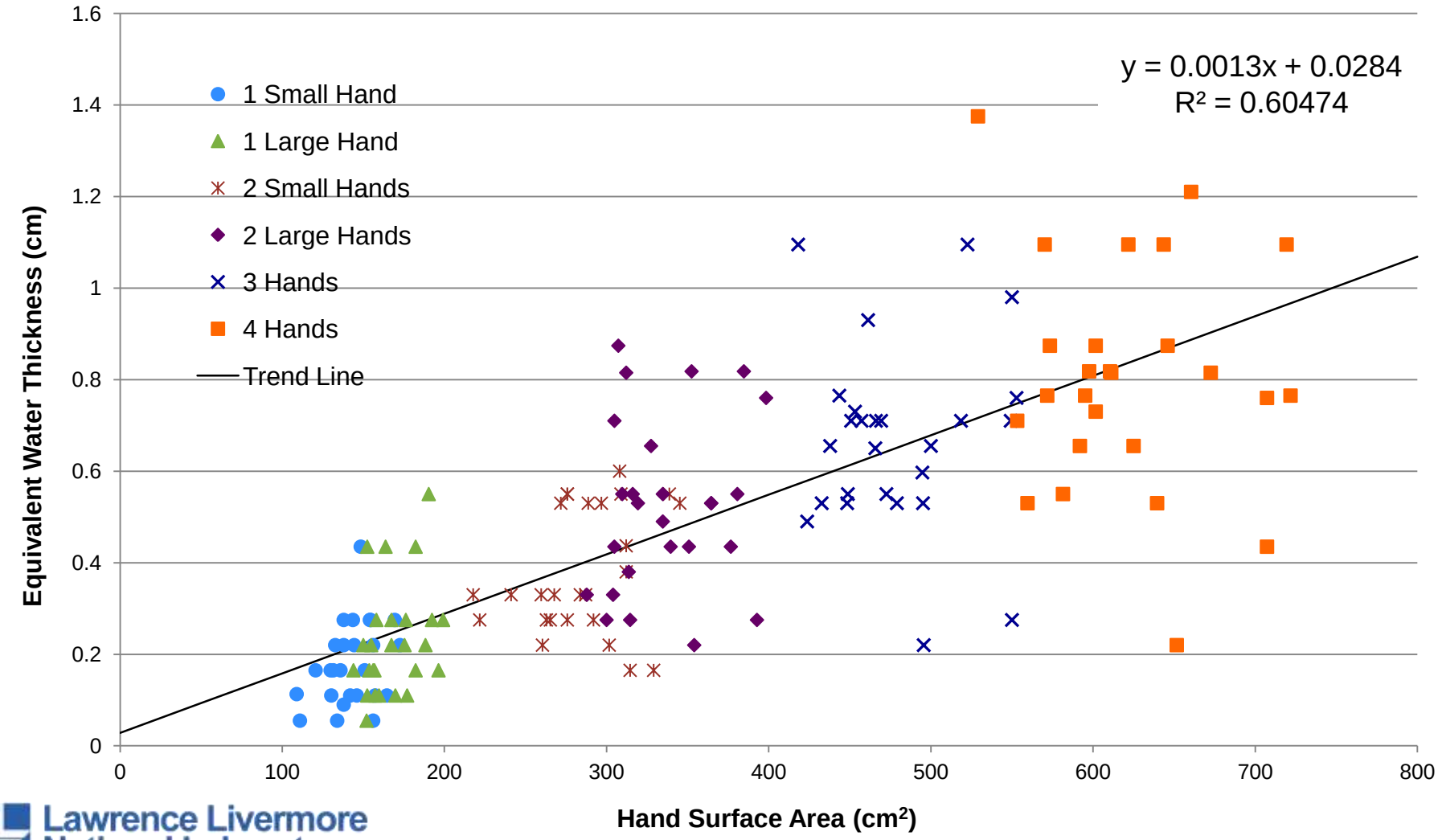
Equivalent Water Reflection as a Function of Hand Surface Area



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Observations

- Equivalent water thickness was generally a linear function of hand surface area and hand volume
- More scatter in the data with 3 and 4 hands- likely due to experimental constraints
- The highest equivalent water thickness for 4 hands was 1.4 cm (0.55 inches)
- Two hands produced a maximum equivalent water thickness of 0.9 cm (0.35 inches)

Conclusions

- TACS is compact in size (low surface area) and has a hard neutron spectrum, ensuring large reflector worth for each hand

- Experimental data illustrates that 1” water criterion is highly conservative, especially when considering large systems

- Based on this data, relaxation of the 1” criterion could likely be argued in many cases