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Title: An Overview of Stockpile Stewardship Research at Los Alamos

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EST. 1943

Abstract

An Overview of Stockpile Stewardship research at Los Alamos

Since 1992 the U.S. Nuclear deterrent has been maintained without nuclear testing. The science in the Stockpile Stewardship Program (SSP) has enabled this change, which is an important step in reducing the proliferation of nuclear weapons. The advances made in the SSP have allowed the U.S. Government to sign first the START, and recently the new Start treaty, which commit to significant reductions in the nuclear arsenals of the Unites States and Russia. I will discuss why science improvements are needed to accomplish this mission, and discuss the new experimental techniques that we are applying to the difficult scientific challenges of the SSP. Many of the advanced techniques are the direct result of previous basic science investments at Los Alamos. I will also discuss a set of new applications resulting from the capabilities developed for stockpile stewardship.

The Viewgraphs submitted for publication entitled "Hitchhiker's guide to stockpile stewardship: the intersting story of Los Alamos influence on U.S. science", first author Susan J Seestrom, 092217 has been reviewed and received the following release number: LA-UR 11-05140. The abstract is U and the text is U
Please call 7-5013 if you have questions.

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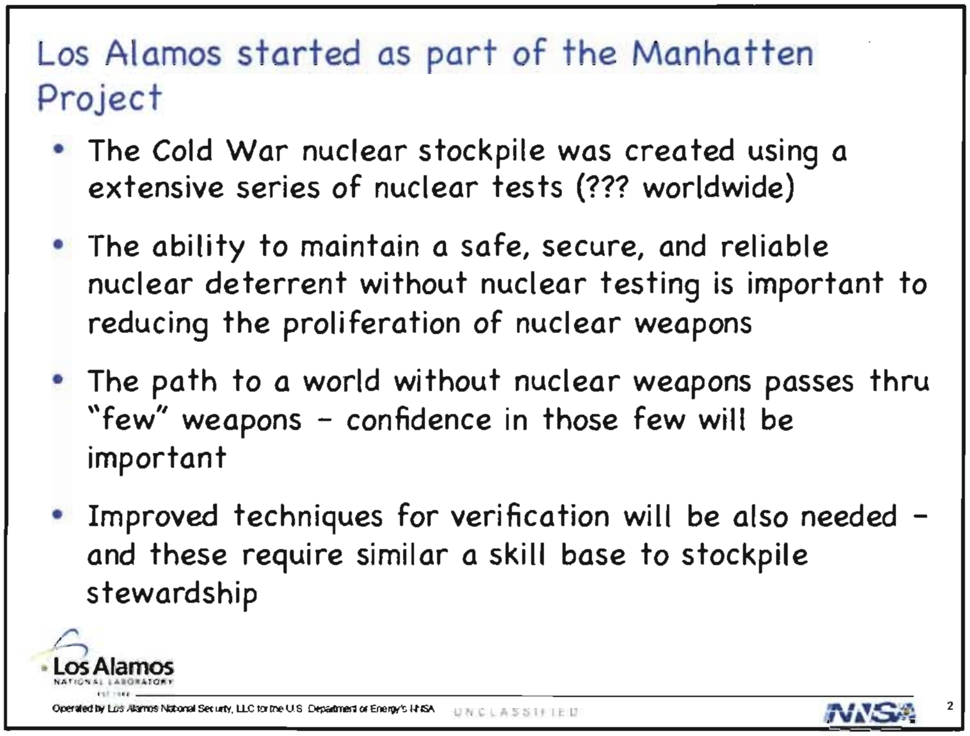
Susan,

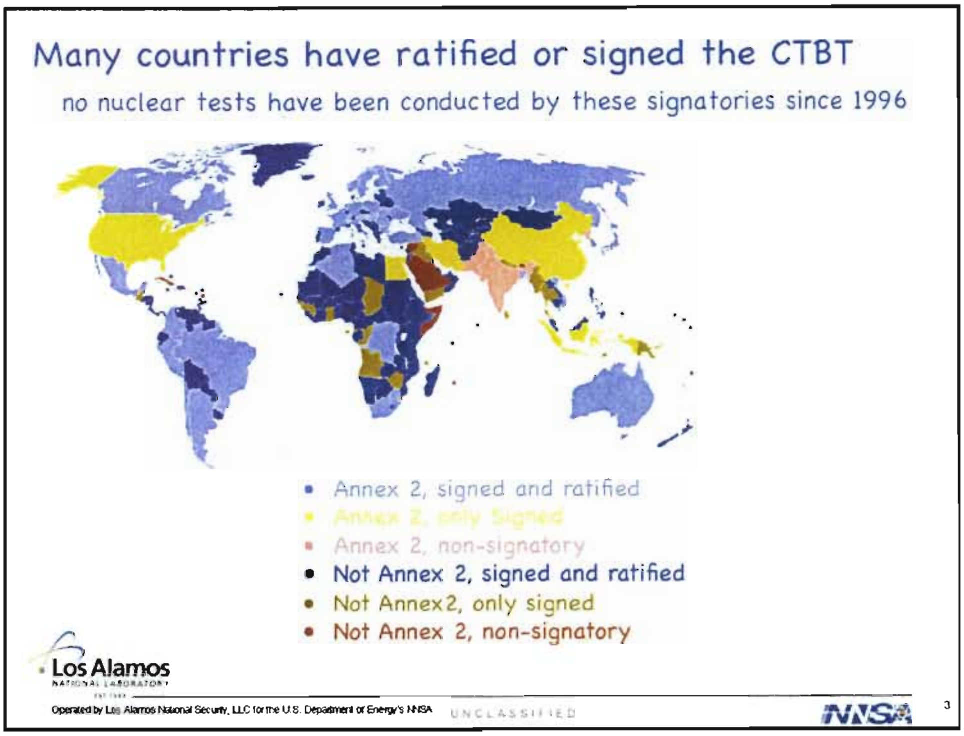
I transferred a copy of the jeep pic to LANL some time ago for Doug's Physics news. The picture was taken by my father abt 1946 on the pipeline road. Hans Bethe on the left front seat. Enrico Fermi behind him. Henry Bethe behind me.

Nick



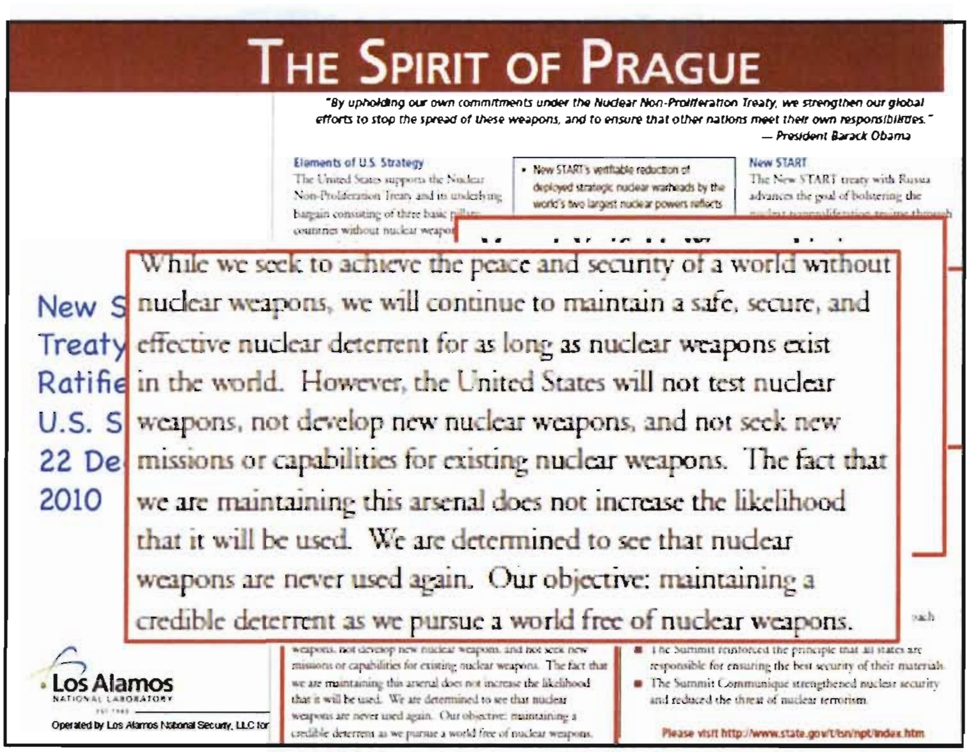
References – e.g APS report:
Science and technology (S&T) will play a critical role in advancing the US plan to balance deterrence
with downsizing the US nuclear arsenal. In particular, S&T are essential to enable three key
goals associated with this plan:
1) verifying the process of downsizing and dismantling stockpiles;
2) sustaining the capability and expertise to ensure that the remaining arsenal is safe, secure, reliable and
effective for as long as is necessary; and,
3) ensuring the peaceful use of fissile materials.

LANL and stockpile stewardship is to broad to cover in a single talk- I will present a particular slice through the subject based on my experience of 30 years as scientist and later leader at LANL
I will also focus on the impact of a single large facility – LAMPF (now LANSCE)



Last nuclear test: ???
US UK Soviet Union last test 1992
China, France tested thru 1996 (when China signed)

Since only India, Pakistan, N Korea
English: Participation in the Comprehensive Nuclear-Test-Ban Treaty as of May 26, 2010
Annex 2, signed and ratified light blue
Annex 2, only signed yellow
Annex 2, non-signatory pink
Not Annex 2, signed and ratified dark bluw
Not Annex 2, only signed green
Not Annex 2, non-signatory red
Date 27 May 2009
Annex 2 – states hvavinf reactors...Algeria, Argentina, Australia, Austria, Bangladesh, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Democratic People's Republic of Korea, Egypt, Finland, France, Germany, Hungary, India, Indonesia, Iran (Islamic Republic of), Israel, Italy, Japan, Mexico, Netherlands, Norway, Pakistan, Peru, Poland, Romania, Republic of Korea, Russian Federation, Slovakia, South Africa, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, United States of America, Vietnam, Zaire


THE SPIRIT OF PRAGUE
"By upholding our own commitments under the Nuclear Non-Proliferation Treaty, we strengthen our global efforts to stop the spread of these weapons, and to ensure that other nations meet their own responsibilities."
— President Barack Obama
Elements of U.S. Strategy
New START
New S
Treaty
Ratifie
U.S. S
22 De
2010
While we seek to achieve the peace and security of a world without nuclear weapons, we will continue to maintain a safe, secure, and effective nuclear deterrent for as long as nuclear weapons exist in the world. However, the United States will not test nuclear weapons, not develop new nuclear weapons, and not seek new missions or capabilities for existing nuclear weapons. The fact that we are maintaining this arsenal does not increase the likelihood that it will be used. We are determined to see that nuclear weapons are never used again. Our objective: maintaining a credible deterrent as we pursue a world free of nuclear weapons.
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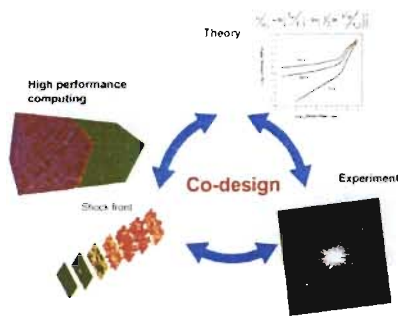
Please visit http://www.state.gov/t/isn/npt/index.htm

Stockpile Stewardship uses the science of prediction & uncertainty quantification for complex systems and networks

- Quantitative tools for decision makers
- Common to multiple areas – climate modeling, electric grid, etc.



A number of scientific disciplines are needed to achieve a predictive capability

Stockpile stewardship requires integration of key tools and disciplines

- Tools
  - High performance computing
  - Experimental facilities
  - Manufacturing facilities
  - Computer codes
- Scientific Expertise
  - Materials, including actinides
  - Nuclear Physics
    Plasma Physics
  - High Explosives
  - Hydrodynamics/ turbulence

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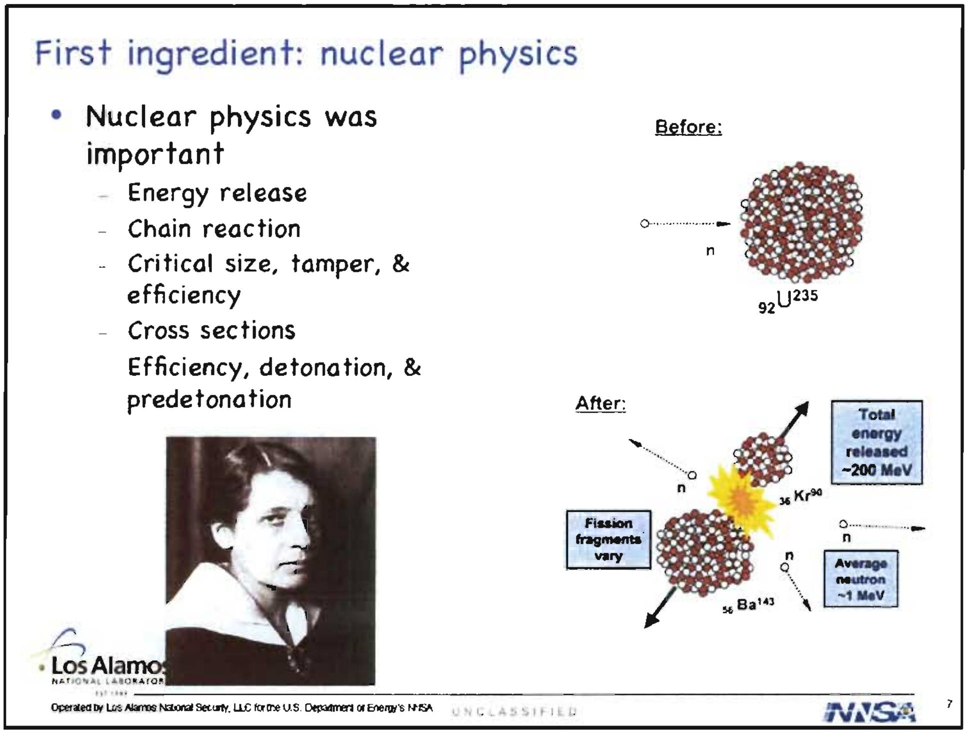
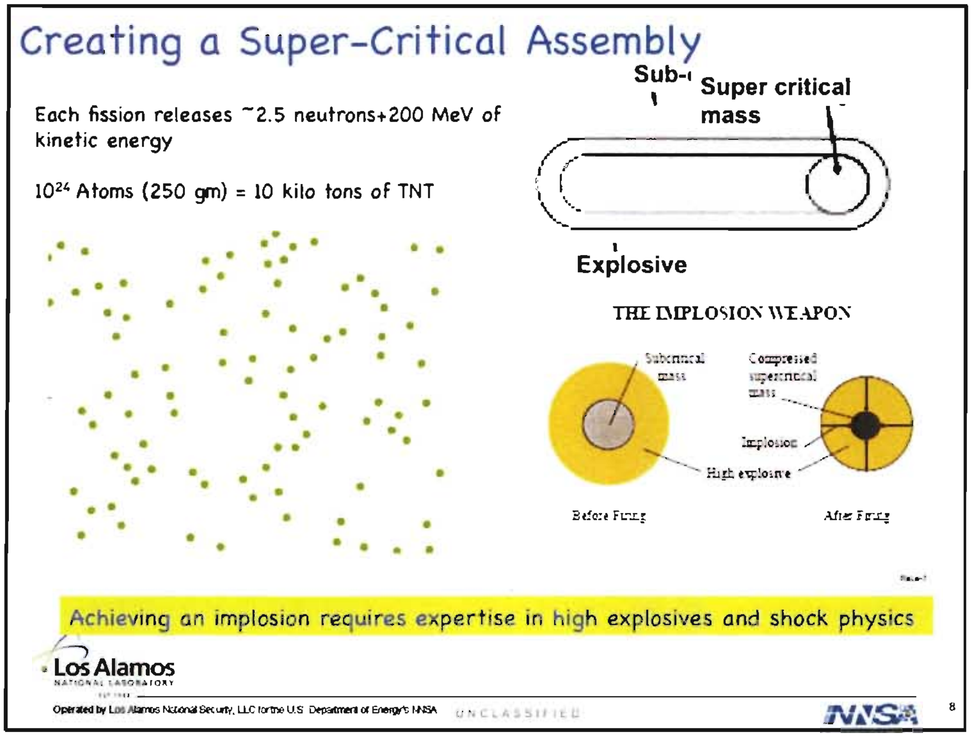
Find an open slide on stockpile numbers
Find some references to CTBT and New start (look at the popa stuff)



Better picture – include Hahn/Meitner/Strassmann – reference to date



Useful to have a reactoe example?

Thin Man Crisis

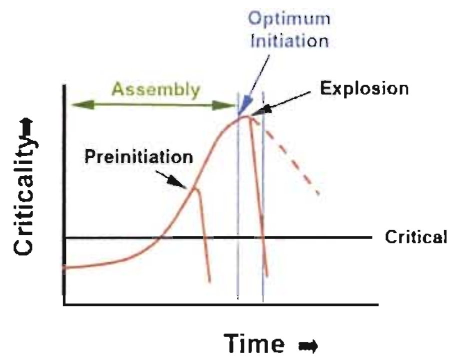
- First samples of reactor produced Pu were received from Oak Ridge for analysis at Los Alamos in April 1944
- Analysis by Segre's group showed high neutron background rate due to spontaneous fission in ^{240}Pu (5X Seaborg's initial sample)
- Assembly speed of Thin Man wasn't fast enough and the plutonium gun was abandoned
- Los Alamos refocused toward development of the implosion weapon

$$^{238}_{92}U + n \rightarrow {}^{239}_{92}U \xrightarrow{\beta^-} {}^{239}_{93}Np \xrightarrow{\beta^-} {}^{239}_{94}Pu$$

$T_{1/2}$: 24 Minutes; 2.4 Days; 24,110 Years

$$^{239}_{94}Pu + n \rightarrow {}^{240}_{94}Pu$$

$T_{1/2}$: 6535 Years



Neutron background rates:
HEU : ~1 neutron/kg/second
WGPu : ~60,000 neutrons/kg/second
RGPu : ~300,000 neutrons/kg/second

Critical Assembly - A Technical History of Los Alamos during the Oppenheimer Years, 1943-1945, republished by Cambridge University Press in 2004

Reactors produce large neutron production rates
- Large neutron flux also results in production of 240Pu via additional neutron capture reactions
- 240Pu has high spontaneous fission rate, resulting in a large neutron background

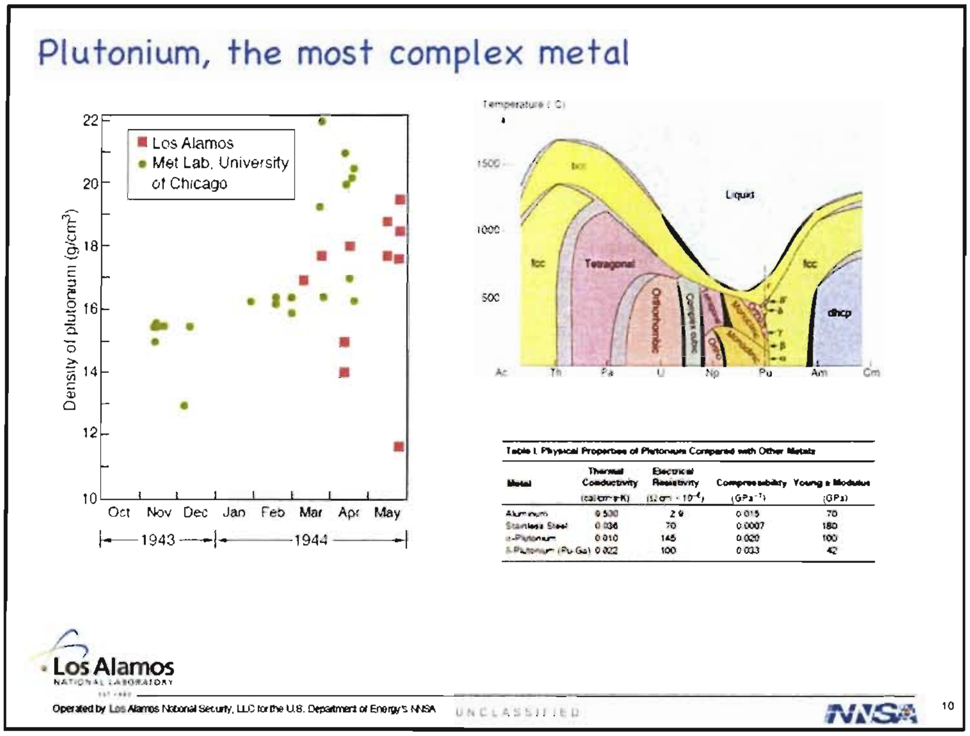


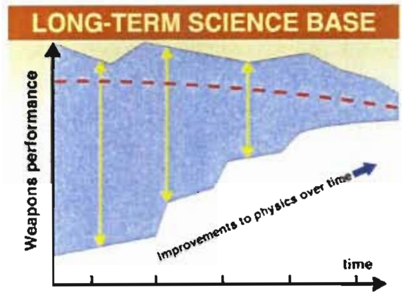
Table I. Physical Properties of Plutonium Compared with Other Metals

Metal	Thermal Conductivity (cal/cm-s-K)	Electrical Resistivity (Ω cm × 10^{-6})	Compressibility (GPa^{-1})	Young's Modulus (GPa)
Aluminum	0.530	2.9	0.015	70
Stainless Steel	0.036	70	0.0007	180
α-Plutonium	0.010	145	0.020	100
δ-Plutonium (Pu-Ga)	0.022	100	0.033	42

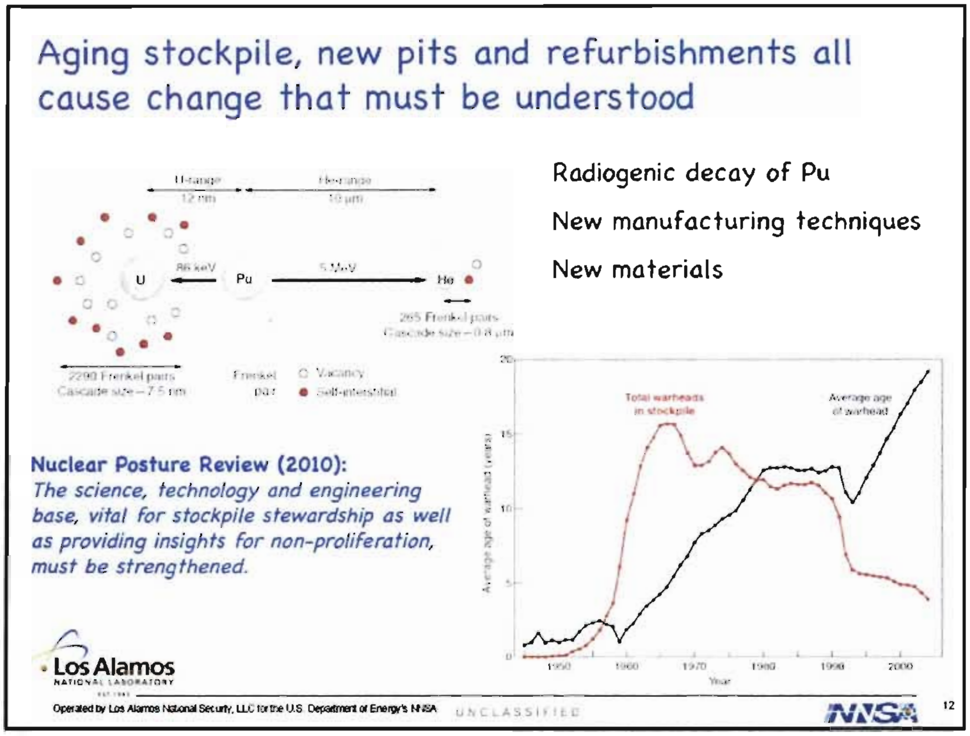
Alll these pictures are from LA Science on PU
Variations in Pu density baffled MP chemists and mettaluryst until about midway thru 1944 – discovered no less than five allotropic [hases
Connected binary phase diagram of the actinides illustrates transition from typical metallic behavior at thorium to complex behavior at PU and back to typical metal past americium

Future certification will depend on increasingly on a science-based assessment of performance

- Quantification of Margins and Uncertainties (QMU) is a methodology to quantify weapon performance at a level of confidence (risk).
- We are presently using QMU to assess changes that are small perturbations on the tested configurations
- Science-based predictive capability must improve as we move farther from the tested regime



Our science base increases in importance as uncertainty about future stockpile requirements increases!



When a plutonium nucleus undergoes α-decay, the recoiling uranium and helium nuclei knock plutonium atoms from their lattice sites. Displaced plutonium atoms come to rest at interstitial sites and leave lattice vacancies behind. Each displaced plutonium atom creates a Frenkel pair—consisting of a vacancy and a self-interstitial. Each decay event creates more than 2000 Frenkel pairs. The cascade size is the space occupied by the Frenkel pairs created during a certain decay event.

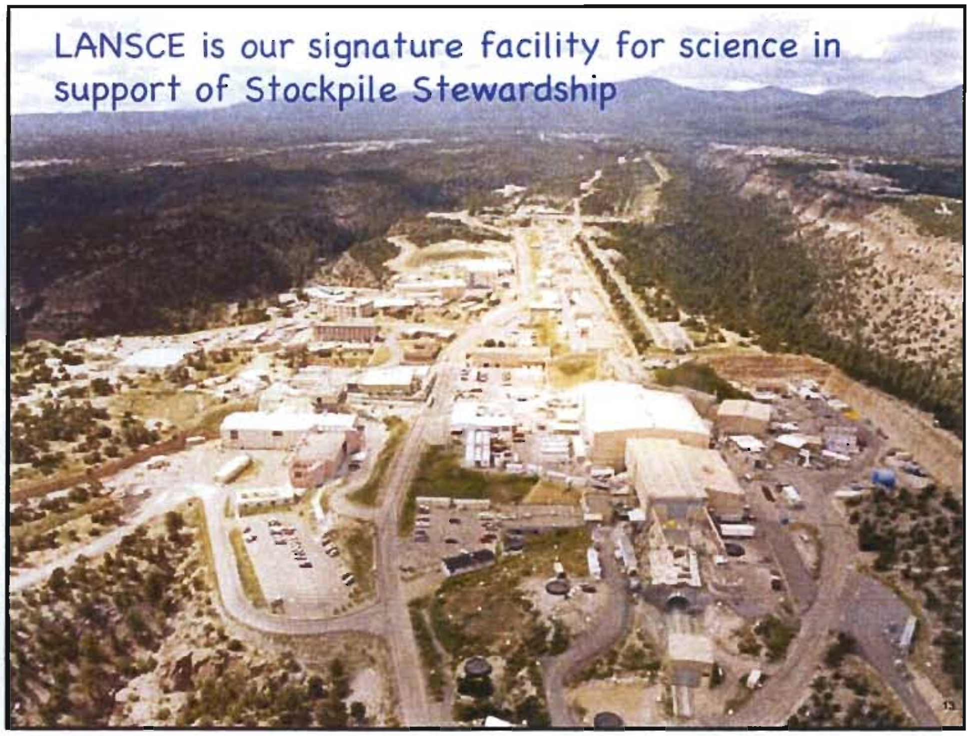
From the NPR: Second, implementation of the Stockpile Stewardship Program and the nuclear infrastructure investments recommended in the NPR will allow the United States to shift away from retaining large numbers of non-deployed warheads as a hedge against technical or geopolitical surprise, allowing major reductions in the nuclear stockpile. These investments are essential to facilitating reductions while sustaining deterrence under New START and beyond.

The NPR concluded:

• The science, technology and engineering base, vital for stockpile stewardship as well as providing insights for non-proliferation, must be strengthened.

• Increased investments in the nuclear weapons complex of facilities and personnel are required to ensure the long-term safety, security, and effectiveness of our nuclear arsenal. New facilities will be sized to support the requirements of the stockpile stewardship and management plan being developed by the National Nuclear Security Administration.

• Increased funding is needed for the Chemistry and Metallurgy Research Replacement Project at Los Alamos National Laboratory to replace the existing 50-year old facility, and to develop a new Uranium Processing Facility at the Y-12 Plant in Oak Ridge, Tennessee.


LANSCE is our signature facility for science in support of Stockpile Stewardship

A history - LAMPF

- Bethe Panel 1964
- Full energy beam 1972
- Scientific highlights
  - Pure neutron/proton states
  - Neutrino Oscillations
  - Parity Violation (p,p)
  - Discovery IVMR in CEX
  - Double analog states in heavy nuclei
  - New proton rich nuclei
  - Spin structure functions
  - Quenching Gamow-Teller
- 1996 - LAMPF becomes LANSCE
  - Focus on neutrons and materials science

Theme: a facility with unprecedented capability leads to unimagined applications!

Alvarez – high power linac – in the 50s he was trying to build a high power acceerator at LLNL to breed fissile materials and make trituion – high power neutron source
Put a pion picture in here?
Need dates
A roadmap (pions (pure n, P), pion DCX, mu-egamma, LSND/neutrino oscillations – neutron source WNR->Lujan n sctatering, parity violation/resonance spectroscopy (->Prad ->murad and UCN in parallel

LANSCE is a unique and diverse set of premier research facilities for addressing complex challenges facing our Nation in national security, energy security, medicine, and fundamental research to highlight a few

Presently composed of five facilites that are driven in common by the 800 MeV proton linac

At the Lujan center - the 800 MeV protons impact a W target and make lots of neutrons - roughly 20 to one. The neutrons are moderated by water (rt) and liquid hydrogen (20 kelvin) and used as a world class materials probe and for invesigating low energy nuclear science.

IPF:ur primary products are Sr-82 (cardiac imaging) and Ge-68 (Positron Emission Tomography calibration). Domestically, LANL produces roughly 70% of these isotopes with BNL producing the balance. INR in Russia provides some raw Sr-82 material that is solely processed by LANL. Nordion (Canada) and iThemba (South Africa) are the only other viable suppliers of Sr-82. We produce at much higher volumes.
Ge-68 is also produced at BNL and a couple Russian sources (Mayak).

Demand for Sr-82 is growing – up 350% since 2005. Ge-68 is also growing as the daughter isotope Ga-68 is being accepted as a new clinical imaging agent. The Mo-99 shortage has accelerated the move from CT scans (employing Tc-99m) to PET. Once clinics have made the investment in PET, they will not likely return to CT. The Sr-82 IS used in a generator technology. Currently 110 generators are fielded each month.....the owner of the generator technology anticipates that by Sept 2011 that the number of generators will be close to 180....the growth potential for Sr-82 is staggering.
Operated as a DOE national user facility - all research performed is competitively selected by a national committee of peers

WNR - unmoderated target -
UCN - further cools neutrons to nano electron volts - used for fundamental nuclear physics research - like probing the standard model of nuclear weak interactions.

pRad - uses the protons directly to dynamically image matter under extreme condition

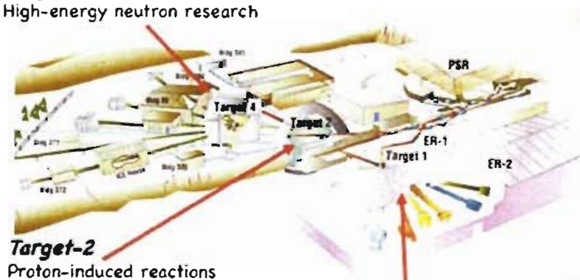
I will focus on three areas

- Nuclear Science
- Dynamic materials
- Neutrons, materials science

Nuclear Science research is performed at many experimental areas at LANSCE

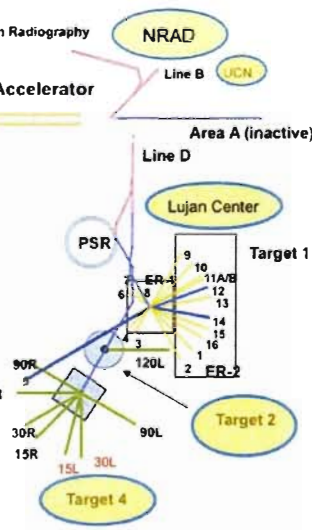
Weapons Neutron Research Facility

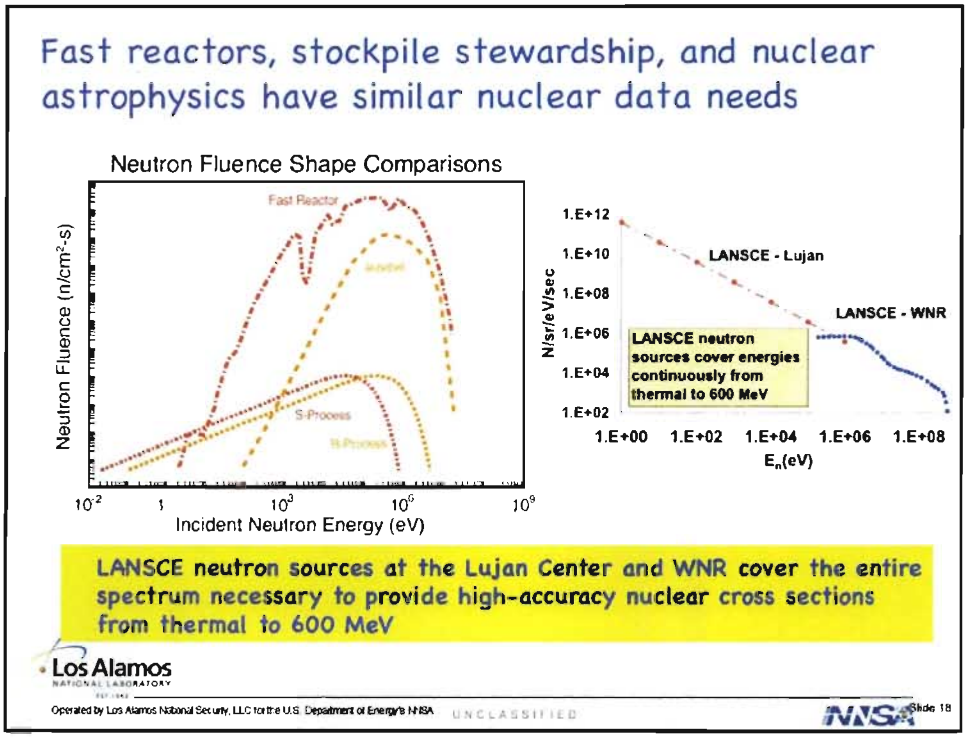
Target-4
High-energy neutron research



Target-2
Proton-induced reactions
Single-pulse experiments (Sandia)
Lead Slowing-Down Spectrometer
SNS target testing
Isotope production testing

Lujan Center
Low-energy neutrons





Quote some relevant neutron energies:
Fission neutrons
Fusion neutrons

Rad Chem is a diagnostic of yield

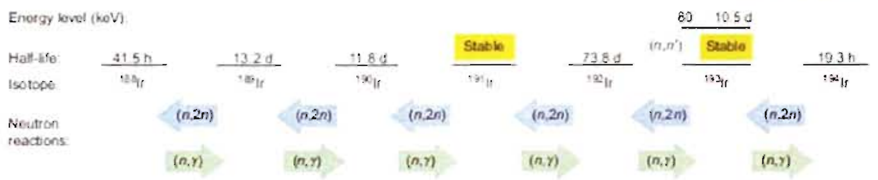


Figure 1. Chain of Neutron-Induced Reactions on Iridium Used in Radiochemical Analysis
Neutron-induced reactions on iridium isotopes are used to infer neutron fluence by radiochemical analysis of the amount of the radioactive isotopes produced. Natural iridium consisting of the stable isotopes 191 and 193 was placed in the device. The radioactive isotopes produced in the test live long enough so that they can be recovered by drill-back procedures and then analyzed in the laboratory. The (*n*,2*n*) reactions have thresholds of approximately 6 MeV and therefore indicate the fluence of neutrons above this energy. The (*n*,) reactions have zero threshold and indicate the neutron fluence generally below 1 MeV. The (*n*,*n*) reaction on iridium-193 producing the 10.5-day excited state at 80 keV is sensitive to neutrons between 1 and 5 MeV, which is the major energy range for neutrons produced in fission.

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NNSA

Many instruments have been developed for nuclear data measurements at LANSCE

GEANIE (n,xγ)

FIGARO (n,xn+γ)

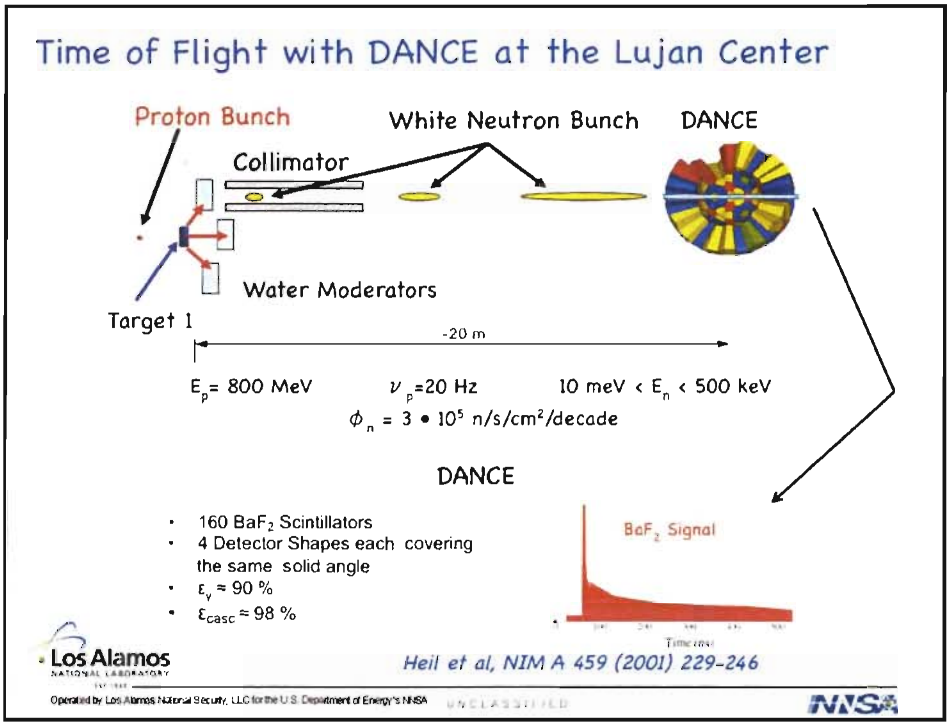
DANCE (n,γ)

N,Z (n,charged particle)

Fission

LSDS

fission ion chamber

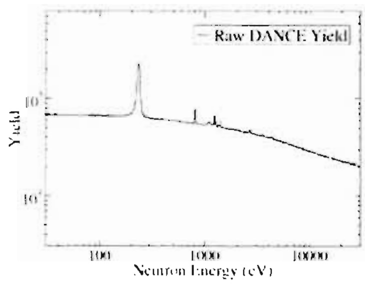


It's actually supposed to be an epsilon_gamma and epsolon_casc for
efficiency of a gamma and a cascade respectively. The first is
the total efficiency for detecting a 1 MeV gamma ray, which is basically
geometric and thus the same as solid angle.

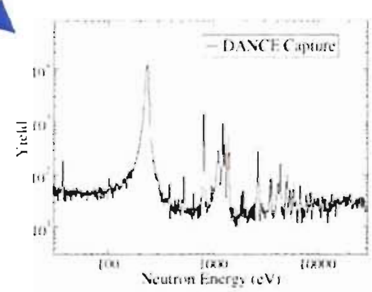
The second is efficiency for detecting at least _something_ from the cascade
(which is the geometric efficiency for a single gamma folded with 3-4
gammas)--the efficiency of detIt's actually supposed to be an epsilon_gamma and epsolon_cas(
efficiency of a gamma and a cascade respectively. The first is
the total efficiency for detecting a 1 MeV gamma ray, which is basically
geometric and thus the same as solid angle.

The second is efficiency for detecting at least _something_ from the cascade
(which is the geometric efficiency for a single gamma folded with 3-4
gammas)--the efficiency of detecting the full cascade is actually quite
a bit lower--I'd guess it is about 40%, but that's a really rough
number.ecting the full cascade is actually quite
a bit lower--I'd guess it is about 40%, but that's a really rough
number.

Effect of DANCE Selection on Q-Value and Multiplicity

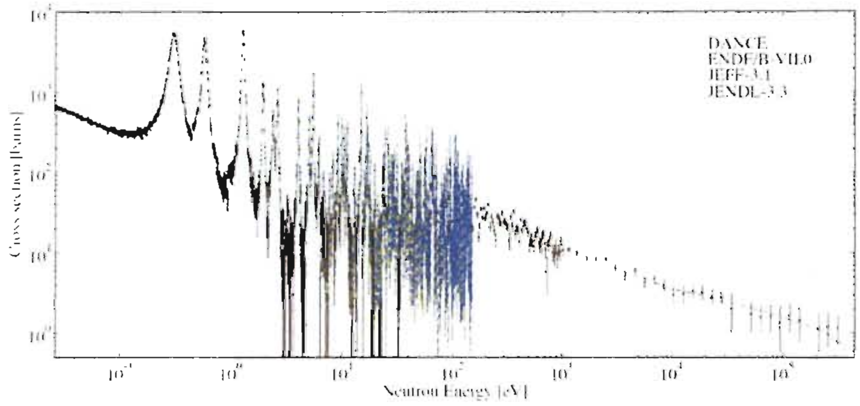


Mult and Q Cuts

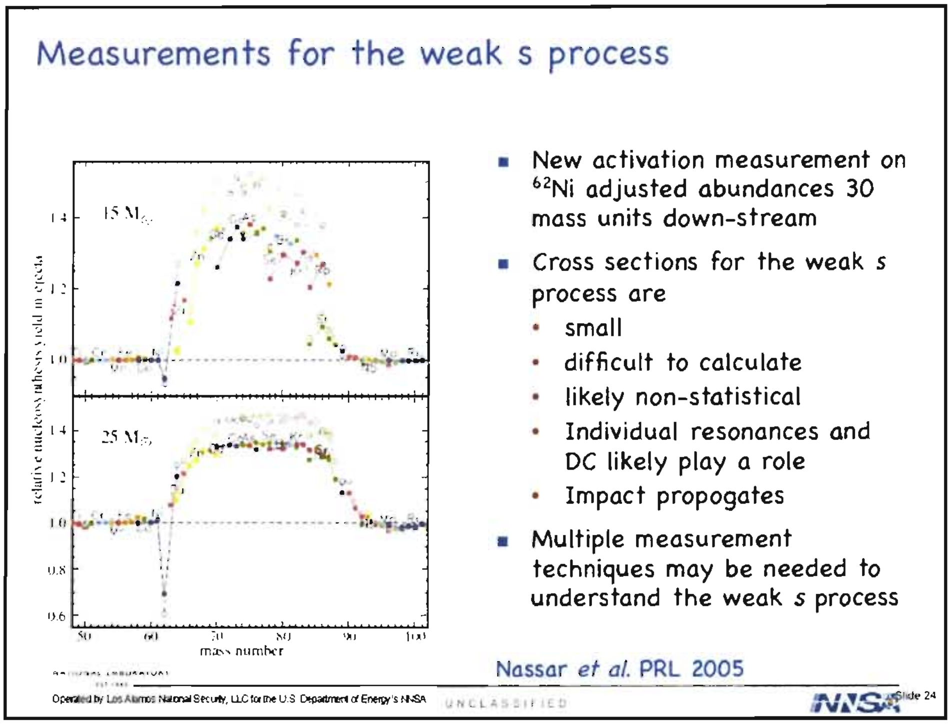


- All measurements are from a 50 mg sample of ^{203}Tl.
- No subtraction of elastic background has been done.
- While the losses in efficiency are large, the enhanced S/N is worth it.

Cross Section Measurement of 241Am(n, γ)



Jandel *et al. Phys. Rev. C* **78** 034609 (2008)

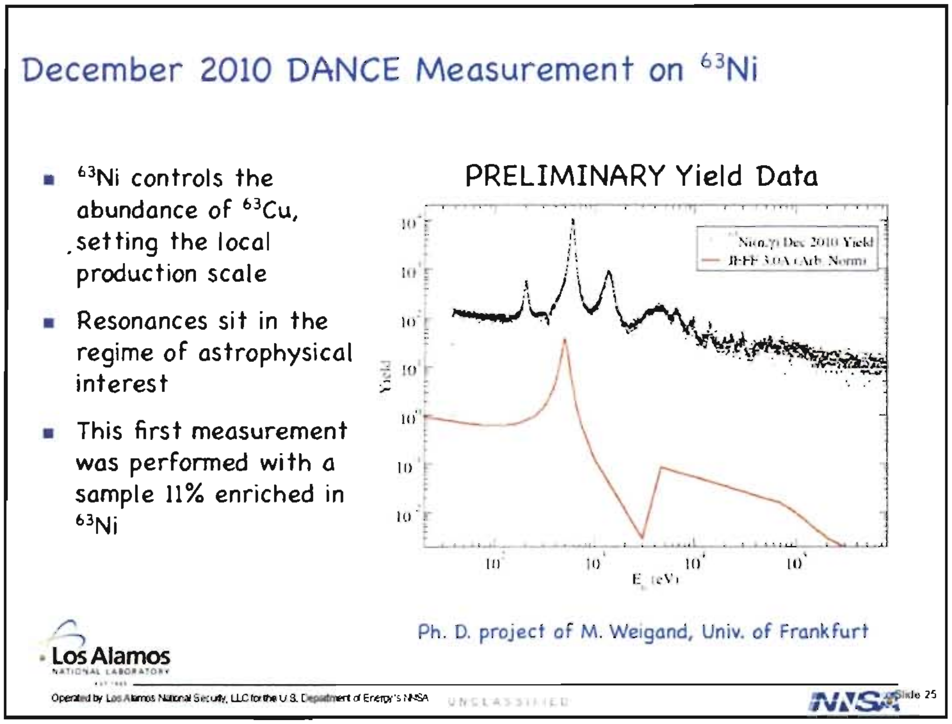


hese are abundance calculations from the weak s-process. The weak s-process operates in > ~
an shell carbon burning. It is responsible for the s-process production of isotope in the 60<A<9
panels is that the upper used a 15 solar mass star for the calculations and the lower used a 25 s
but it is cluttered as for any given element, it can have multiple masses and for any given mass,
element, and the line connects isotopes of the same elements.

Each dot is a actually the ration between two calculations--the only change between the two is
axis is the ratio between the abundances calculated using "standard" cross section and the nev
abundance of a certain isotope is unaffected by the 62Ni cross section (Fe and Mn e.g.). A ratic
isotope is produced with the new cross section than the standard one.

The solid dots are from a cross section of 28.4 mb (which was the value measured in this work,
of 35.5 mb. The standard cross section was 12.5 mb. These are allMaxwellian averaged cross s

There are (at least) two things that were really surprising about thiswork. First, for the main s-
changing a single cross section, even by more than a factor of two, usually only affects the abur
because the mass flow is in equilibrium. The fact that one cross section changed so many isoto
nuclear physics challenges of the weak s-process. The other surprise is that the cross section re
accepted uncertainty in the case of 62Ni was about 20%. There was a reason to re-visit it as th
they were not reflected in the uncertainties. Some of the challenges have been listed on the sli
isotopes in this region exhibit similar propogation effects and there are several cases in this ma



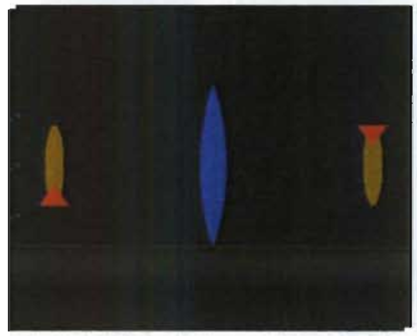
he 63Ni is recent work
for the weak s-process. That work was done with Rene Reifarth and Mario Weigand who may well be in the audiance.

I will focus on three areas

- Nuclear Science
- Dynamic materials
- Neutrons, materials science

LANSCE 800 MeV proton radiography facility

$$t = e^{-\frac{l}{\lambda_2}}\left(1 - e^{-\frac{\theta_c^2}{X}}\right)$$

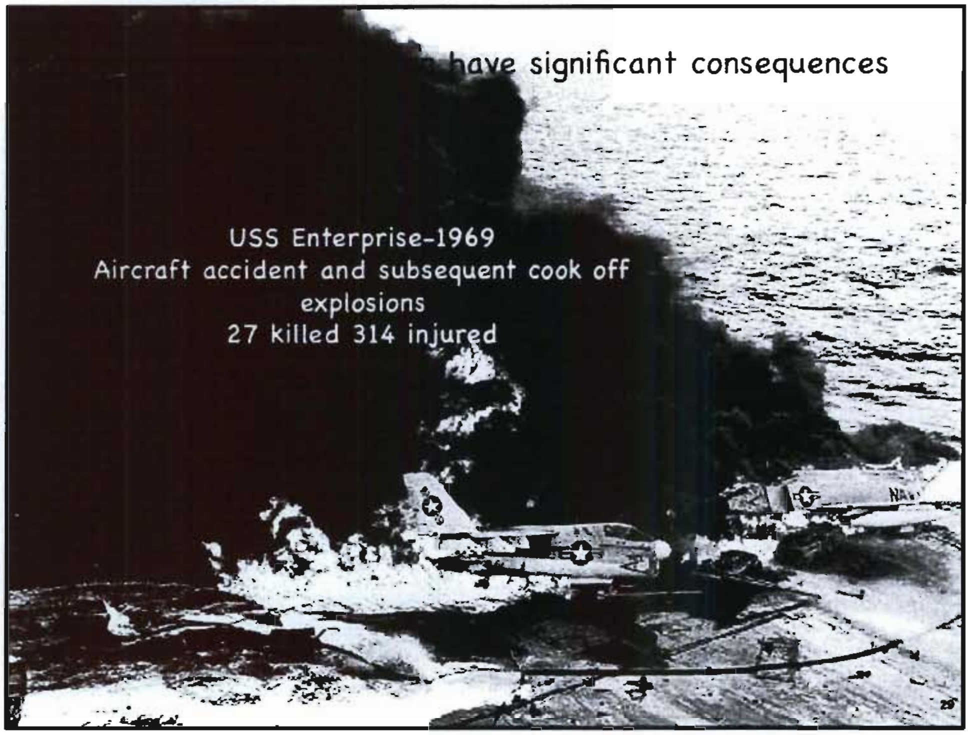


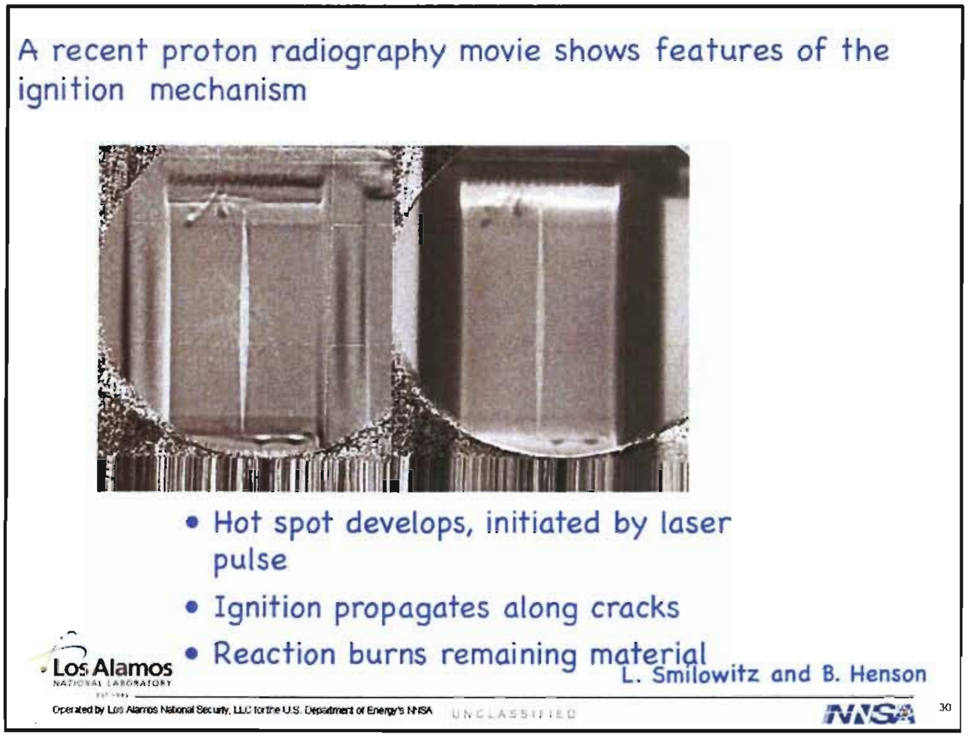
pRad allows unique studies of high explosive detonation and equation of state

- Corner Turner
- Rate Stick
- Colliding Detonation Waves
- Failure Cone

- Measure the detonation and shock wave locations as a function of time.
- EOS parameters
- HE detonation dynamics

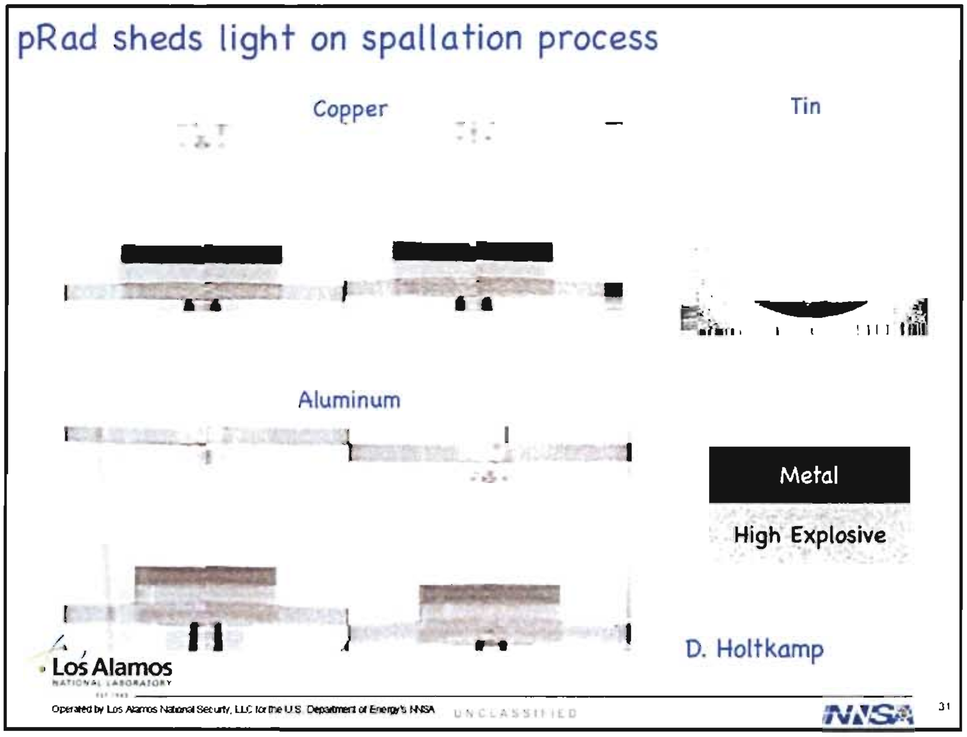
Eric Ferm


have significant consequences
USS Enterprise-1969
Aircraft accident and subsequent cook off
explosions
27 killed 314 injured

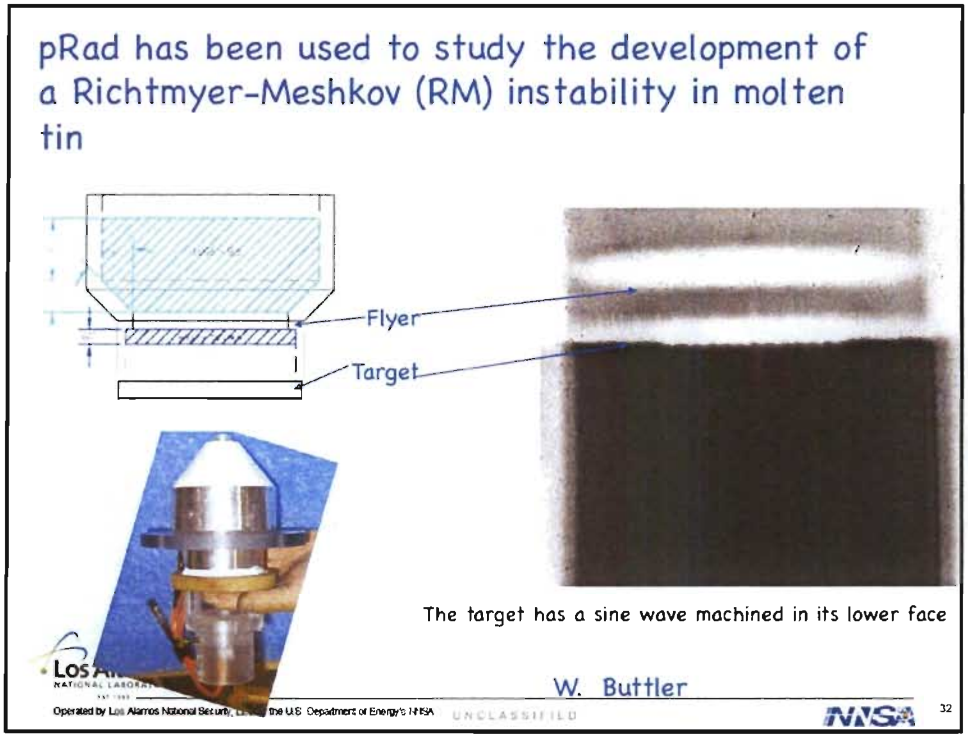


Heated with heating coils
Starts to thermally run away (T increases exponentially)
Laser pulse injected at midpoint to ensure it initiates in coincidence with beam

Proton with a ring – more flexibility in when a pulse is delivered – would help this work

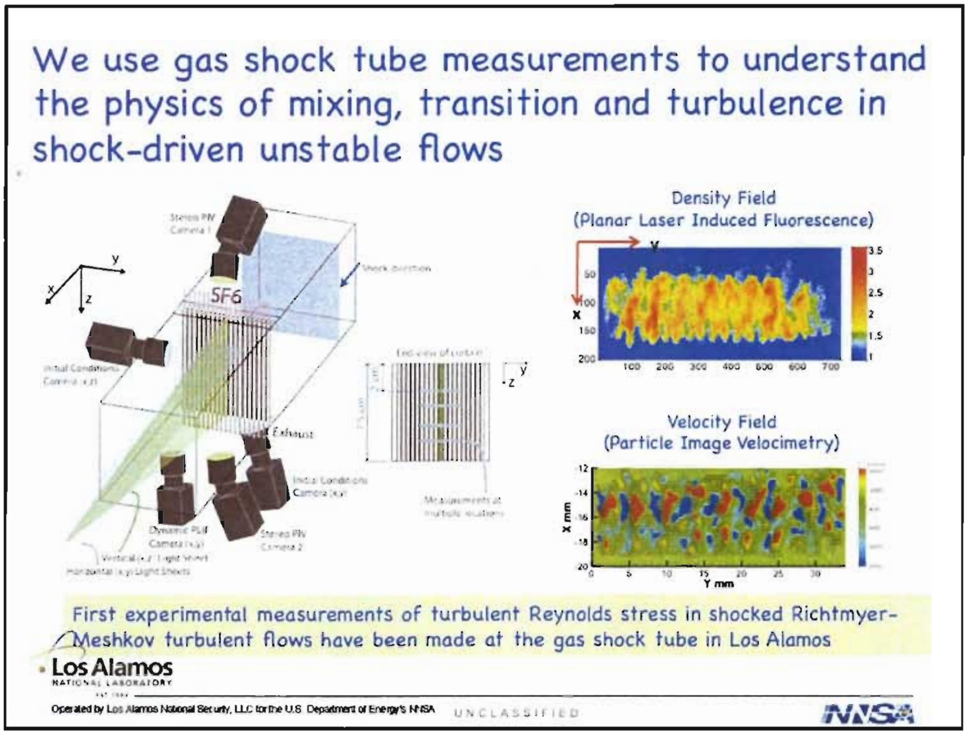


82,83 upper copper
84,85 lower Aluminum
90 right Tin

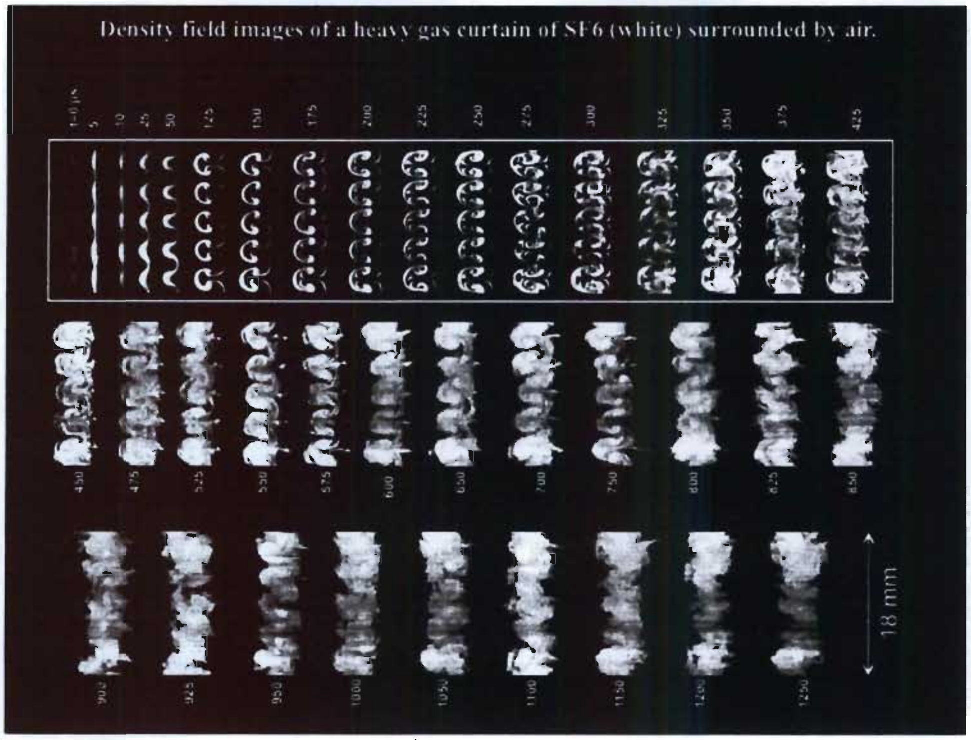


Prad181.avi

(W. Buttler)

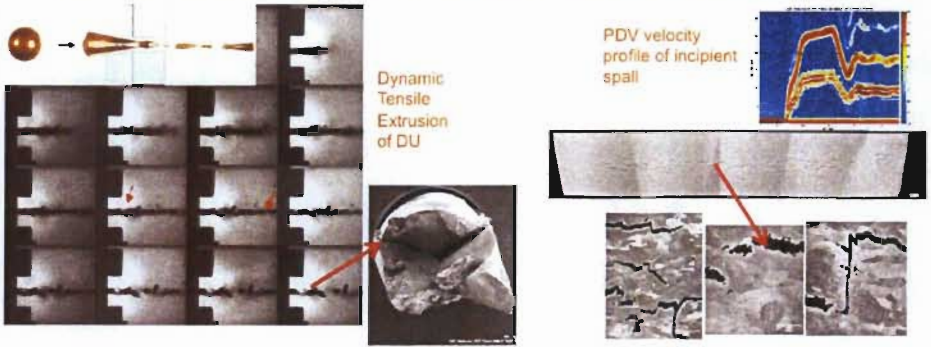


The horizontal shock tube uses optical laser diagnostics to look at the evolution of the mixing of a heavy gas curtain of SF6 surrounded by air. The shock moves along the tube in the x direction (streamwise). Y is the spanwise direction, and z is the vertical direction. Measurements of density and velocity are in the x-y plane.



Shock moves from left to right, then the flow evolves over time to become turbulent.

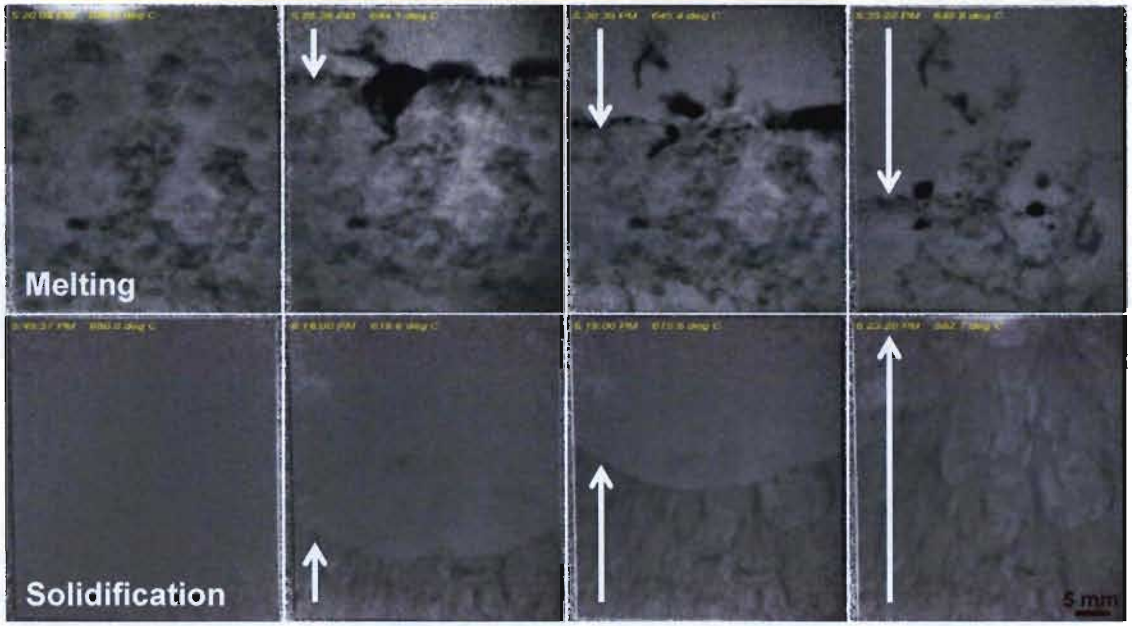
Dynamic tensile extrusion and incipient spallation experiments are informing predictive model development



- Unlike similar experiments on Cu and Ta, DU breaks up into greater than 5 pieces and break appears to be shear dominated during dynamic extrusion
- Incipiently spalled DU shows tensile cracking and severe plastic shearing often associated with inclusions and no evidence of microvoid formation and coalescence

Predictive modeling of dynamic damage evolution in DU requires complex shear processes to be described in next generation coupled strength / damage models under development

In-situ Monitoring of Melting and Solidification at Temperature Extremes Using 800 MeV Proton Radiography (pRad) at LANL (August 2011); Al-In, Ga-Bi, Al-Cu, Sn-Bi



Example images obtained during melting (upper images) and solidification (lower images) for a 6 mm thick Al-In sample using pRad. Darker regions are In-rich. A movie is provided on the right.

Advantages of pRad at LANL:

•Time-resolved imaging
•Large field of view
•Interrogation of thick samples (1 - 6 mm examined in the current work)
•Ability to examine high density materials

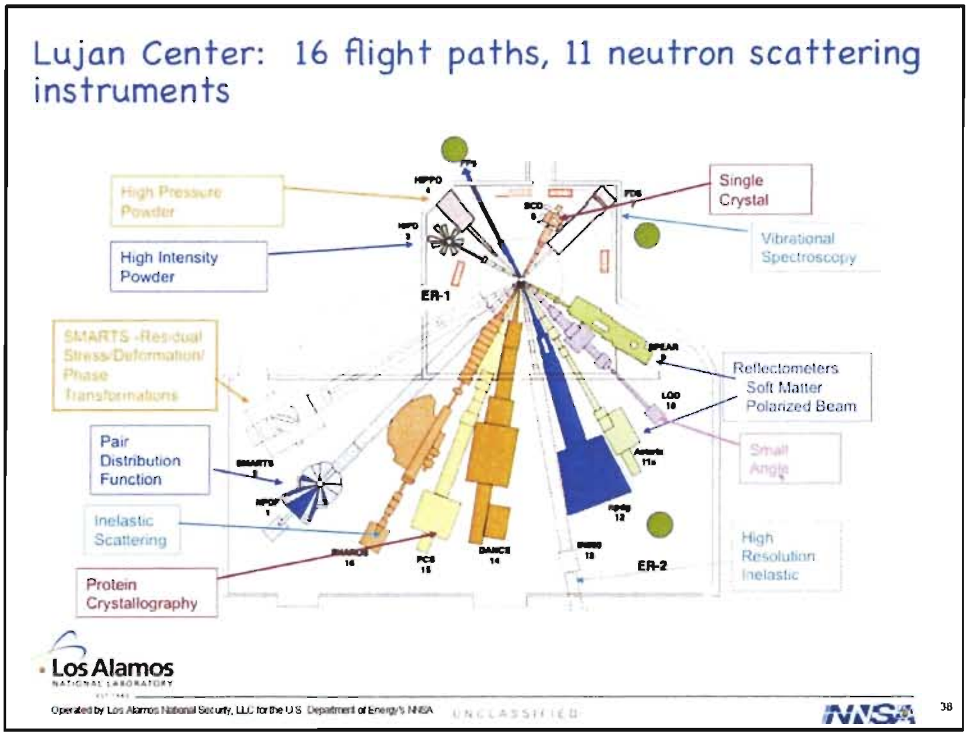
Disadvantage of pRad at LANL:

•Spatial resolution of ~65 microns

Approximately 10 micron resolution would be achievable using 4.5 GeV proton radiography at GSI...

I will focus on three areas

- Nuclear Science
- Dynamic materials
- Neutrons, materials science



Transition to materials story

Why neutrons? (get Mason Physics today)
-thick samples - penetrating power
-sensitivity to different materials (not z^2); can see light stuff (I.e. Hydrogen)
- wavelength - ….

What is Lujan

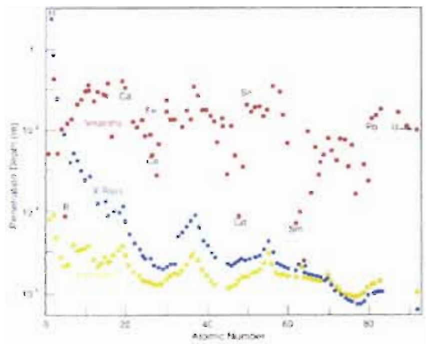
Uniqueness:
Instruments
Source (# neutrons)
Actinides
Classifed
Environments

SMARTS: Spectrometer for Materials Research at Temperature and Stress

- Neutron powder diffractometer optimized for engineering structural material research.
  - Stresses to 2GPa.
  - 90K-2000K
  - Tension, compression, fatigue
  - 1 mm spatial resolution
- Materials application examples
  - Residual Stress
  - Deformation mechanisms
  - Phase transitions
- User program
  - ~50 external user experiments
  - ~10 DP experiments
  - Competitive selection

LANL and SMARTS have unique capabilities

- Neutrons will characterize the bulk structure allowing analysis of engineering components.
- X-ray radiation will characterize only the surface which often contains a damaged layer.
- Non-destructive
- Ability to perform complicated *in situ* experiments.
  - Temperature
  - Tensile and compressive loading
  - Hydrostatic Pressure
- Demonstrated ability to perform experiments on classified components.



Integration with other capabilities at LANL, e.g. manufacturing, characterization, code development, is required for us to succeed in our stockpile stweardship mission.

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Slide 40

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Campaign 4.2 (Radiation Case Dynamics)

Developing valid constitutive models for use in latest codes predicting performance

Enhanced Surveillance Campaign

Lifetime prediction of U-Nb alloys

Deformation prediction of U-Nb alloys

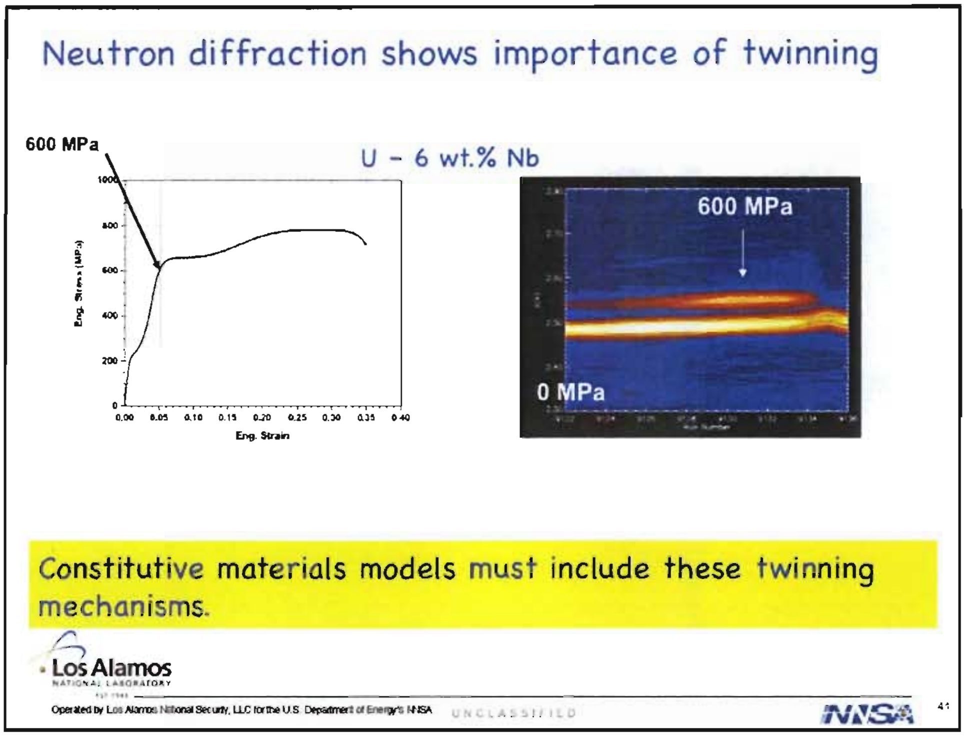
Material Characterization for Hydrodynamic Testing

Deformation prediction of test components

Helping to resolve manufacturing issues

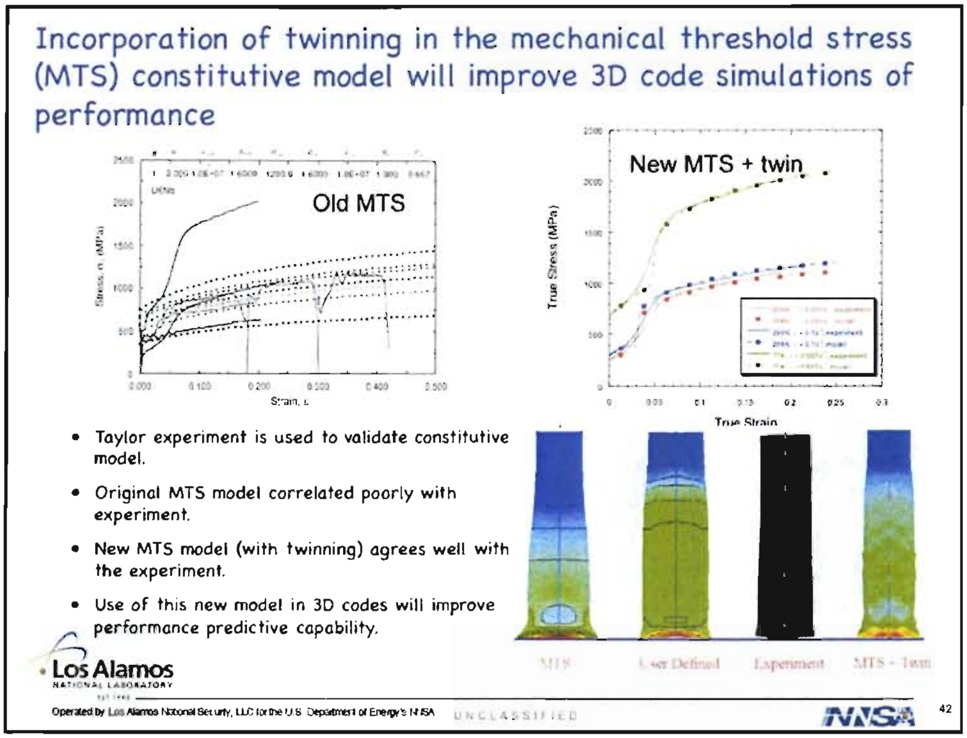
Pit Certification

Measurement of Be weld residual stresses.



Change in the intensity if of lines corresponsing to either d spacing (or 2 theta) and a function of strain
In situ tensile straining of U – 6 wt.% Nb part shows twinning to be the predominant deformation mechanism at low strains

Twin boundaries occur when two crystals of the same type intergrow, so that only a slight misorientation exists between them. It is a highly symmetrical interface, often with one crystal the mirror image of the other; also, atoms are shared by the two crystals at regular intervals. This is also a much lower-energy interface than the grain boundaries that form when crystals of arbitrary orientation grow together. Twin boundaries are partly responsible for shock hardening and for many of the changes that occur in cold work of metals with limited slip systems or at very low temperatures. They also occur due to martensitic transformations: the motion of twin boundaries is responsible for the pseudoelastic and shape-memory behavior of nitinol, and their presence is partly responsible for the hardness due to quenching of steel.



Taylor test – rt circular cylindiner into an anvil (u6Nb)
Color – intensity of strain
Old – simple monotonic
Understanding deformation behavior of shape memory materials

- U-6%Nb (LANL)
- NiTi based materials (U. Central Florida and NASA)

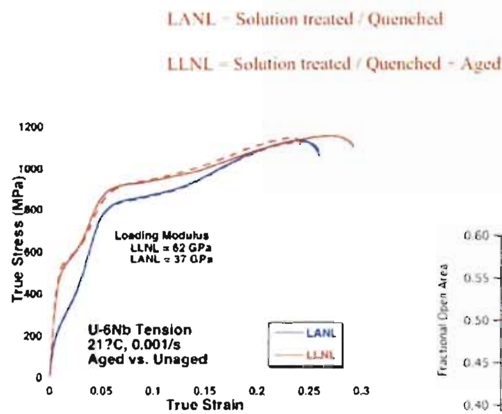
Residual Stress Measurements in Welds

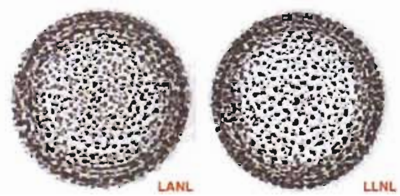
- Be (LANL)
- Zr (Austrailian Nuclear Science and Technology Organization)

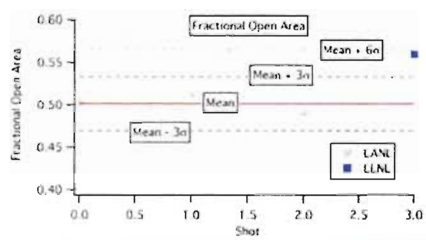
Understanding Twin Deformation Mechanisms

- U-6%Nb and Be (LANL)
- Mg (U. Virginia)

Mechanical behavior and HE-driven fragmentation of U-6Nb show strong influence of metallurgical state







Process-aware understanding of materials performance is lacking

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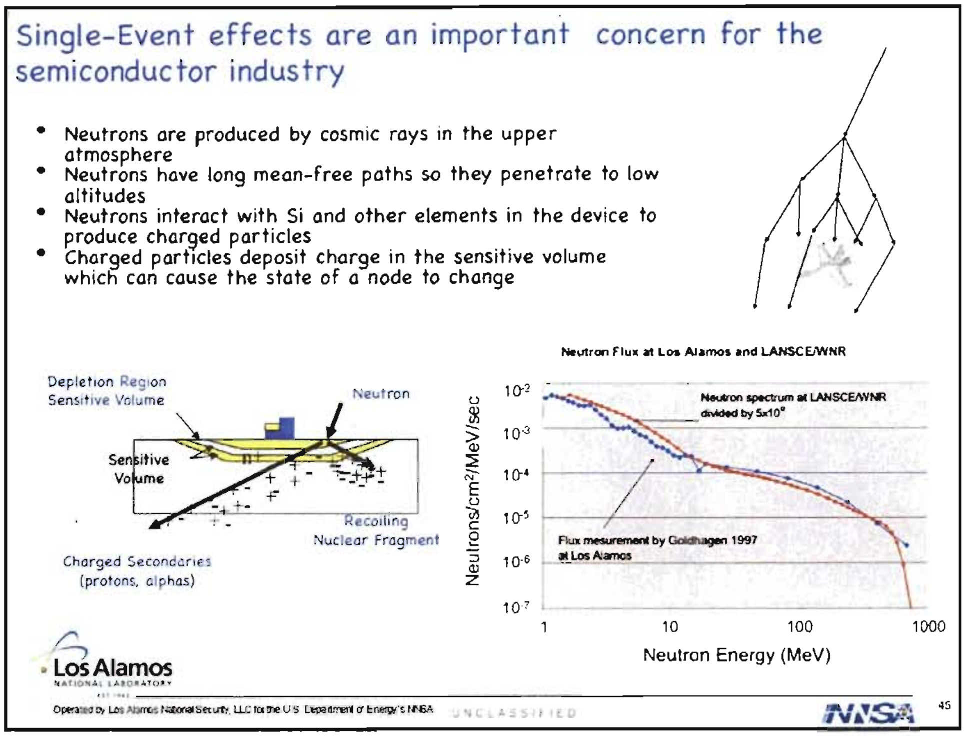
Basic Science -> Application -> Additional Application

- The basic science experimental capabilities left by LAMPF were developed into important new tools for stockpile stwedardship
- These capabilities were applied to a variety of other applied problems
- In addition – a spectrum of basic research is still supported by these facilities

I will present two examples: Single Event Upset studies and Muon Tomography

Isotope production???



Neutron Single Event Effects (SEE) are faults in electronic devices caused by neutrons from cosmic raysTypes of single-event effects

- Soft errors
  - Single event upset
  - Multiple event upset (a few % of SEU rate)
- Hard errors
  - Single event latchup
  - Single event burnup, gate rupture, etc.

High power devices: IGBTs

First experiments were performed by the Boeing Co. for 777 certification

Industry trends to lower voltages and smaller feature size are thought to increase the failure rate due to SEE

Similar devices have very different failure rates

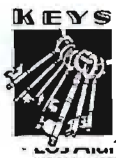
The failure rate due to SEU is equal to all the other failure modes combined

Semiconductor reliability is growing concern in industry

Neutrons induced nuclear reactions create charged particles. Generated charge collects in depletion region and generates a logic upset.

Current border protection for nuclear threats is weak

- Shielding can obscure passive signal
  - Portal monitors are great for detecting innocuous radioactivity
  - The absence of a signal doesn't prove the absence of a threat
- Radiography should be the primary screening method



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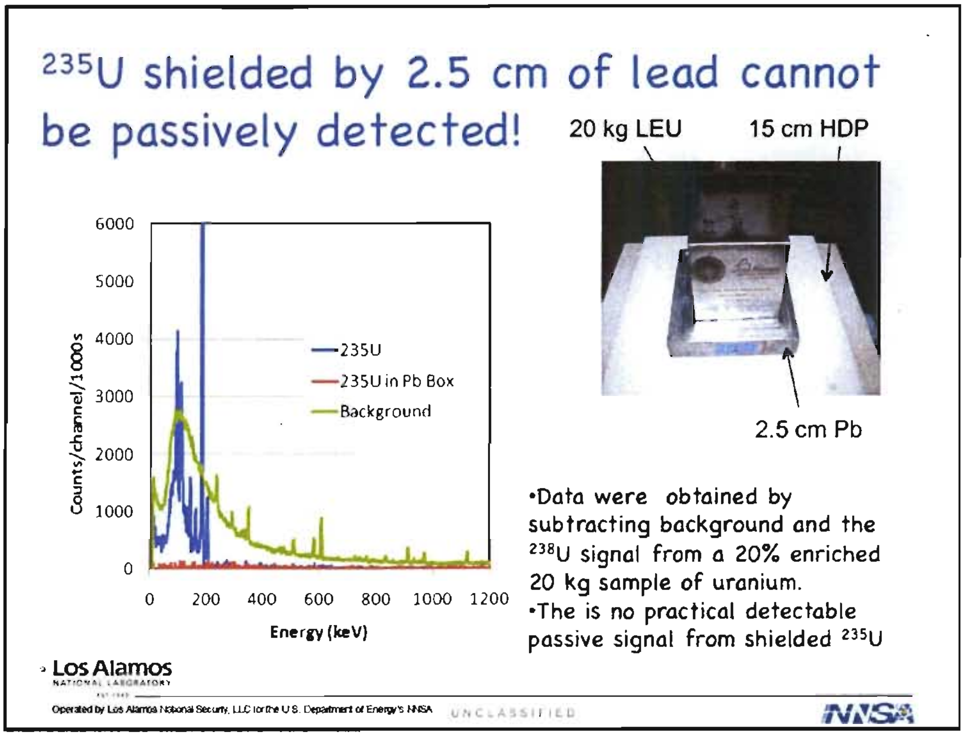
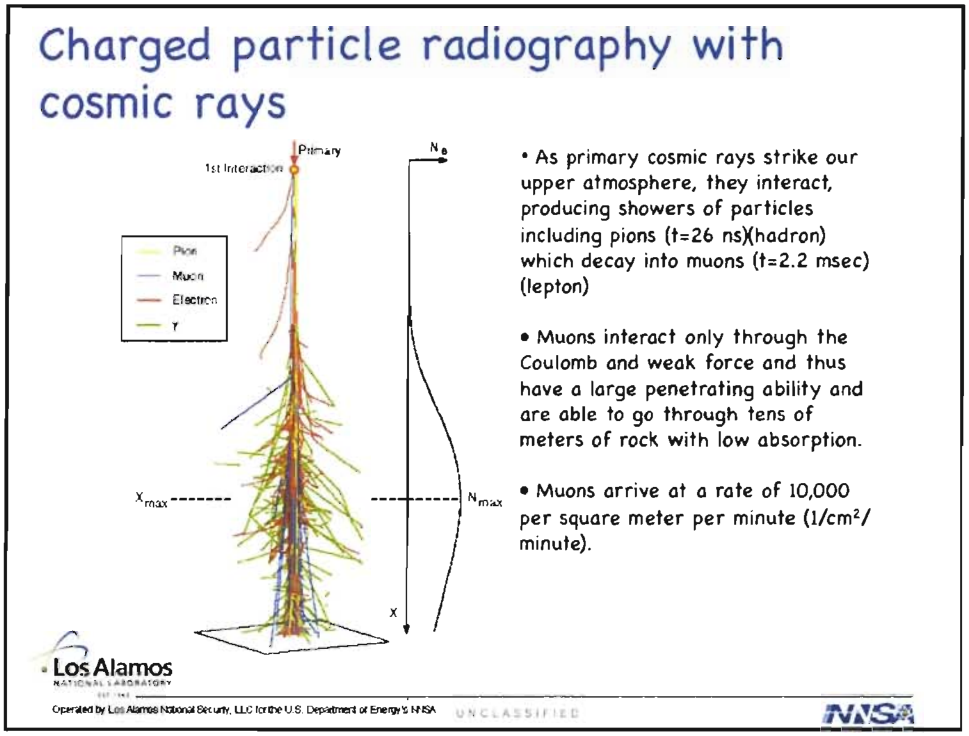


20 minutes of running
The amount of 235 U in LEU U
Skin thickness – couple mm – all gamma rays come from the surface



Range
- Useful for pyramids

Energy loss
- Most sensitive but expensive

Multiple scattering
- Cost effective and simple

What does a scanner look like?

- **Technical approach:**
  - **Measure passive radiation**
  - **Use muons to generate "scattering density" image**
    - » Built in momentum measurement
    - » Automatic calibration using flux through empty detector
  - **Combine signals to identify threats**
- **Advantages over other methods:**
  - **No radiation**
  - **Simple technology**
  - **Inexpensive**
  - **Can penetrate thick cargos**
  - **Automatic Identification**

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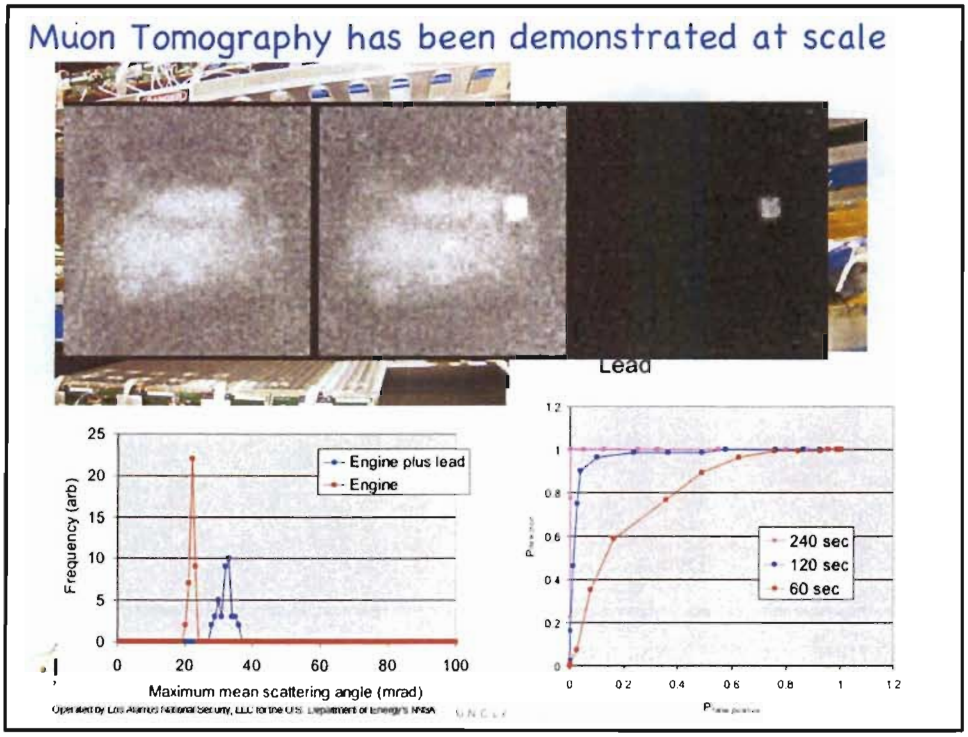
Briefly Describe:

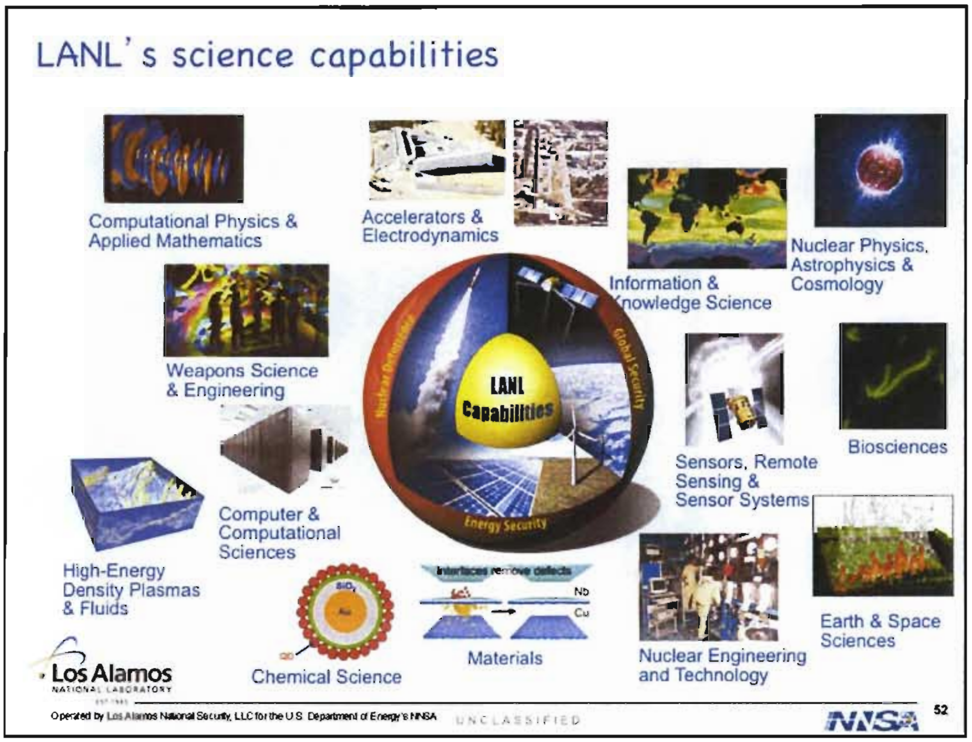
1) Technical approach/ method
2) Key technical challenges / risks
3) Risk management strategy

Include a sketch if possible


Muon Tomography has been demonstrated at scale
Lead
Engine plus lead
Engine
Frequency (arb)
25
20
15
10
5
0
0
20
40
60
80
100
Maximum mean scattering angle (mrad)
240 sec
120 sec
60 sec

Summary

- The science and technology applied to stockpile stewardship is essential in maintaining CTBT
- This work builds on basic science work, e.g. LAMPF
- SSP includes furthering our understanding of certain physical phenomena (e.g. material behavior in dynamic extremes) and well as improved physical data (e.g. cross sections)
- All this is encorporated in computational models requiring extensive high performance computing capability (e.g. Roadrunner)
- The new capabilities developed lead to further applications and new basic science capability



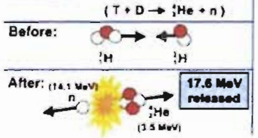
Thirteen total capabilities in 2011.
Additional HED, computer and computational sciences, NPAC, nuclear engineering and tech, and sensors, remote sensing and sensor systems.

spares

Boosted fission weapons use fusion to enhance the chain reaction

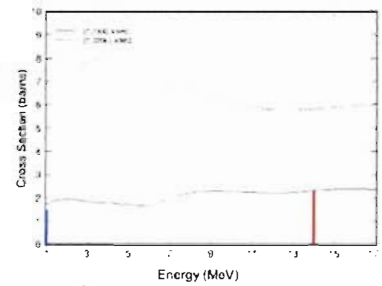
Example: ${}^{3}_{1}H + {}^{2}_{1}H \rightarrow {}^{4}_{2}He + n$
$(T + D \rightarrow {}^{4}_{2}He + n)$

Before: / **After:**

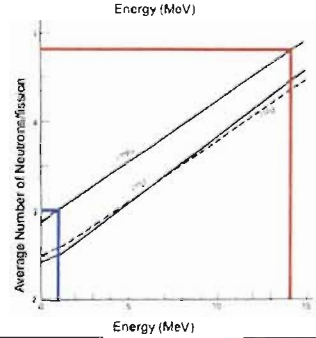


Other reactions of interest:

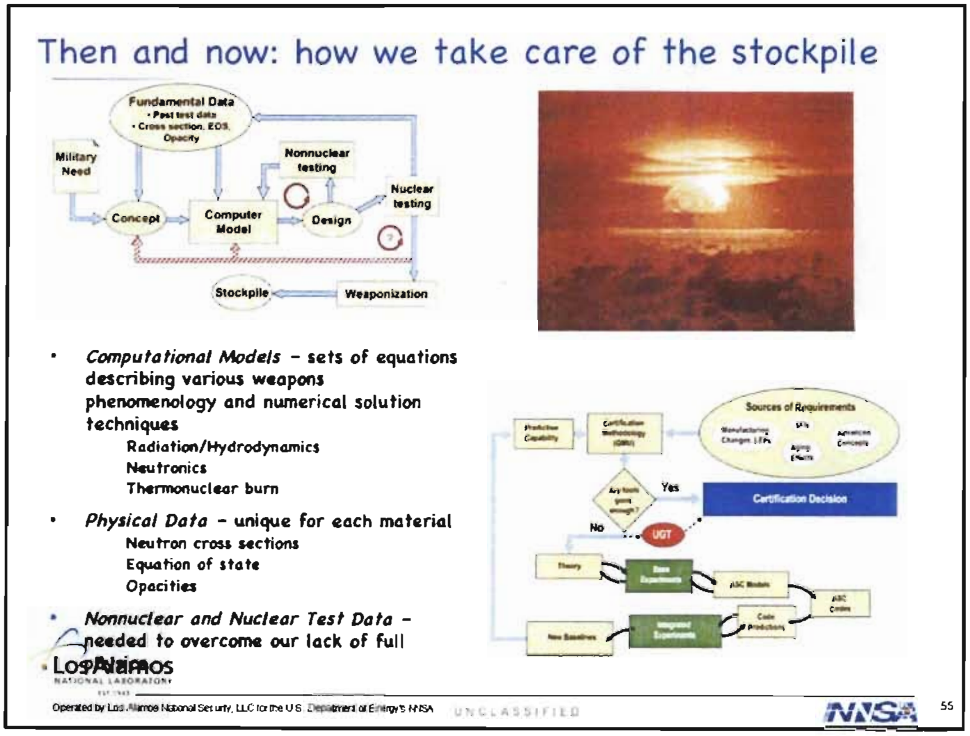
$D + D \rightarrow {}^{3}_{2}He + n + 3.2\ MeV$
$D + D \rightarrow T + p + 4.0\ MeV$
$D + {}^{3}_{2}He \rightarrow p + {}^{4}_{2}He + 18.3\ MeV$
$T + T \rightarrow {}^{4}_{2}He + 2n + 11.3\ MeV$



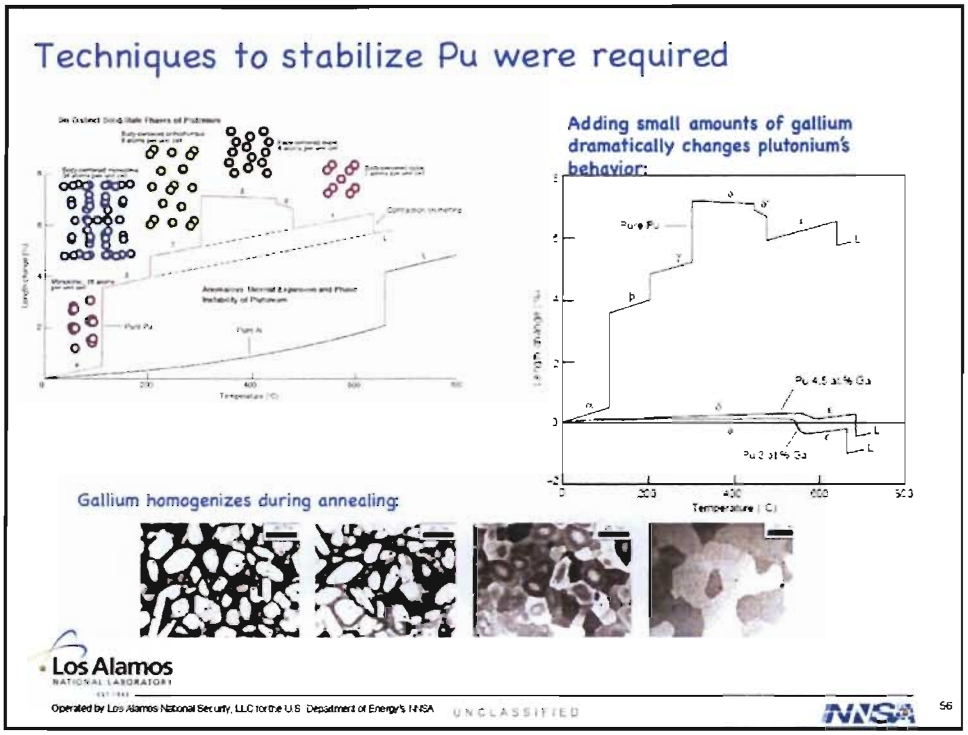
- Mixture of deuterium and tritium (boost gas) is introduced from a reservoir to pit's central cavity
- During implosion, boost gas is compressed along with the fissile material
- Driven by energy from fission, D-T fusion occurs, flooding compressed pit with high energy neutrons
- These neutrons produce additional fissions, driving nuclear yield to much higher values



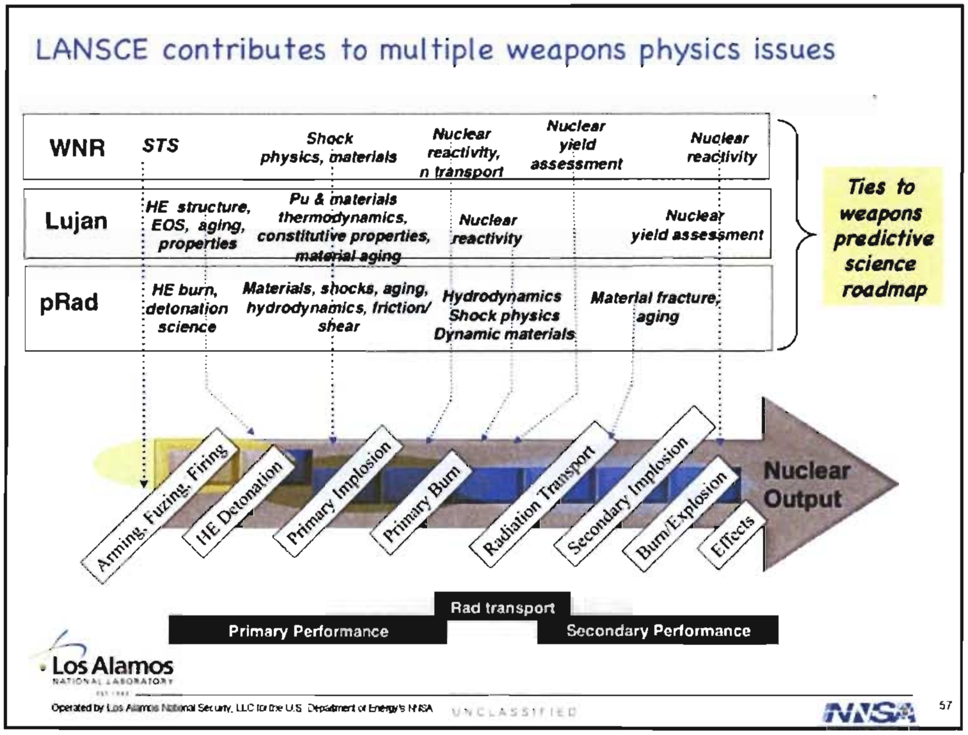
As incident neutron energy increases, the cross section (and probability) for causing a fission event increases



Castle/Bravo: tested 2/28/54 at Bikini
Largest US detonation at 15 Mt



few atomic percent gallium is typically added to plutonium to retain the facecentered-cubic phase, which is easily shaped into components. However, as Pu-Ga alloys cool during casting, gallium segregates and leaves a nonuniform distribution across the metallic grains.
This sequence of micrographs demonstrates gradual gallium homogenization during annealing for long times at 460°C.
The as-cast sample on the left exhibits regions high in gallium in the grain centers (etched to appear very light). At longer times, the gallium concentration becomes more uniform, as demonstrated by the more uniform coloration within the grains. After720 h, the sample is completely uniform—the variations from grain to grain result strictly from differences in crystalline orientation.


LANSCE contributes to multiple weapons physics issues
WNR
STS
Shock physics, materials
Nuclear reactivity, n transport
Nuclear yield assessment
Nuclear reactivity
Lujan
HE structure, EOS, aging, properties
Pu & materials thermodynamics, constitutive properties, material aging
Nuclear reactivity
Nuclear yield assessment
pRad
HE burn, detonation science
Materials, shocks, aging, hydrodynamics, friction/ shear
Hydrodynamics Shock physics Dynamic materials
Material fracture, aging
Ties to weapons predictive science roadmap
Arming, Fuzing, Firing
HE Detonation
Primary Implosion
Primary Burn
Radiation Transport
Secondary Implosion
Burn/Explosion
Effects
Nuclear Output
Rad transport
Primary Performance
Secondary Performance
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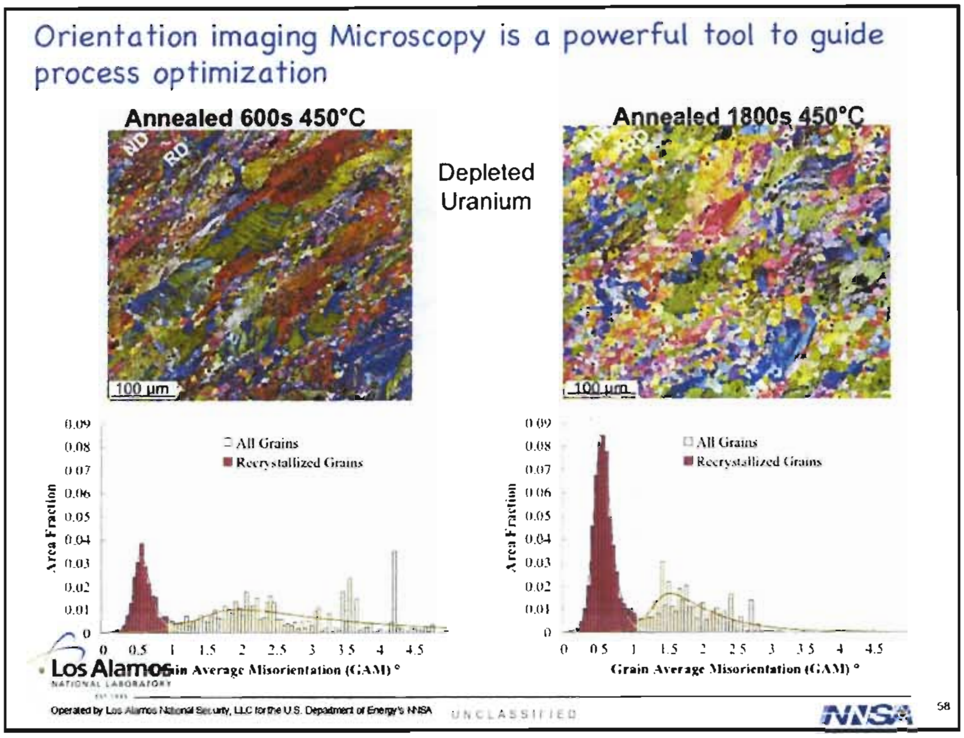
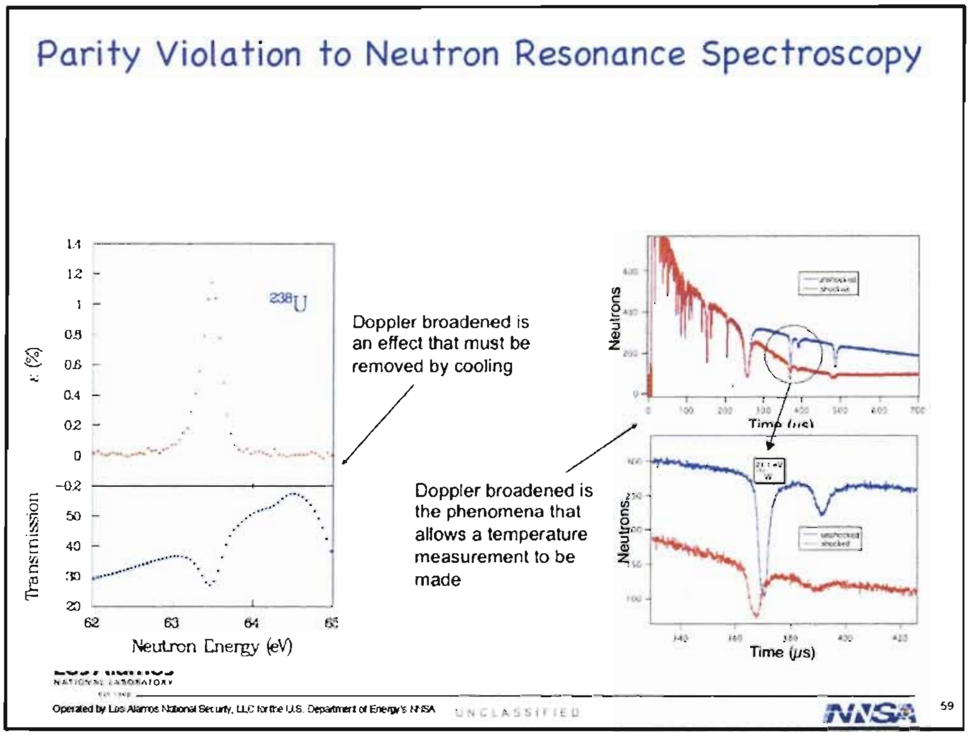


This shows how we are using OIM generated by Electron Backscatter Detection (EBSD) to optimize the heat treatment schedule for wrought DU used in hydro experiments.

GAM measures the deviation from ideal atomic alignment, which tells us if there is retained plastic strain within a given grain. GAM has enabled quantification of the recrystallization process, including statistical analysis, as shown. Even in ideal conditions, there are defects, which is why anything below 1 is considered recrystallized (never gets to zero).

On left, note deformed crystal structure still reflecting wrought condition in early stages of recrystallization. There are patches of small equiaxed grains starting to form.

On the right is a longer heat treatment in which there is a tight distribution of small equiaxed grains and much fewer of the deformed grains remain. It takes ~100,000 seconds at 450 C to become fully recrystallized which is the desired condition.



On the left:
Lower figure is neutron transmission through a thick 238 U sample. Dip is a specifc p-wave resonance.

Upper figure is the asymmetry the differenc ein helicyt states divided by sum
(T+ - T-)/T+ + T-)

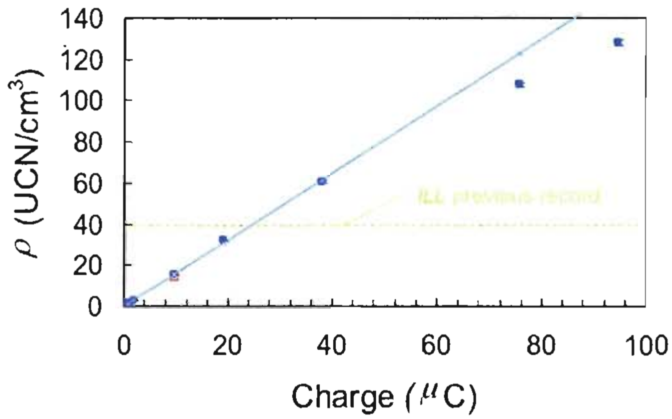
A non zero value indicates parity violation. Many case were observed in U, Th, Cd, etc at LANSCE flight path2
These were made with sample coold to LN2 temperature to reduce Doppler broadening.

On Right:
Same detector setup measures transmision through sample doped with resonsnce conatining isotope.
Width and location of resonance changes in shocked material - indicating heating.
Width changes due to Doppler boradedning.

World Record Ultra Cold Neutron Density

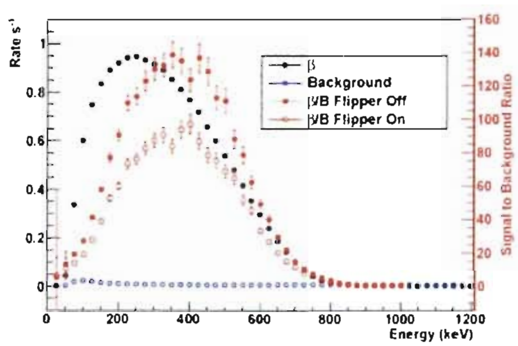
6/29/00

EPICS counting house – on-line results

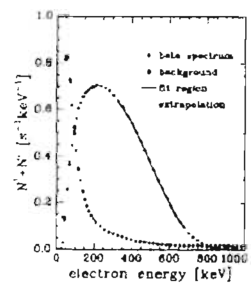


Results from UCNA

UCNA 2010



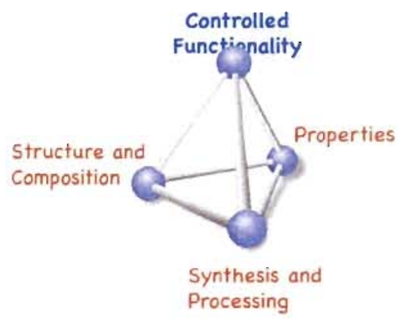
PERKEO II (2002)



S/B [200 < E keV < 625] = 105

S/B ~ 7

Controlled functionality in materials would reduce cost and increase confidence for the stockpile



- Current Stockpile
  - Prediction of materials lifetime & failure
- Rebuild & Lifetime Extension
  - Materials 'by design' rather than re-learning old processes
- Weapon performance
  - Effects of microscale materials properties on dynamic performance for key physics

Move from process-based certification towards product-based certification

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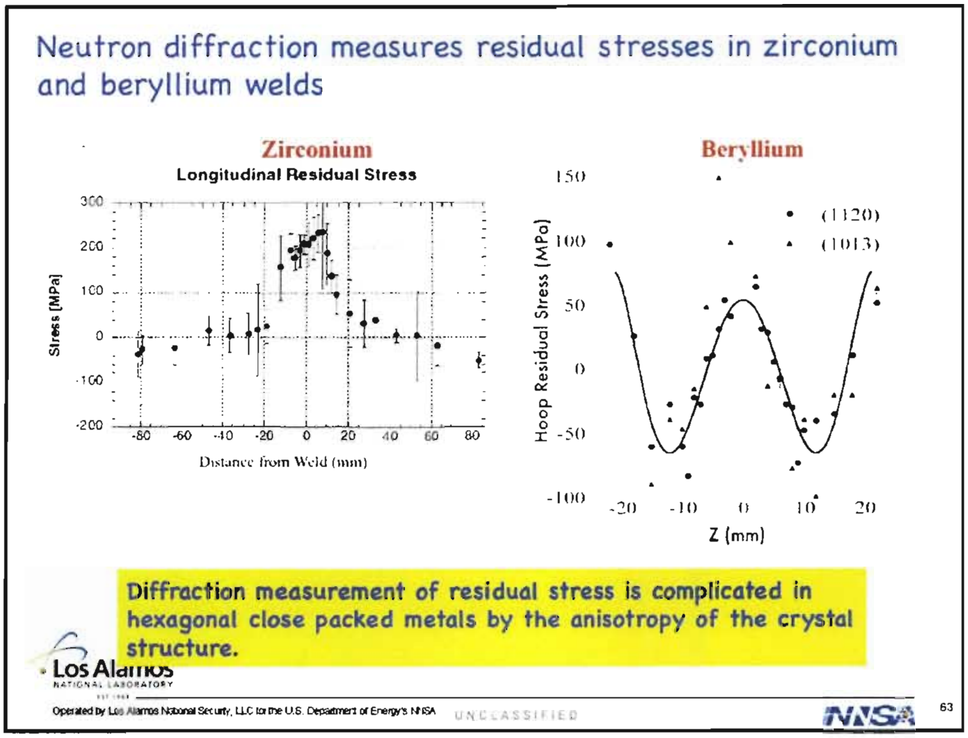
For fixing issues, extending lifetime, or considering advanced concepts

Remind about NPR

We must move from structure → property paradigm

To a new paradigm of function → structure



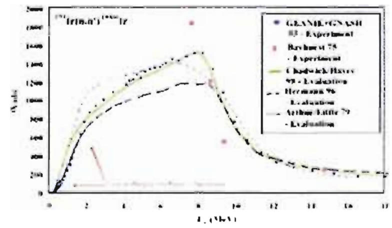
User: Maurice Ripley (ANSTO in Australia)
- relevant to cladding of nuclear fuel rods.
User: Don Brown (LANL)
- relevant to pit certification.

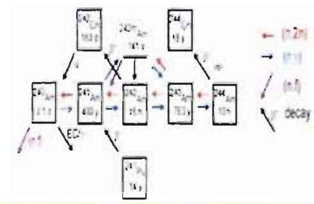
Improved cross section data is needed for reducing uncertainties

Nuclear data is needed for:

- Energy production
  - Fission cross sections on ^{239}Pu
  - Neutron and gamma ray outputs following fission
  - Neutron-induced reactions on ^{6}Li- tritium production
  - Reaction rates on fission products
  - Effects of isomeric states
- Radiochemical diagnostics
  - Early time (n,2n) reactions give information on device performance
  - Late time (n,γ) reactions are important for understanding (n,2n) reactions and late time neutrons
- Other diagnostics

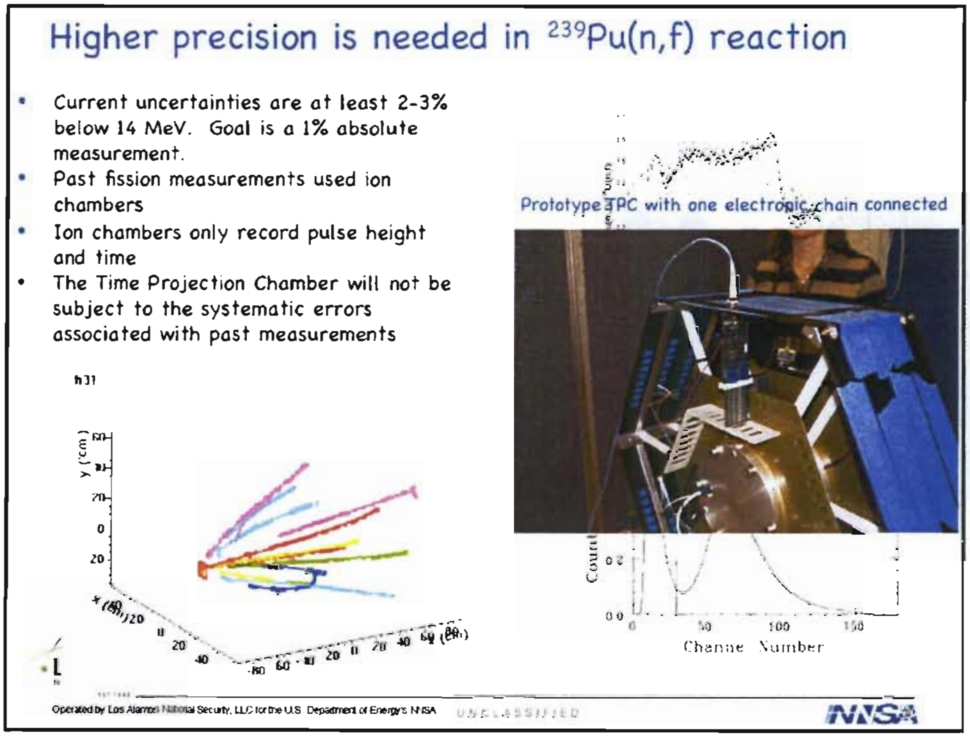
Experiment and theory for 10.5-day half-life ^{193}Ir





Difficult new measurements of nuclear reaction rates help us reduce simulation uncertainties and better exploit data from past nuclear tests

MeV neutrons important for weapons
WNR unique in its ability to simultaneously cover the entire energy range (white source)



- **TPC will provide 3D "pictures" of the charged particle trajectories**
  - Alpha backgrounds removed
  - Sample auto-radiograph (α particles)
  - Beam non-uniformities
  - Multi-actinide targets
- **TPC will use thin backing foils (<50μg/cm²)**
  - Minimize beam interaction backgrounds
  - Maximize efficiency
  - Minimize multiple scattering of fragments
  - H_2 drift gas will also minimize scattering
- **TPC will provide data on both fission fragments simultaneously**
  - Random backgrounds removed (vertex requirement)
  - Fission vertex with <100 μm resolution (fission radiograph)

Turbulence models require experimental validation

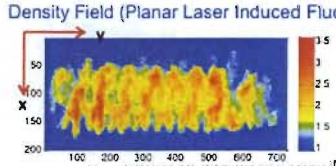
$$\frac{\partial \bar{\rho} K}{\partial t} + \frac{\partial \bar{\rho} K \tilde{u}_n}{\partial x_n} = a_n \frac{\partial \bar{p}}{\partial x_n} - R_{in} \frac{\partial \tilde{u}_i}{\partial x_n} + \frac{\partial}{\partial x_n}\left(\bar{\rho} \nu_t \frac{\partial K}{\partial x_n} \right) - \bar{\rho} \frac{K^{3/2}}{S}$$

Production (exact) Diffusion Dissipation

$$R_{ij} = \overline{\rho u_i u_j} = \bar{\rho}\overline{u_i u_j}\ (1) - \bar{\rho}\overline{a_i a_j}\ (2) + \overline{\rho' u_i' u_j'}\ (3)$$

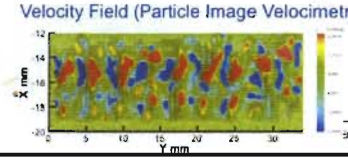
In order to measure components of the Reynolds Stress, *Rij*, simultaneous density and velocity measurements are needed:

Density Field (Planar Laser Induced Fluorescence)

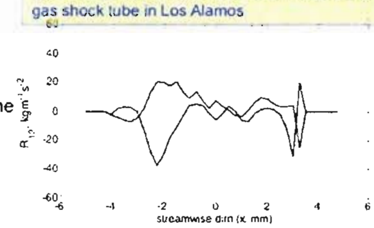


...unit mass, is one of the

Velocity Field (Particle Image Velocimetry)



First experimental measurements in the world of turbulent Reynolds stress in shocked Richtmyer-Meshkov turbulent flows have been made at the gas shock tube in Los Alamos



* D. Besnard, F. Harlow, R. Rauenzahn, C. Zemach, 1992, "Turbulence Transport Equations for Variable-Density Turbulence and Their Relationship to Two-Field Models. Los Alamos Report LA-12303-MS.

LANL RAGE code uses a variable-density turbulence RANS model that was developed at Los Alamos*– but it needs high-resolution turbulence measurements for validation