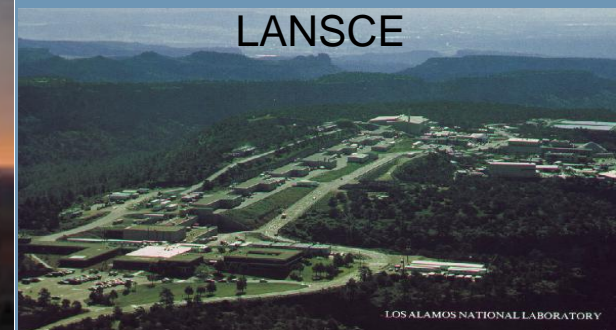


Materials Sustainability



SANTA FE INSTITUTE

LANSCÉ



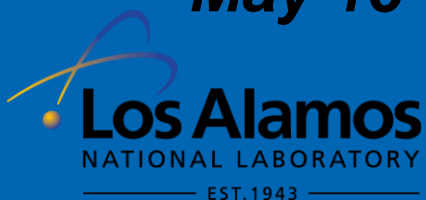
***Partnerships, Science, and Innovation for
Sustainability Solutions***

NAS

May 16-18, 2012

Alan J. Hurd

***Los Alamos National Laboratory
Santa Fe Institute***



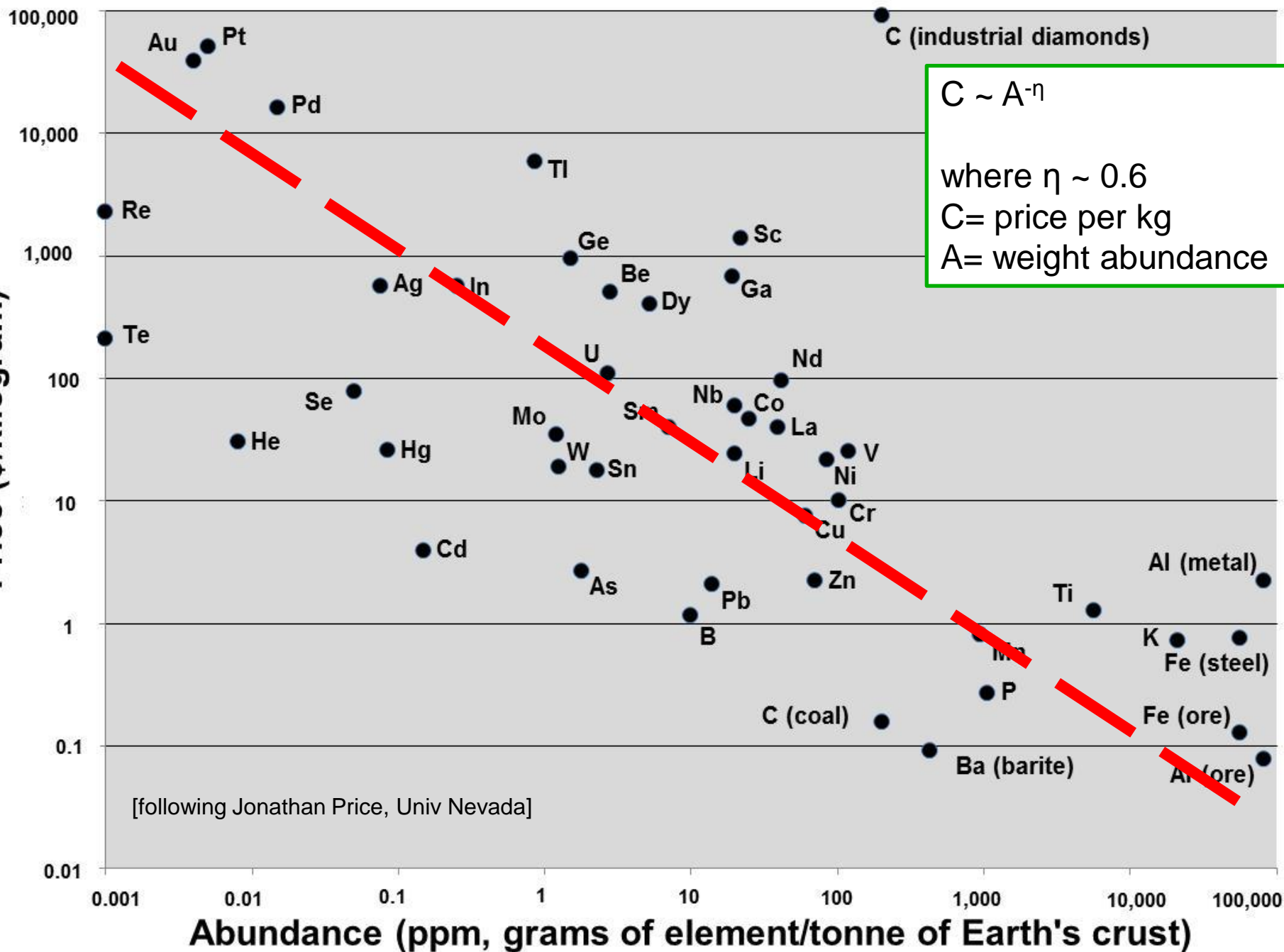
The APS-MRS set of Energy Critical Elements

(American Physical Society and Materials Research Society)

Alan J. Hurd, Santa Fe Institute and Los Alamos

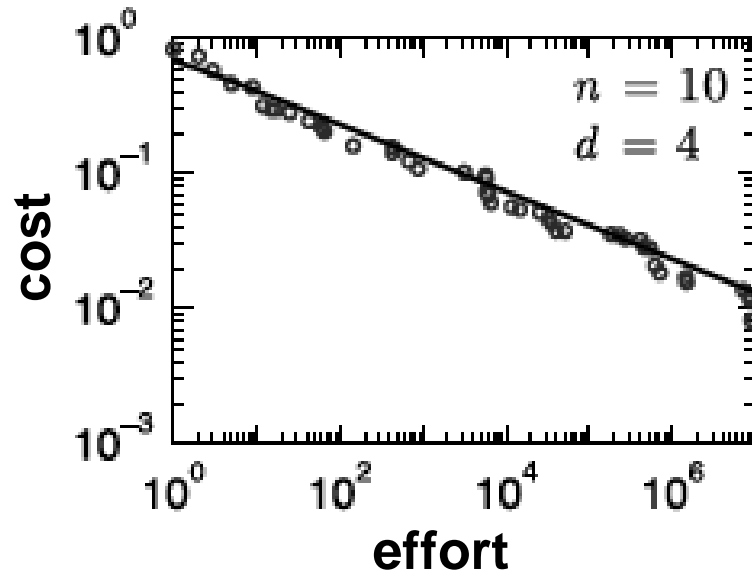
1 H Hydrogen 1.01																	2 He Helium 4.00														
3 Li Lithium 6.94	4 Be Beryllium 9.01																	5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18								
11 Na Sodium 22.99	12 Mg Magnesium 24.31																	13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95								
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 68.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80														
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29														
55 Cs Cesium 132.91	56 Ba Barium 137.33	57 La Lanthanum 138.91	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)														
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	101 Rf Rutherfordium (261)	102 Db Dubnium (262)	103 Sg Seaborgium (266)	104 Bh Bohrium (264)	105 Hs Hassium (269)	106 Mt Meitnerium (268)																							
																		58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
																		90	91	92	93	94	95	96	97	98	99	100	101	102	103

Price (\$/kilogram)

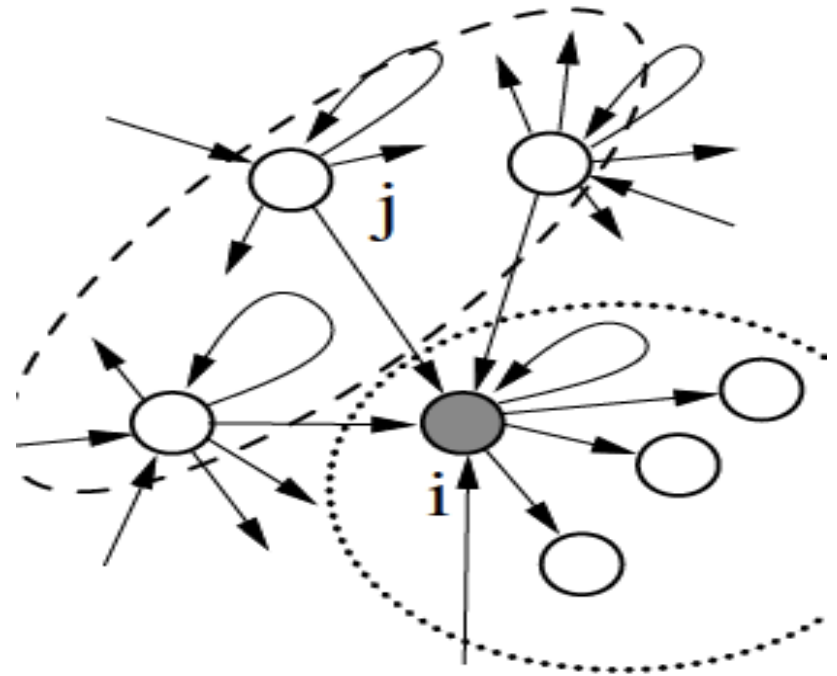


Role of design complexity in technology improvement

McNerney, Farmer, Redner, and Trancika *PNAS* **108** 9008 (May 2011)



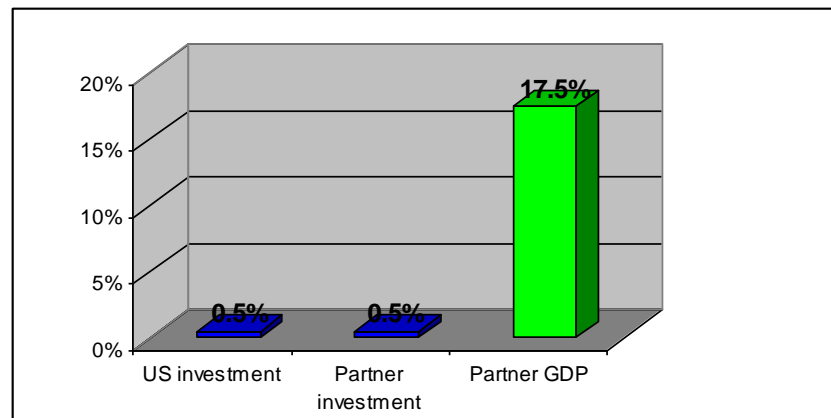
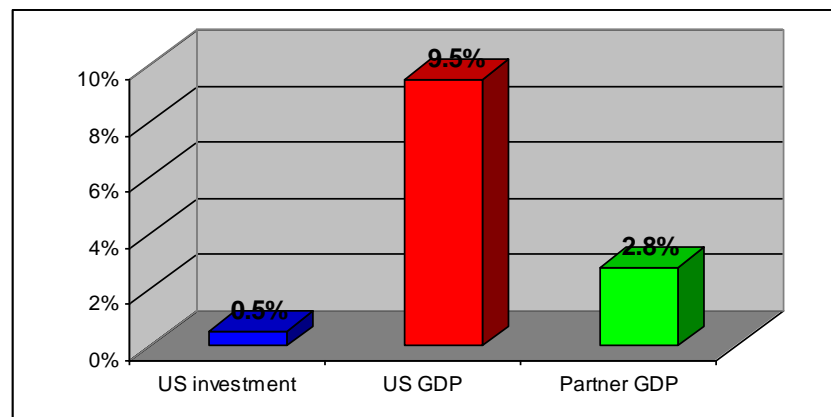
Wright's Law: Power law



Return on Investment and Economic Spillover

- **If U.S. increases domestic R&D by 0.5% of GDP then**
 - its own GDP will rise 9.5%
 - other industrialized countries' GDP will rise 2.8%
- **If *all* industrialized countries increase R&D by 0.5% of GDP**
 - their GDP would rise 17.5%.
- **U.S. would nearly double its GDP growth compared to the scenario of “going it alone.”**
- **[Coe and Helpman (1995, 1999, 2009)]**

After 15 years



World Materials Summits

2007 Lisbon; 2009 Suzhou; 2011 Washington DC



Materials Research Enabling
Clean Energy
and Sustainable Development

VISION It is an inherent right of everyone on Earth to have access to clean energy and water in a sustainable way. Achieving this goal is a global endeavor that will require international coordination, cooperation and collaboration. Materials play a critical role in enabling viable solutions to these problems.

Back up slides

International and National R&D Directions—What's needed for S&T for Sustainability

- ☐ How is the sustainability challenge being framed and addressed in scientific research?
- ☐ What are the major sources of knowledge and information?
- ☐ Often, sustainability challenges are complex. How does research begin to grapple with that complexity?
- ☐ How much of the knowledge can be used to inform programs/policies? Who were the key partners and how did they work together?
- ☐ What does the scientific community say is needed for S&T for sustainability?
- ☐ Based on your experience, what are the key S&T needs for sustainability, and what is needed to pursue them?
- ☐ Are there institutional barriers to funding or doing research in this area? If so, what can be done to address them
- ☐ Where are we today in terms of identifying the right issues and gaps in the science and technology research being done to support sustainability? What new directions are needed in international and national R&D?

Materials research

- 1. Raw materials supply risk, especially energy critical elements and the sustainability challenge they present.**
- 2. Technology improvement learning curves for sustainability development.**
- 3. Return on investment for federally funded R&D.**

Thoughts

- **Surrender the Climate Change battle**
 - Public opinion lost
 - No irrefutable logic, like the debt
 - No Sagans appeared
 - No one left has credibility
 - » Right: tainted by profits
 - » Left: tainted by questionable loyalty, scandals
 - Move to mitigation and accommodation of effects such as sea rise
 - Enjoy some new advantages such as navigation
 - Lengthen the overtime period; it will be sudden death
- **Broaden the discussion to Sustainability, a superset with CC in it**
 - Better captures the sus
 - Irrefutably depletion tech is limited.

Joe Sixpack

- **Watches NOVA**
- **Reads Sci Amer**
- **Likes awe he feels from looking at pictures that invoke spiritual feelings**
 - Hubble
 - Sun satellite
 - Rover
- **Understands the National Debt math—same as household budget**