SAND2013-8234C

Green, Does It Make Sense (cents)?
(Green: Improving the Quality of Life)

Sandia National Laboratories

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

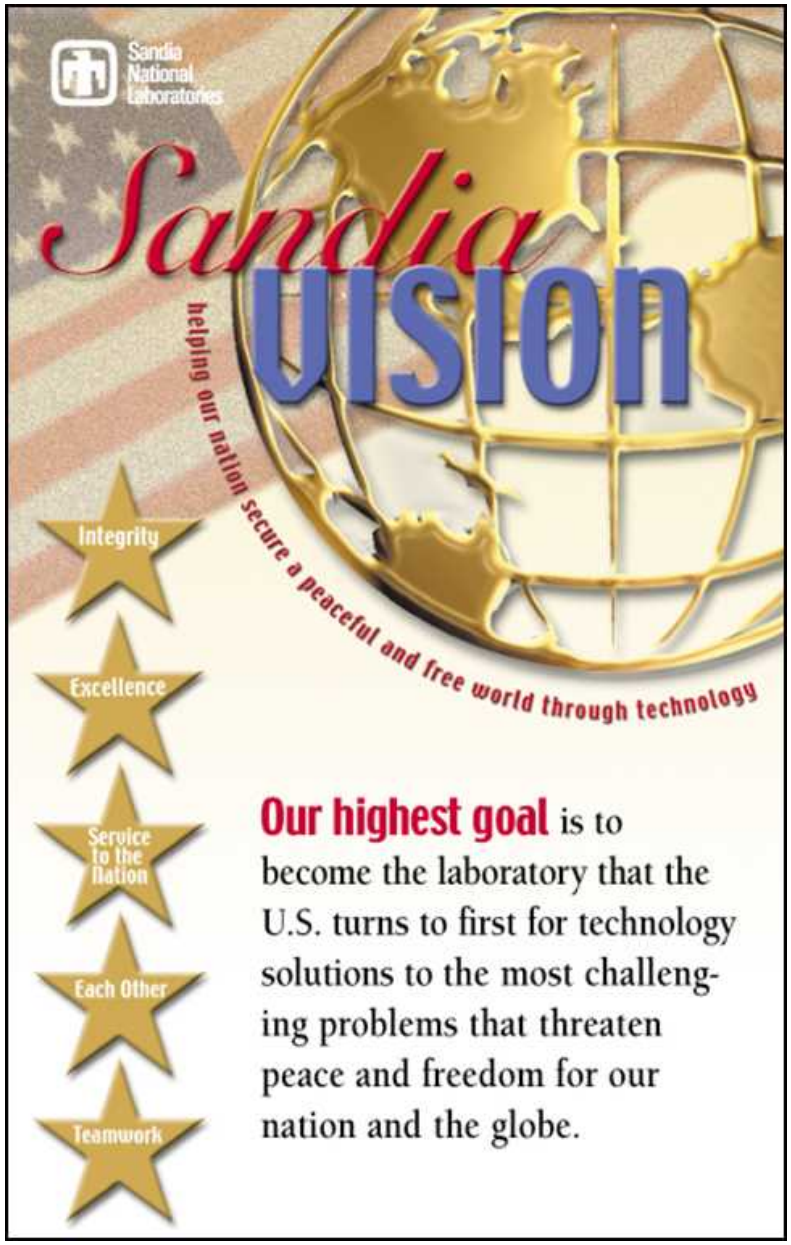
New Mexico


Welcome
— to —
NEW MEXICO
Land of Enchantment


Roswell Daily Record
RAAF Captures Flying Saucer On Ranch in Roswell Region
Claims Army Is Slacking Courts Martial
House Passes Tax Slash by Large Margin
Security Council Paves Way to Talks On Arms Reductions
No Details of Flying Disk Are Revealed
Ex-King Carol Weds Mme. Lupescu

Sandia National Laboratories

"Helping our nation secure a peaceful and free world through technology"



THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Harry Truman

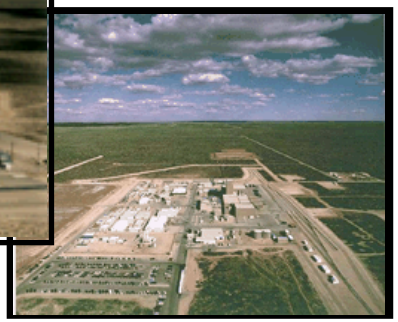
Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

exceptional service in the national interest.

Sandia National Laboratories is distributed

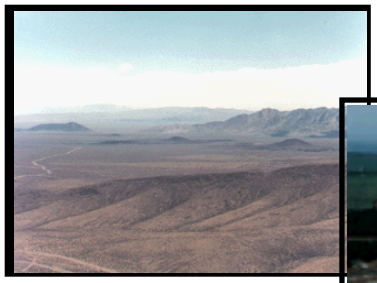
Albuquerque, New Mexico

Tonopah Test Range, Nevada



WIPP, New Mexico

Livermore,California

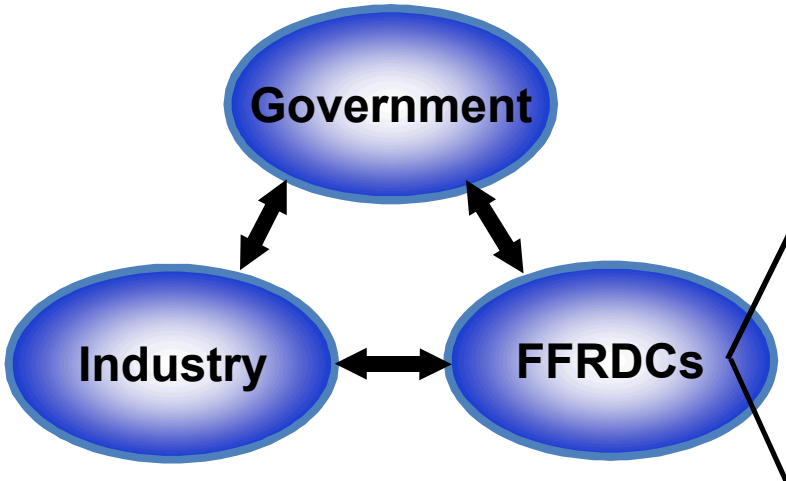


Yucca Mountain, Nevada

Kauai Test Facility, Hawaii

Sandia National Laboratories

Successful Business Model



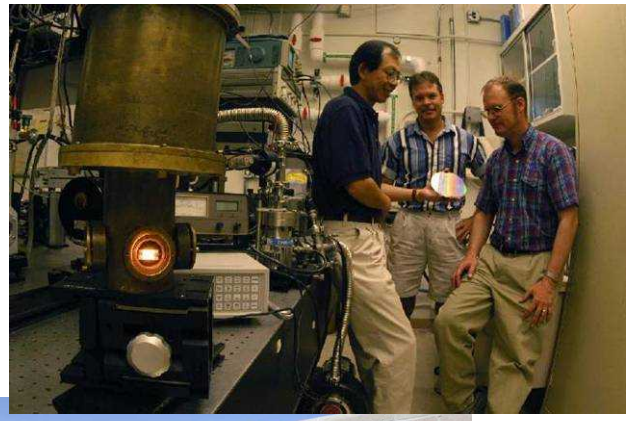
This government directed teaming model has several desirable attributes:

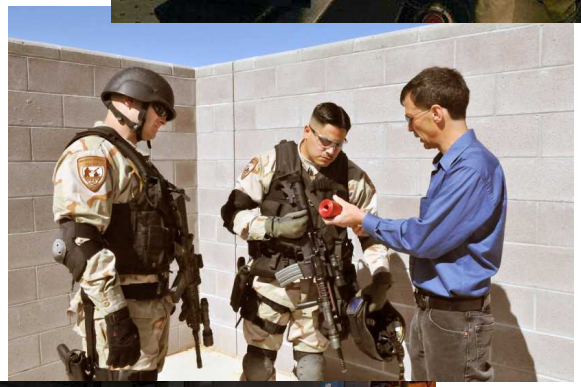
- Uses strengths from Labs & Industry
- Allows rapid insertion of technology into deployed systems
- Spans the technical "valley of death"
- Exercises core Lab technical strengths
- Exposes Lab staff and management to realities of operational issues
- Builds mutual respect
- Requires trust

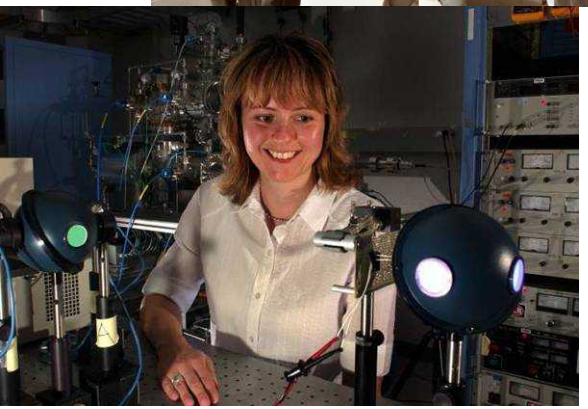
We have been very successful in applying this approach and technology capability to complex national challenges!

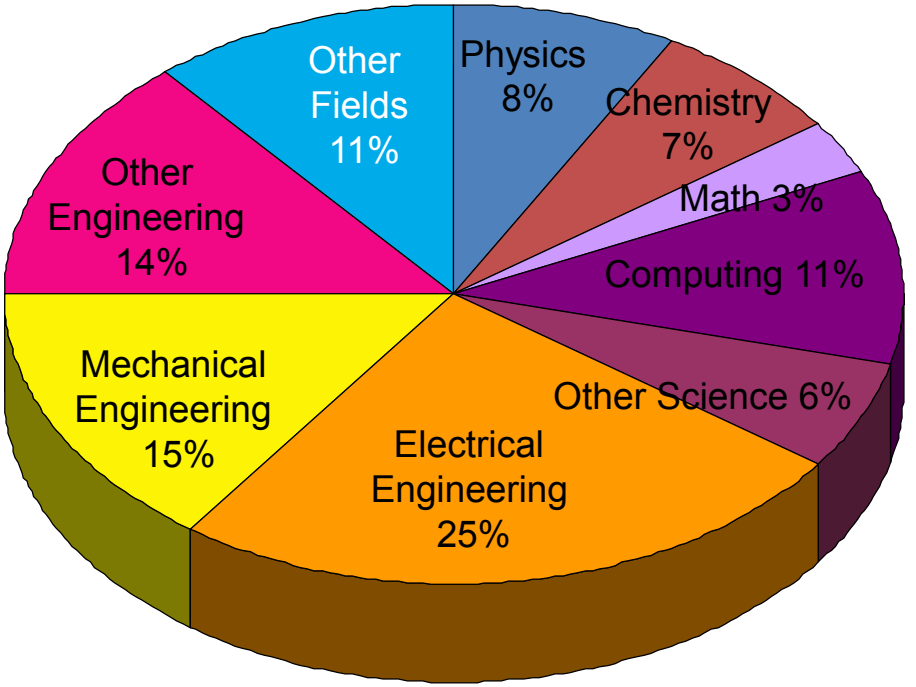
Sandia National Laboratories

Sandia has a Highly Skilled Staff





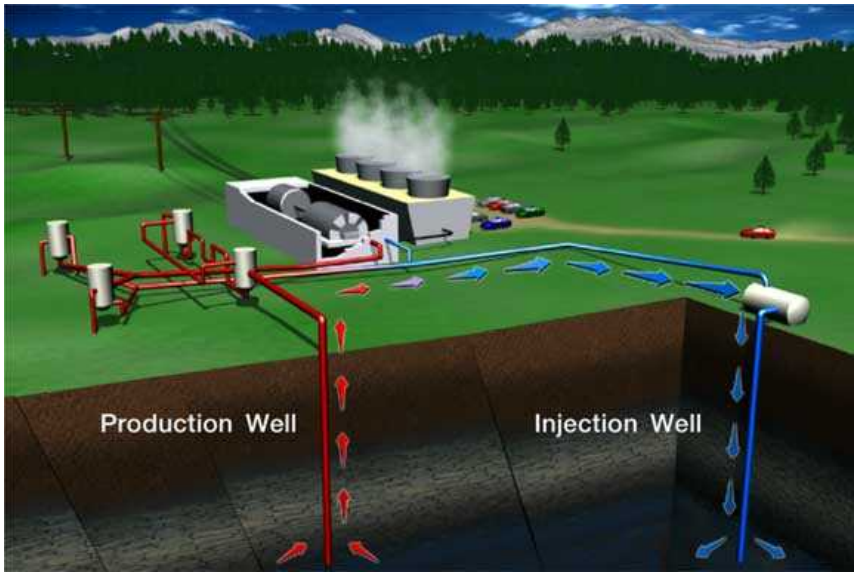


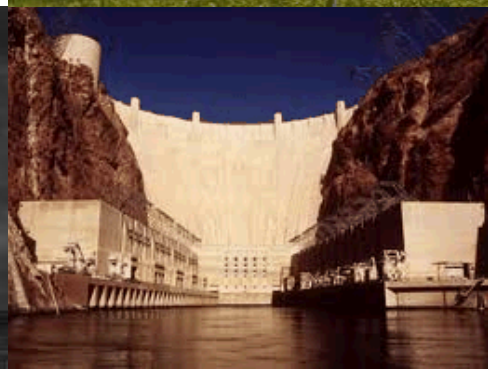


- **~11,000 full-time staff**
- **~1,500 PhDs and ~2,500 MS/MA**
- **~1000 on-site contractors**
- **~ $2.0+ billion operating budget**

Sandia National Laboratories

Green Energy ?

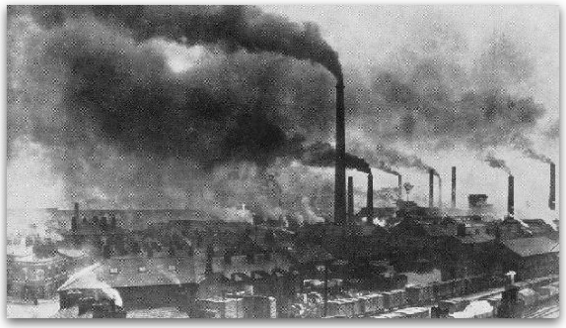




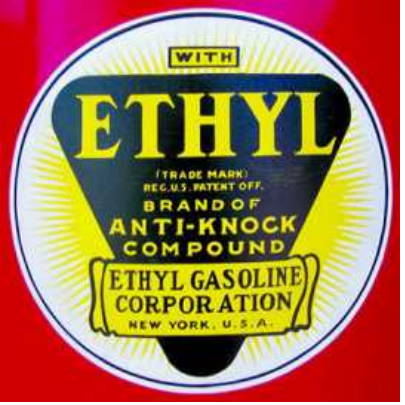
- Wind
  - Fluctuations
- Solar
  - 1/0
- Hydro
  - Limited
- Geothermal
  - ~Unlimited
- Nuclear
  - Unlimited, clean?, Subject to HC-human error
  - (SL1, Fermi 1, TMI, Chernobyl, Fukushima)
- Oil & Gas
  - Historically green ???
- Coal
  - Scrubbers, environmental issues
- Wood/Peat/Dung, etc.
  - Really dirty!

Green oil and gas? Historically: Yes!

- History
  - Oil used since recorded history
  - First well: Edwin L. Drake Titusville PA, USA, August 27, 1859… Apparently not… But it was below bedrock!
  - James Miller Williams, Enniskillen Canada, 1858…. Nope…. A staggering 12 foot deep reservoir!
  - N.Y. Krylov, A.A. Bokserman, E.R.Stavrovsky. The Oil Industry of the Former Soviet Union. CRC Press, 1998 .
    - Azerbaijan in 1848 !

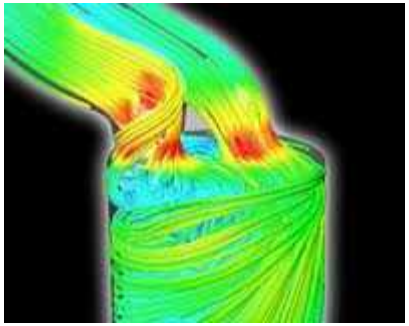


- The world economy evolved:
  - Whale oil used for lighting into the 19th century
  - Wood and coal used for heating and cooking into the 20th century.
  - The "Industrial Revolution" generated an increasing need for energy which was fueled mainly by coal and whale oil. – This did not make the whales happy.
  - Once discovered that kerosene could be extracted from crude oil and used as a lighting & heating fuel; Petroleum was in great demand. By the 20th it had become a most valuable commodity traded on the world markets.
    - Central power generation, vehicle fuels, economies of scale and convenience.
    - Life is good
    - Technology evolves to improve the standard of living of mankind but occasionally takes a step backwards.



But… examples…

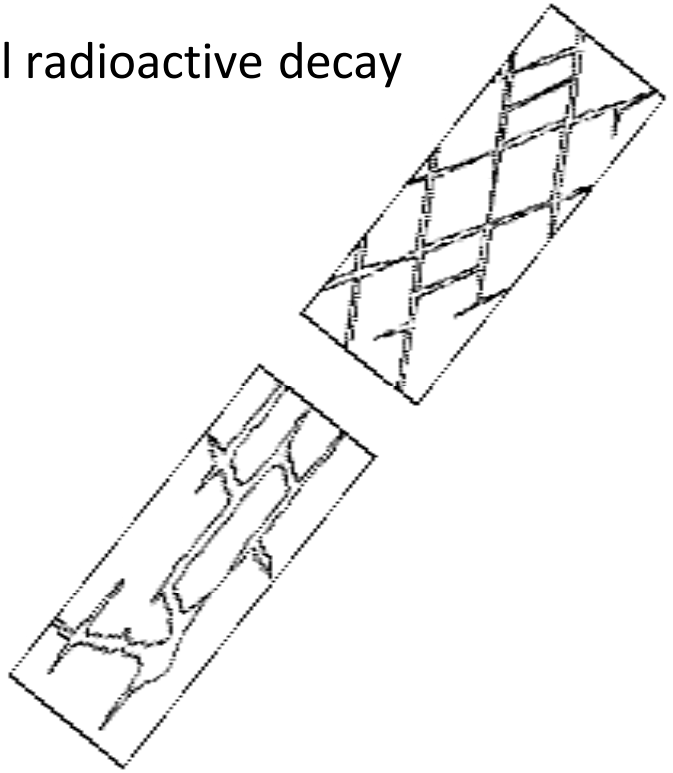
- **Tetra-ethyl-lead**
  - Chemical technological miracle
    - Octane improver
    - Valve seat lubricant
  - At the time this seemed like a good idea eve though the dangers were known.
  - Distributed (inoculated) over the earth and concentrated in cities. Early human history: lead pipes!
    - The solution:
      - Stellite valve seat ($) + improved valves ($) and modern engine management plus CFD.
      - 1+HP/in3 reliably



- **Chlorofluorocarbon**
  - Replacement for ammonia
  - Brings cheap refrigeration to the world
  - Ozone attack
    - The solution:
      - New HCFCs, etc.
- Green is a function of history, but not a Green's function (sorry, terrible joke).
- Technology evolves to improve the standard of living of mankind but occasionally takes a step backwards after the fact.

GEOTHERMAL ENERGY

- Hydrothermal- existing hot fluid systems
- Enhanced Geothermal Systems (EGS) or hot dry rock geothermal energy
  - Require high surface are heat exchanger and low pressure drop (permeability)
- How much? 44TW ~replenished by natural radioactive decay
  - Largest renewable energy resource
  - Engineering is the trick



How do we get it?

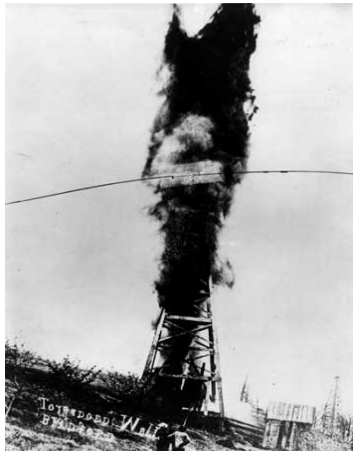
- Controlled Stimulation:



- Rate and Peak Pressure

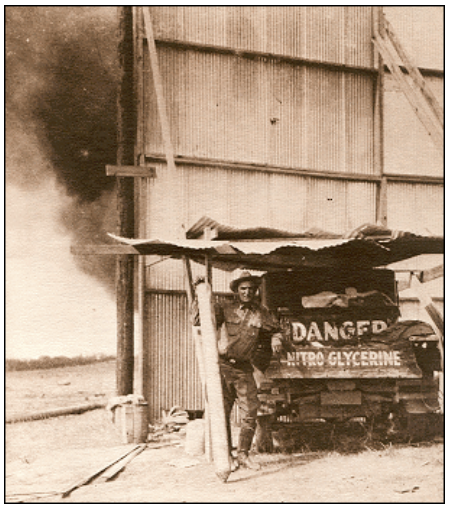
History

- 1846 Ascanio Sobrero: Nitroglycerin invented, thought to be inert (Oops!).
- 1859 Col. Edwin L. Drake completed the commercial first well drilled specifically for oil.
- 1865 Col. E.A.L. Roberts made the first successful oil well shot on the Ladies Well, using 8 pounds of black powder (nitroglycerin was first used 2 years later), ushering in the era of "Oil Well Shooting".
- 1947 early hydraulic fracturing… 1997 modern hydraulic fracturing developed
- Sandia develops Tailored Pulsed Loading, TPL Inc., blended gun propellant(dp/dt)
- Another "Lab" shoots a geothermal well with HE and ruins it. Not good.
- 2004 Autonomous micro-explosives subsurface tracing system. SNL
- Times marches on….

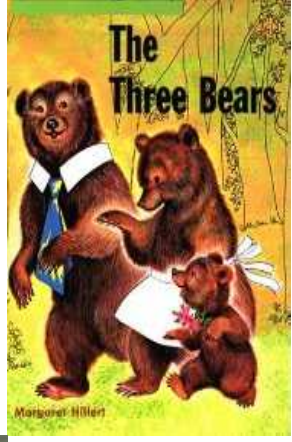


1884-1978

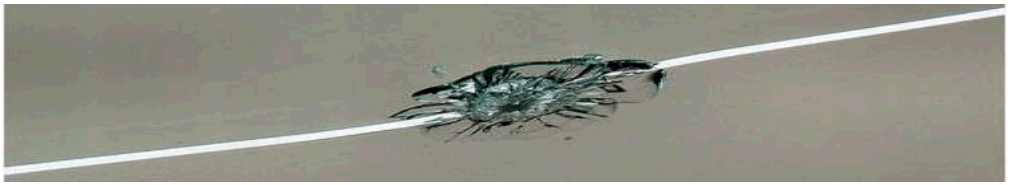
OTTO-CUPLER
OIL AND GAS WELL SHOOTING
TORPEDO CO.
P.O. Box 119
Pleasantville, PA 16341



Why is rate Important?
Why is peak pressure important?



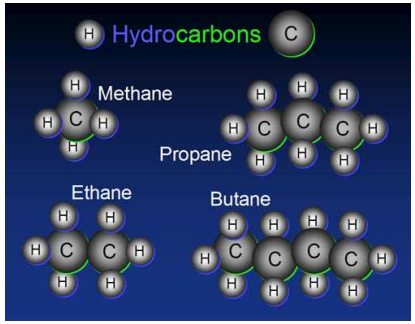
- dp/dt
  - Low rate generates single fracture. Hydraulic fracturing
  - High rate generates multiple fractures



- Peak pressure
  - Must be high enough to overcome material properties and in situ stress (crack propagation)
  - Low enough to prevent crushing (well bore damage)
- High explosive (detonate): A detonation is defined as a reaction wave propagating at supersonic velocity relative to the unreacted material immediately ahead of the reaction zone
  - Can be too fast and too high (solid HE)
- Pyrotechnics & Propellants (deflagrate - burn): A deflagration is defined as a reaction wave propagating at subsonic velocity relative to the unreacted material immediately ahead of the reaction zone
  - Can be too slow

Fuel-Ox System

+



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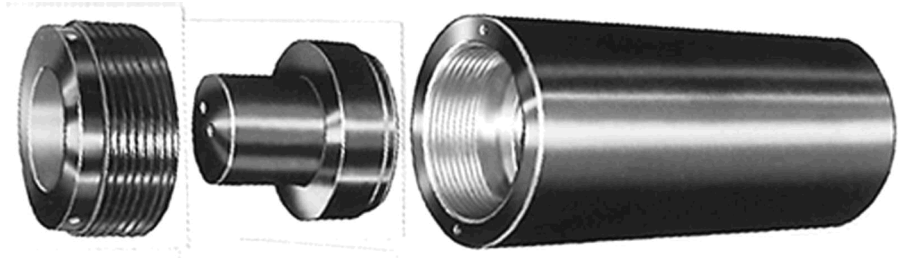
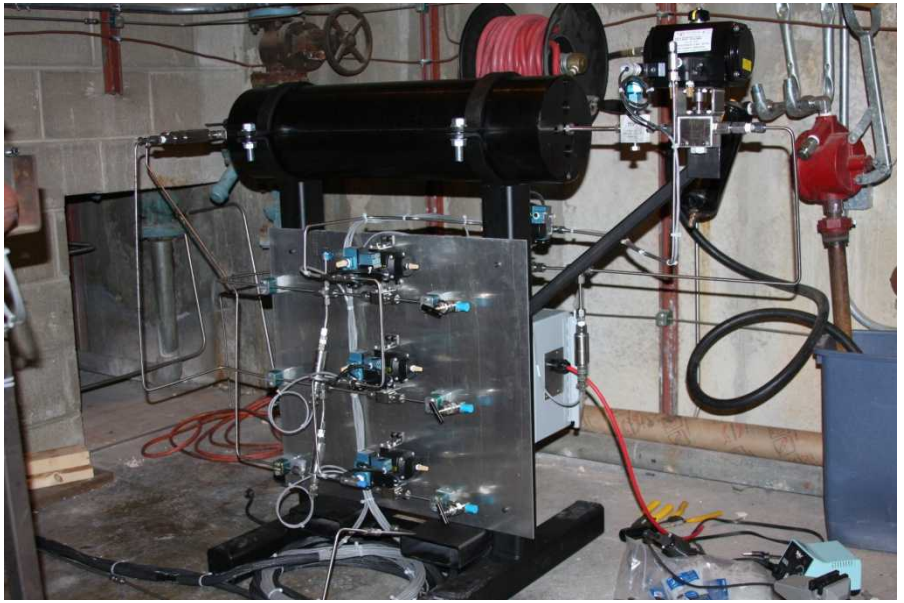
OR

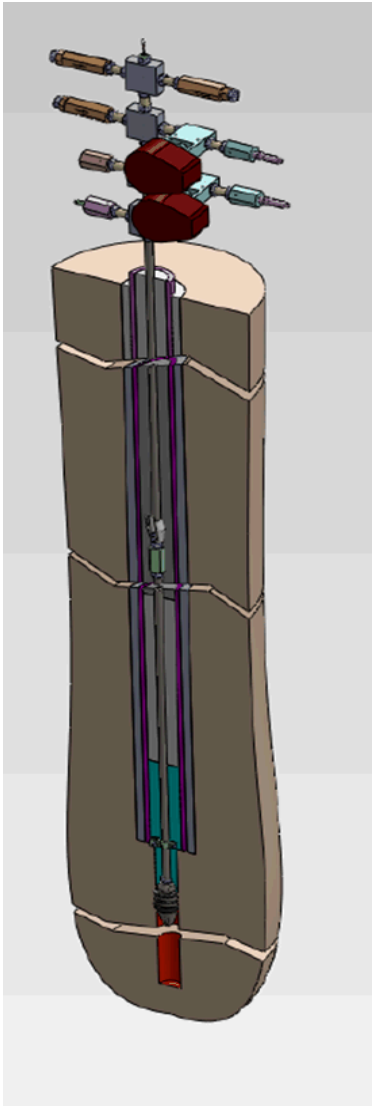
Fuel/Ox Well Bore Simulator & Field Test Hardware

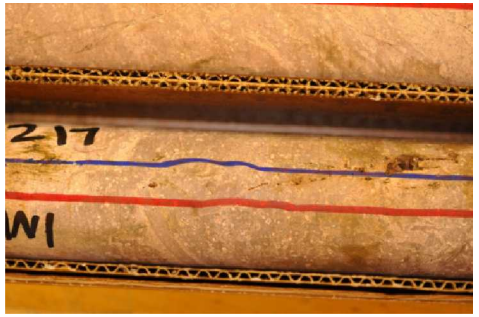
- Detonation bomb
  - Remote charge and fire
  - 4 x 24 inch ID
- Short run up to DDT
  - ~7000 ft/s
  - Pressure 300 - 80,000 psi





Field Testing





4000 hp Hydrogen Peroxide Gas Generator
Zucrow Labs Purdue University

PURDUE PROPULSION

Energetic + Metal System

(fuel rich gas generator)

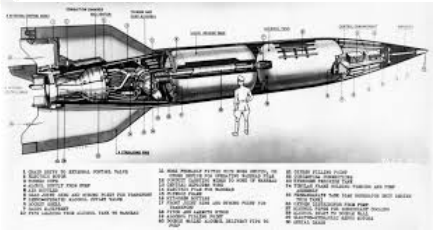
- Energetic + M
- M = Al, Si, B, TiH_2, $NaBH_2$, etc
  - High temperature stability (> 500F)
  - Reaction rate control
  - Pseudo low velocity “detonation”
  - Fuel rich gas generator (fuel water combustion)

Geothermal > Oil and Gas

- Techniques developed for EGS have direct application to oil and gas
  - Non-hydraulic fracturing

- Why is this green?
  - Extraction of residual oil and gas makes well more profitable
  - Less environmental impact
  - More efficient utilization of resources
  - No contaminated water

Propulsion; Green is here! (sort of...)



- Nitrous Oxide Hybrid or ….
- HP
- No replacement for NTO/MMH/UDMH

HP + Kerosene > 810,000 $lb_{f(vac)}$

LNG the new (cheap)heavy lift fuel?

Constituents	Chamber Pressure	Expansion to	Pressure Ratio	Isp	Ivac
LOX LH2	3000	14.7	204.08	397.40	424.40
LOX LH2	1000	14.7	68.03	361.10	394.10
LOX LCH4	3000	14.7	204.08	332.50	355.80
LOX LRP1	3000	14.7	204.08	321.01	343.81
LOX LCH4	1000	14.7	68.03	301.10	329.70
LOX LRP1	1000	14.7	68.03	290.13	317.79

J.D. Lindblom, CEA

Pyrotechnics

(examples)

- Fireworks industry, eliminated “most” toxic material
  - Paris green (copper acetoarsenite)
  - Lead Oxide
  - Mercury
  - Barium
  - Etc…

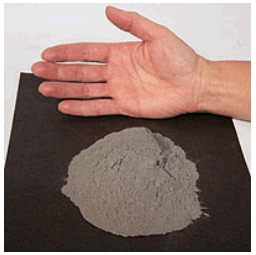
- Commercial applications:
  - Thermites and Intermetallics
    - Comprehensive work:
  - Fischer, Susan H.; Mark Grubelich “A Survey of Combustible Metals, Thermites, and Intermetallics for Pyrotechnic Applications”, SAND95-2448C, Sandia National Laboratories, Albuquerque, NM, June 1996. *Presented at the 32nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference, held July 1-3, 1996, in Lake Buena Vista, FL. AIAA-1996-3018*
  - Fischer, S.H., Mark Grubelich, “Theoretical Energy Release of Thermites, Intermetallics, and Combustible Metals”, SAND98-1176C, Sandia National Laboratories, Albuquerque, NM, May 1998. Presented at the 24th International Pyrotechnics Seminar, held July 27-31 1998, Monterey CA.

    - Elimination of chromates/perchlorates and heavy metal in pyrotechnic formulation possible

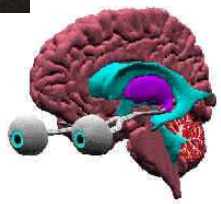
A practical example:
A diversionary Device

- A pyrotechnic item designed to produce a brilliant optic output (flash) and loud acoustic output (report or bang).

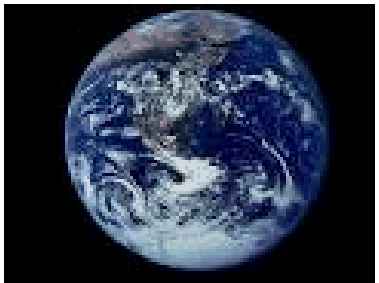
- Pyrotechnic material: Typically a binary blend of potassium perchlorate and aluminum power (also know as "flash powder" in the fireworks industry and "photoflash" powder by the military).



- Construction: Mechanical fuze attached to a "soft" frangible body or rigid vented body containing the pyrotechnic material.



- Design function: Temporarily (seconds) distract or divert the attention of an adversary. ***May induce temporary flash blindness and auditory offset. Does not intentionally cause permanent injury.***
  - Mechanism: invokes startle response in humans.
- Global use



Fuel Air Device

NO potassium perchlorate

GRAIN DUST EXPLOSIONS

Inside the can, right, is a lighted candle. Through the tube, cornstarch is blown into the candle's flame which explodes it so the cover of the can will be blown off. In this experiment, the destructive explosions in grain elevators are duplicated on a tiny scale. At extreme right, drawing shows arrangement of apparatus for experiment

CORN STARCH IN FUNNEL

Giant Explosions

REPRODUCED IN MINIATURE

by Home Chemists

To prove that every burning candle is a gas plant, incline a tube over the flame, as is shown above. In a short time, gas, escaping from the tube, can be lighted

HARMLESS, miniature explosions make experimenting with combustibles a thrilling, yet safe, amusement for the amateur chemist. With inexpensive homemade apparatus, he can duplicate the explosions in a gasoline motor and amuse his friends by burning air.

When we say a substance burns, we imply that it combines with oxygen to produce heat and sometimes light. Hydrogen and carbon, as well as many other substances containing these two elements, display this property. A candle, for instance, is made of paraffin, a combination of carbon and hydrogen. When the wick is lighted, the paraffin melts and produces hydro-carbon gases, which decompose to form other inflammable gases and carbon.

If a cold object is held in a candle's yellow flame, a black coating will be deposited on its surface, proving that free carbon is given off. That burnable gases are present can be shown by inserting the end of a short metal or glass tube in the flame and igniting the unburned gases issuing from its outer end.

In the case of the candle, the hydro-carbon gases unite slowly with the oxygen of the air. If by some means this action is speeded up, an explosion results. It is this speeded-up type of hydro-carbon combustion that is used to drive the pistons in an automobile motor.

A miniature explosion of this type can be carried out safely in the home laboratory by making use of the hydro-carbon vapors given off by a few drops of gasoline. First select a suitable tin can having a friction top that does not fit too tightly. Make a half-inch hole in one side near the top, place two or three drops of gasoline in the can, and fit the friction top.

With the can supported on a stand, place a lighted candle near the hole and heat the bottom or side of the can with a gas or alcohol flame. As the can is heated the inflammable liquid will vaporize, mix with the inclosed air, and leak out the half-inch hole in the side of the can. When the mixture contains just the right amounts of air and hydro-carbon vapors, it will be ignited by the candle and an explosion will follow. The cover will be gently blown from the can or the receptacle will kick sideways away from the candle. Being small and in an unconfined vessel, the explosion will be quite harmless if directions are carefully followed.

In fact, any of the miniature explosion experiments to be described can safely be performed in the living room, provided you use reasonable care.

News items telling of violent explosions that blow up grain elevators always strike a note of mystery. Grain and explosions somehow do not seem related. However, by using cornstarch, the amateur chemist can create such an explosion and study the strange phenomena caused by the instantaneous burning of grain dust.

To do this, punch a small hole in the bottom of a half-gallon tin can. A funnel containing a teaspoonful of cornstarch is then placed in the hole from the inside so its stem extends below the can. Connect a short length of rubber tube to the outer end of the funnel, place a lighted candle in the can, and fit the friction cover in place. As before, the cover should not be a tight fit.

Place the free end of the rubber tube in your mouth and blow suddenly into the hose. The cornstarch will be scattered into the air inclosed in the can and, aided by the heat from the candle flame, will unite rapidly with the oxygen. In most cases, the resulting explosion will blow the cover from the can and raise it a half foot in the air.

Flour, charcoal, lycopodium, fine coal dust, and other common combustibles can be made to ignite and explode in the same way. Better results often can be obtained if the substance is first heated to remove any moisture that may be present.

48 POPULAR SCIENCE MONTHLY

Dust Explosion

- No ground water contamination
- No explosive hazard
- Brighter flash
- Equivalent bang

The future…More regulation

(forward thinking required)

- **EU: REACH - Registration, Evaluation, Authorization and Restriction of Chemicals**
  - The main aims of REACH are to ensure a high level of protection of human health and the environment from the risks that can be posed by chemicals, the promotion of alternative test methods, the free circulation of substances on the internal market and enhancing competitiveness and innovation.
- **EU: RoHS Restriction of Hazardous Substances,**
  - Lead (Pb)
  - Mercury (Hg)
  - Cadmium (Cd)
  - Hexavalent chromium (Cr6+)
  - Polybrominated biphenyls (PBB)
  - Polybrominated diphenyl ether (PBDE)
- **US: EPA - Keeps things in check**