Search for the Origins of the Anomalous Heat Effect (AHE) in Deuterium-loaded Palladium Driven Far From Equilibrium

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ILENR Conference
College of William and Mary

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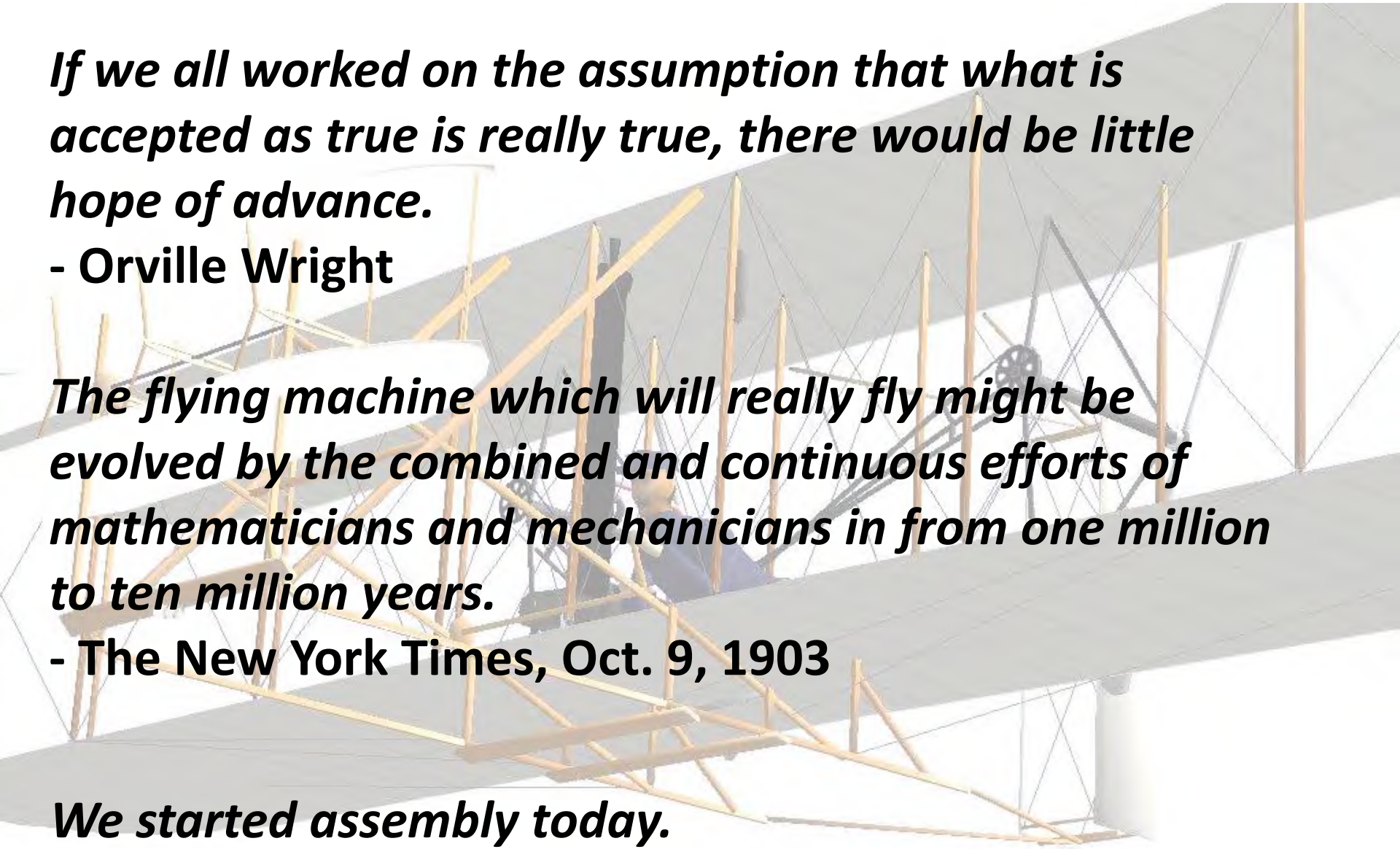
Discovery is Creatively Disruptive



If we all worked on the assumption that what is accepted as true is really true, there would be little hope of advance.
- Orville Wright

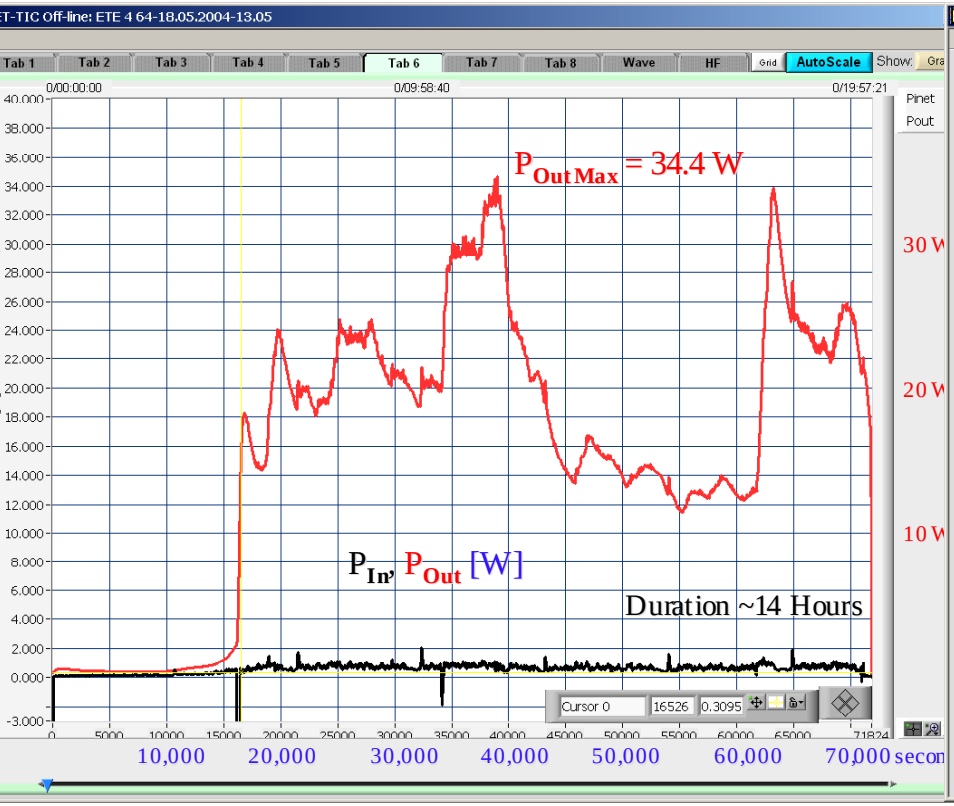
The flying machine which will really fly might be evolved by the combined and continuous efforts of mathematicians and mechanicians in from one million to ten million years.
- The New York Times, Oct. 9, 1903

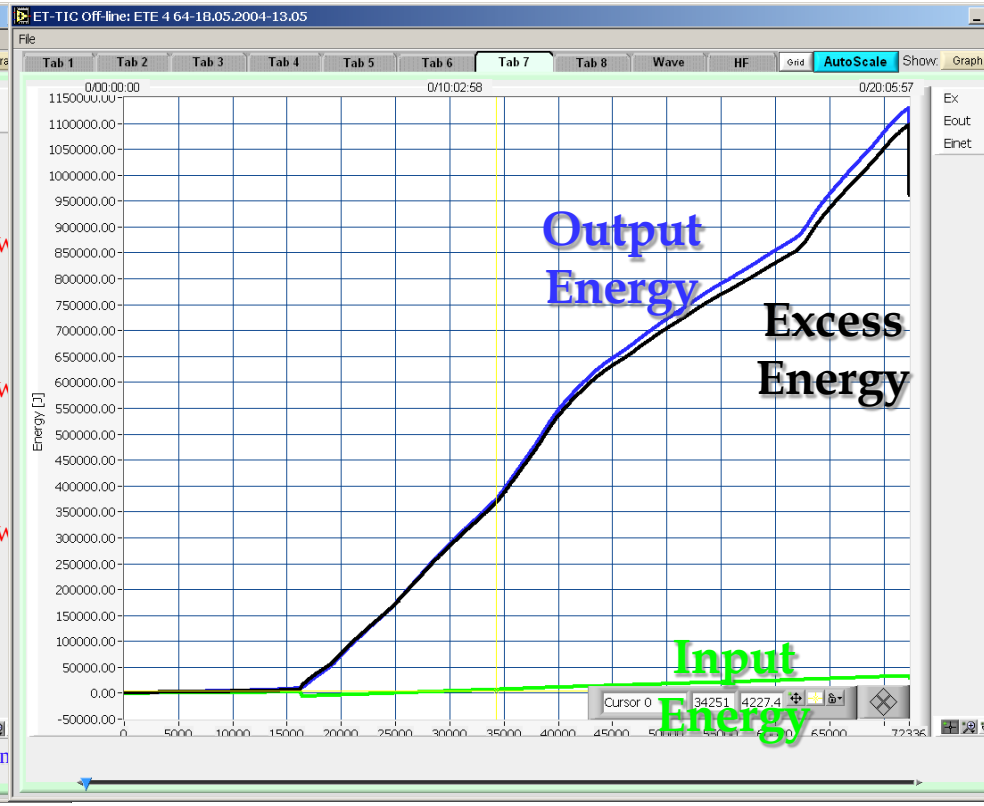
We started assembly today.
- Orville Wright's Diary, Oct. 9, 1903

A Long History of ‘Cold Fusion’ Reports

- **First report of a possible nuclear fusion in palladium loaded with hydrogen: Berlin, Germany, September 17, 1926 by Professors Paneth and Peters, later retracted due to helium in glass.**
- **Some patent activity in and after 1927 by Tandberg in Sweden**
- **Detection of confirmed nuclear fusion in liquid heavy hydrogen at -422 F (-252 C) in Russia, Berkeley and other places from 1954 to 1959. This fusion is catalyzed by naturally occurring muons**
- **Fleischmann and Pons (FP) fateful Press Conference on March 22, 1989**

Excess Heat Result from Energetic Technologies in 2004





E_{out} = 1.1 MJ, E_{in} = 40 kJ

The Excess Heat Effect: far Greater than Chemical Heat Release

- The ET Pd cathode mass was 0.3 g ($2x10^{-3}$mole)
- Chemical release of heat:
  - ΔH for Pd +D → PdD is about 43 kJ/mole
    - So about 100 J if this heat release was somehow delayed
  - ΔH for $2D_2 + O_2 \rightarrow 2D_2O$ is about 242 kJ/mole
    - So about 500 J of delayed released heat
- Many measurements show:
  - Typical heat release per episode of 50,000 J
  - Occasional heat release of over 1,000,000 J
- Heat release is usually from ambient temperature to about 100 ^{o}C, with occasional reports of heat release at much higher temperatures

So What is Going On?

- We don't know – it will take a lot of well controlled experiments to figure this out.
- The 'excess heat' is real, and this has been confirmed by NRL, ENEA, and many other labs. That is enough to motivate <u>serious</u> study
- A nuclear process?

  - Fusion? Look for nuclear by-products

  - LENR? First electro-weak nuclear energy release? If so, look for cold neutron effects

  - Something else?

Junk Science or Empirical Data?

- Persistent observations, like excess heat in Pd – D, should be treated as empirical evidence that our understanding of physics remains incomplete.
- It is simply too convenient and too scientifically counter-productive to dismiss these observations as ‘junk science’.
- The Scientific Method is the only thing we have got, and fortunately it is the <u>only</u> thing that we need!
  - Simply apply the scientific method without prejudice, and go where the data leads you

Sidney Kimmel Institute for Nuclear Renaissance (SKINR) at MU

Sidney Kimmel FOUNDATION

$5.5 Million gift, plus equipment,
Five-year minimum duration

SKINR's objective is to determine the physical origin of the Anomalous Heat Effect

"I chose MU for this important gift because it is a comprehensive university, experienced in using its deep scientific research capacity across many fields with its firm commitment to serve the public good."

The Sidney Kimmel Institute for Nuclear Renaissance (SKINR)

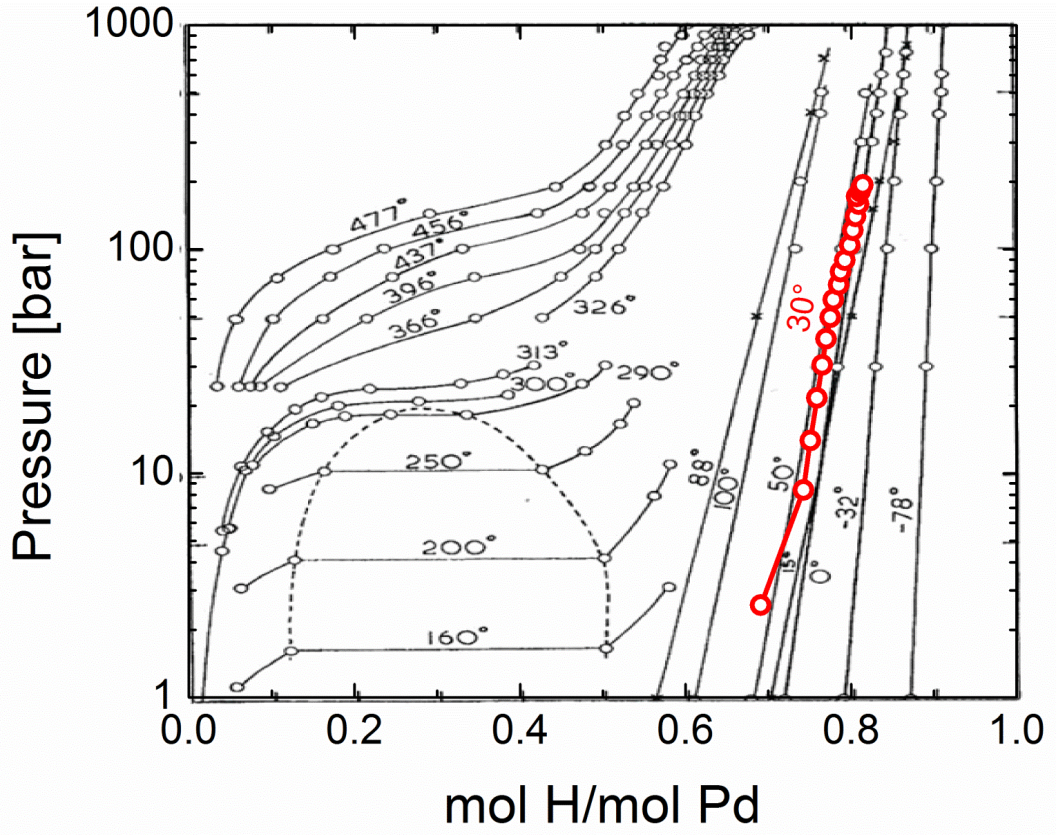
- Established on a $5.5M gift from Sidney Kimmel
- Exclusive license to utilize all of Energetic Technologies' prior technology and IP
- Dedicated to applying the Scientific Method to determine the origins of the AHE
- Secondary mission to secure relevant additional IP as the science develops
- Dedicated to open publication and transparency is our scientific mission

SKINR's Scientific Focus

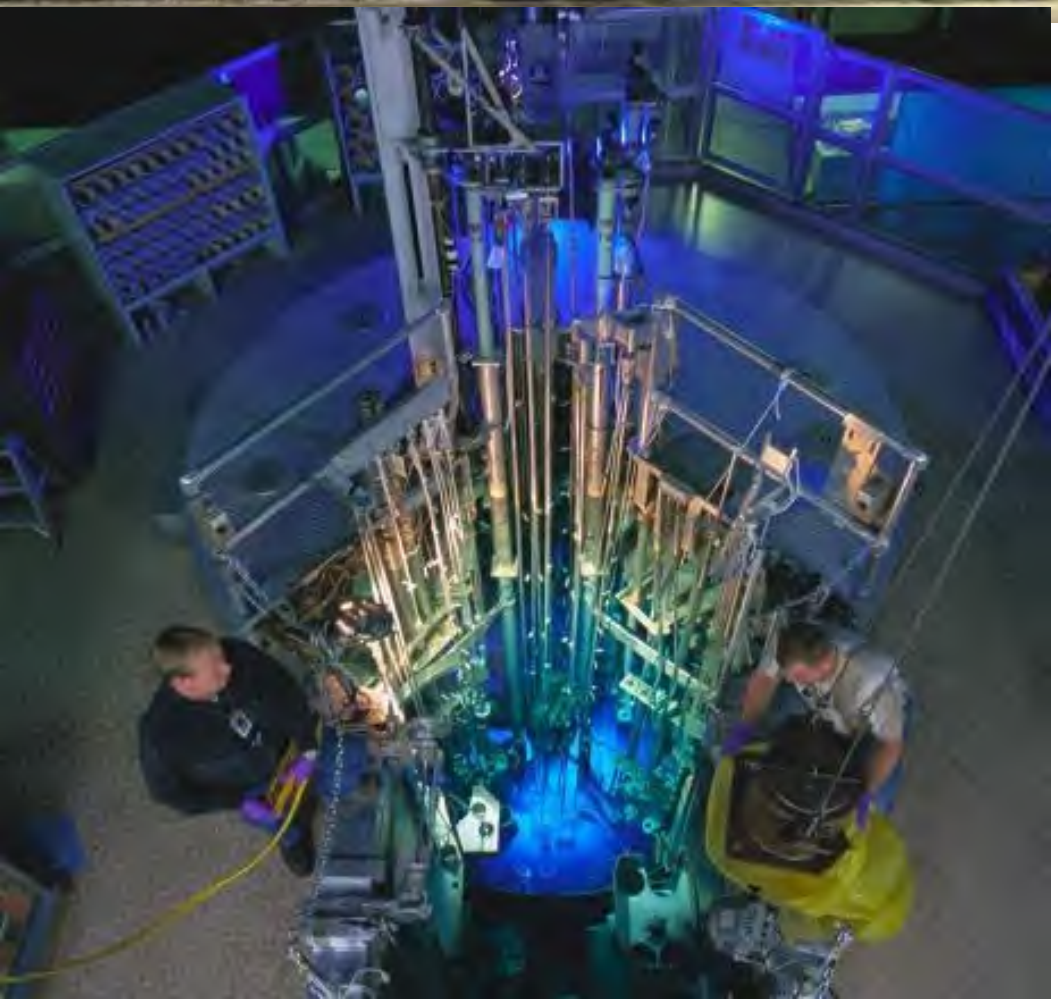
- Always run careful controls (hydrogen vs. deuterium) in all experimental loading techniques, including 'electrolytic', 'implant', and 'gas loading'.
- Be 'hypothesis driven' throughout. What are we trying to disprove?
- Characterize the Pd metal surfaces carefully, and evaluate surface changes in all samples regardless of the level of excess heat release – standardize the protocol – utilize 'top-down' fab and 'self-assembly'
- Comprehensive chemical analysis and isotope abundance determinations

SKINR's Scientific Focus (Con't)

- Extend the parameter ranges of loading
  - Gas Loading: P up to 200 bar, T down to 20 K



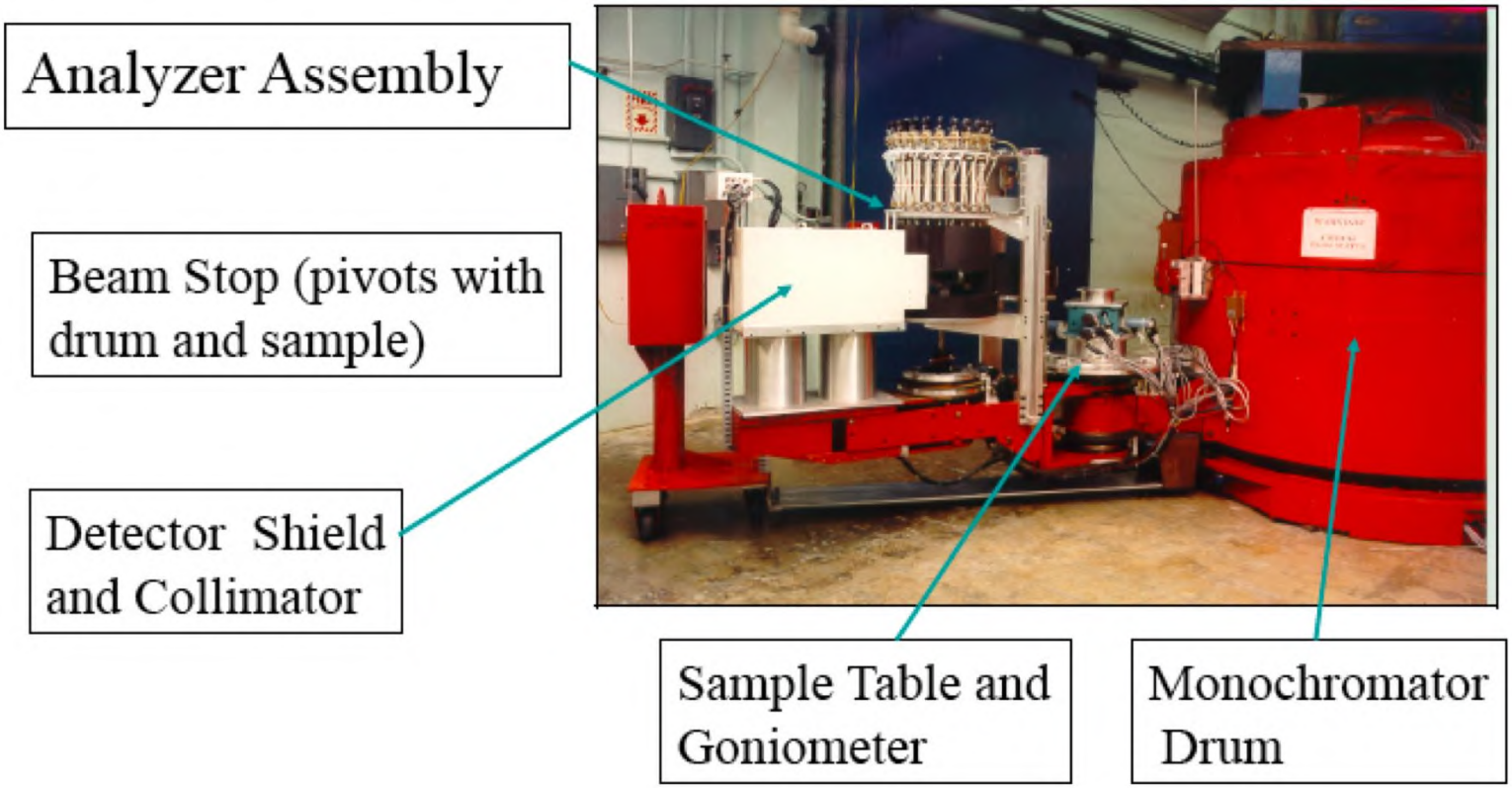
MU Research Reactor



At **10 MW**, MURR is the largest neutron source on a US campus and provides a flux competitive with national user facilities. It has a total of **six beam ports**, three of which are presently dedicated to **four neutron scattering instruments**: a triple-axis spectrometer (TRIAX), a neutron reflectometer (NR) and two double-axis diffractometers (2X-C and PSD).

SKINR's Scientific Focus (Con't)

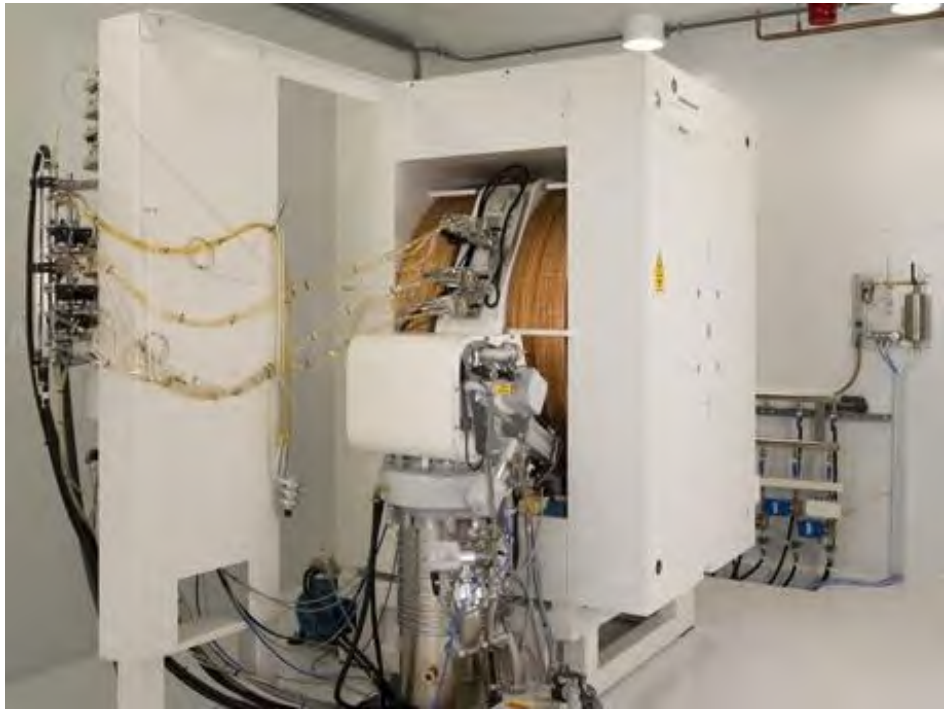
- Neutron scattering to determine the structure and dynamics of the hydrogen / deuterium system; x-ray scattering to determine Pd lattice



SKINR's Scientific Focus (Con't)

Implant Loading… Energy from 'discharge loading' up to the Coulomb barrier (cyclotron)

General Electric, 16.8 MeV p accelerator (MU and Essential Isotopes, LLC)



In a big radiation vault, so we bring the beam out to impinge on target

D+ on naturally occurring Pd targets

D+ on natural Pd loaded with D

p on naturally occurring Pd targets

p on ^{64}Ni

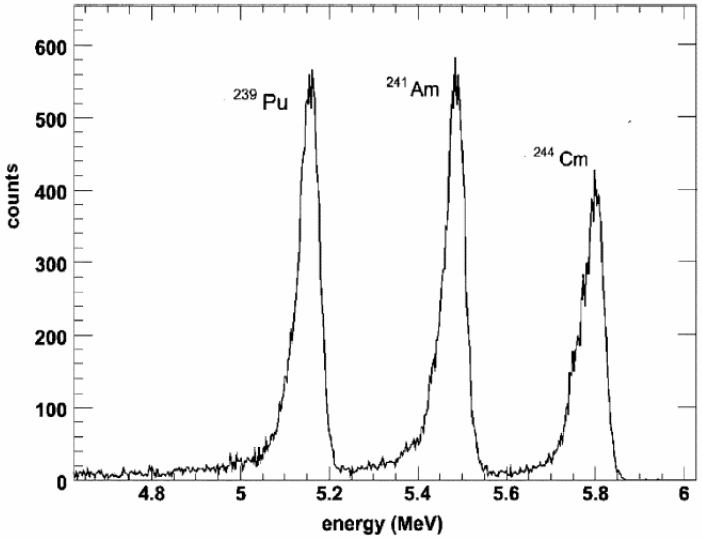
SKINR's Scientific Focus (Con't)

- Neutron activation analysis to search for 'cold neutron' effects (data below from Firestone, *et al*.)
- See Bush and Lagowski: *Trace Elements Added to Palladium by Electrolysis in Heavy Water, EPRI, Palo Alto, CA: 1999 (TP-108743):* $^{108}Pd/^{110}Pd$ down 28%!
- Determine ^{108}Pd /^{109}Ag stable isotope ratio

Isotope	Abundance	neutron σ_{th} (barn)
^{102}Pd	1%	0.9
^{104}Pd	11%	0.61
^{105}Pd	22%	21.1
^{106}Pd	27%	0.36
^{108}Pd	27%	7.6
^{110}Pd	12%	0.10

SKINR's Scientific Focus (Con't)

- Use diamond substrate particle detectors to check for internal conversion



See Mark Prelas and Eric Lukosi for more information. Figure copied from A. Galbiati *et al.,* IEEE Transactions on Nuclear Science, Vol. 56, No. 4 (2009), 1863-1874.

- Local fields (NMR) to search for molecular formation and crystal lattice position
- external initiation trigger measurements
- New novel experimental configurations that have displayed results, such as a new on-demand neutron source

Possibility of fast valance fluctuations?

Ni: $4s^2\ 3d^8$

Pt: $6s^0\ 5d^{10}$

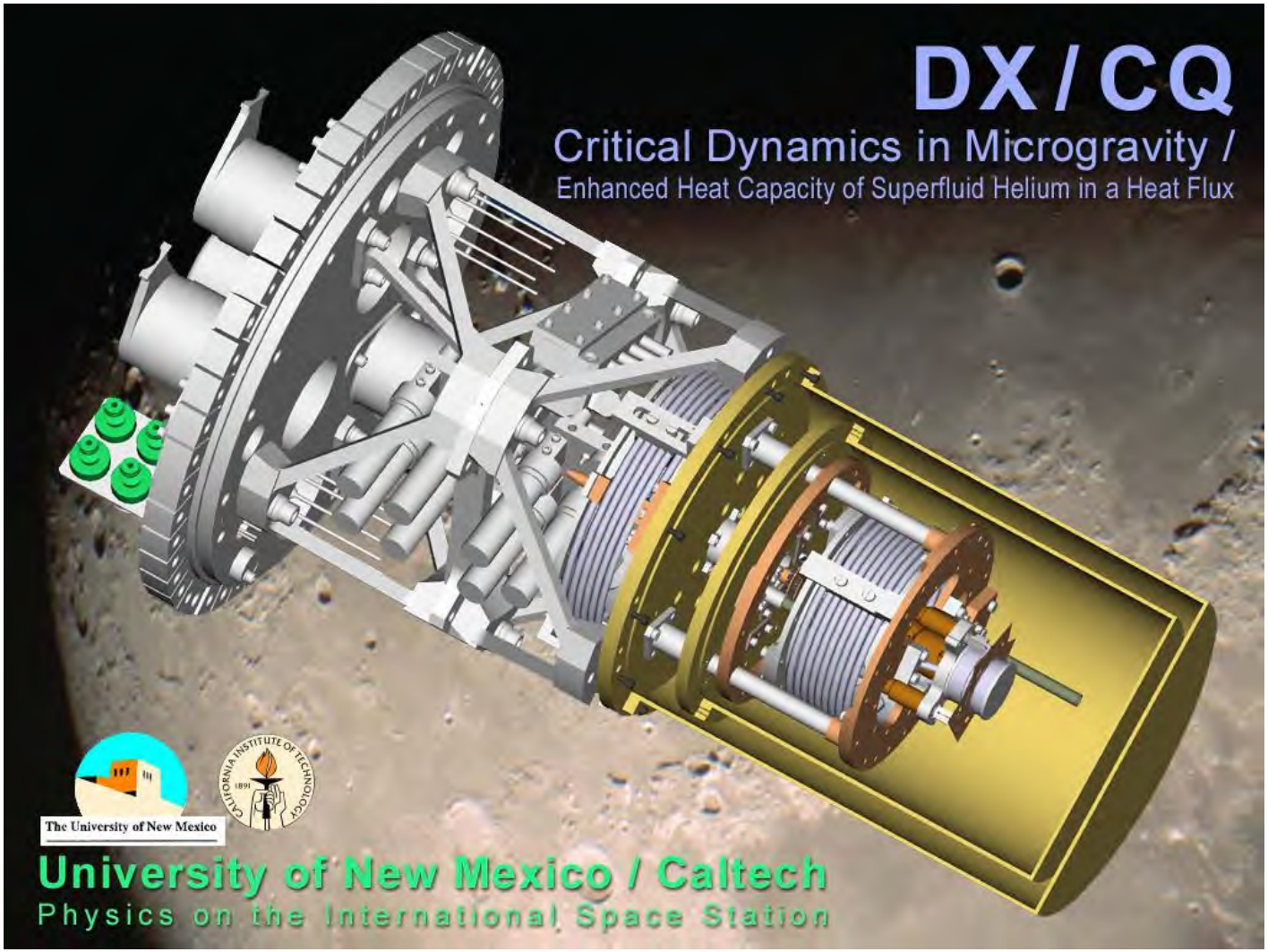
but Pd switches, hence Stoner Enhancement, etc.

Period	1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 ------- VIII ------- ------- 8 -------	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 vIIIA 8A
1	1 H 1.008	2 He 4.003																
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.47	Ni	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	Pd	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 190.2	Pt	79 Au 197.0	80 Hg 200.5	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac~ (227)	104 Rf (257)	105 Db (260)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 --- ()	111 --- ()	112 --- ()		114 --- ()		116 --- ()		118 --- ()

Lanthanide Series*	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinide Series~	90 Th 232.0	91 Pa (231)	92 U (238)	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (249)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lr (257)

Space flight is the only way to avoid ξ_g

See Barmatz, Hahn, Lipa, and Duncan, "Critical Phenomena Measurements In Microgravity: Past, Present, and Future", Reviews of Modern Physics 79, 1 (2007)



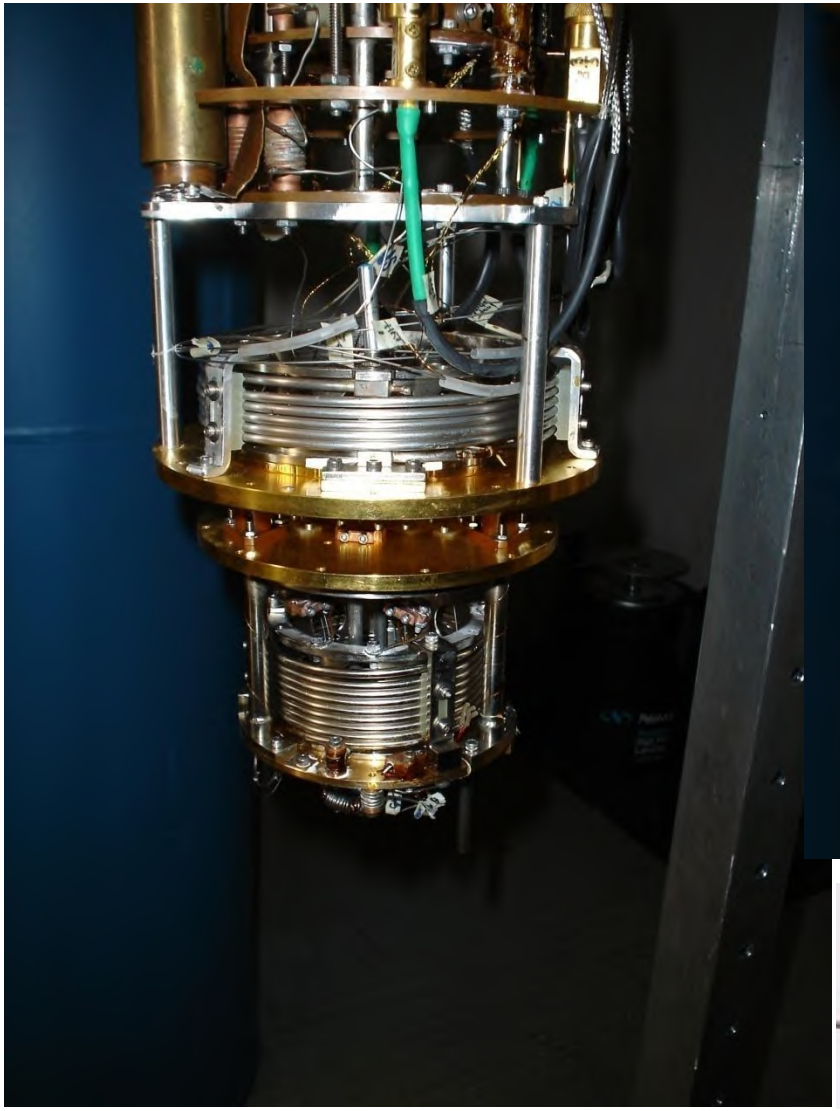
Successful CDR in 2003

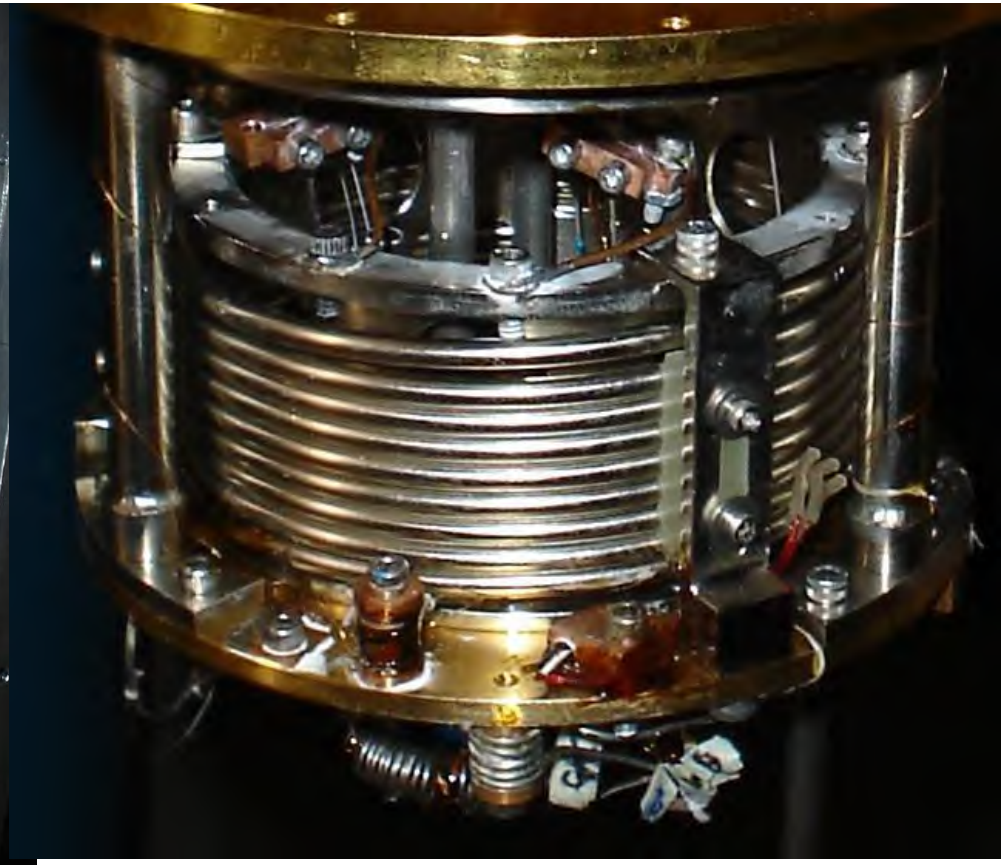
Cancelled in 2004

All 117 'ClassB' approved hardware drawings are in place.

Need:
- **new PI team**
- **flight dewar**
- **platform**
- **ride**

‘T5’Critical Thermal Path





Conclusions / Recommendations

- Follow the Scientific Method to determine the physical mechanism
- Encourage all funding agencies to be more empirically evidence-based as well
- Expand experimental techniques and the range of physical measurements
- Create a more formal international trade organization, and meet to standardize terminology, and to develop standards
- Open Source versus Proprietary approaches