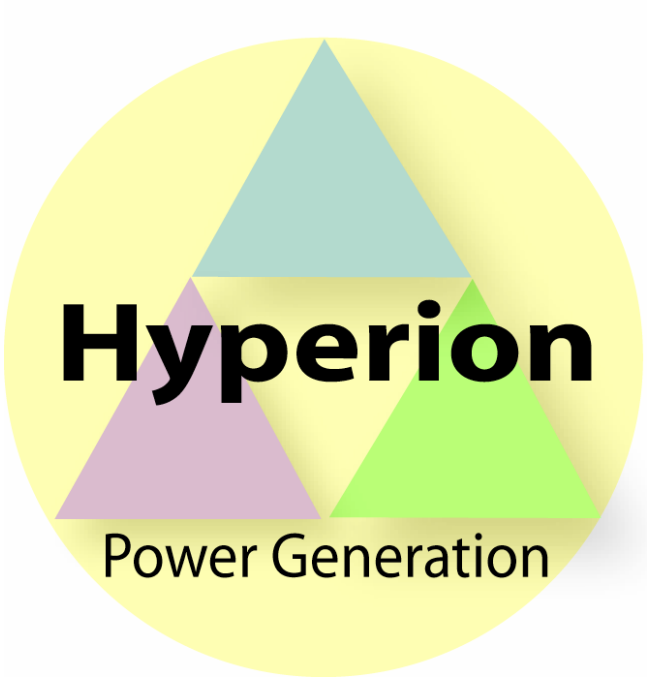
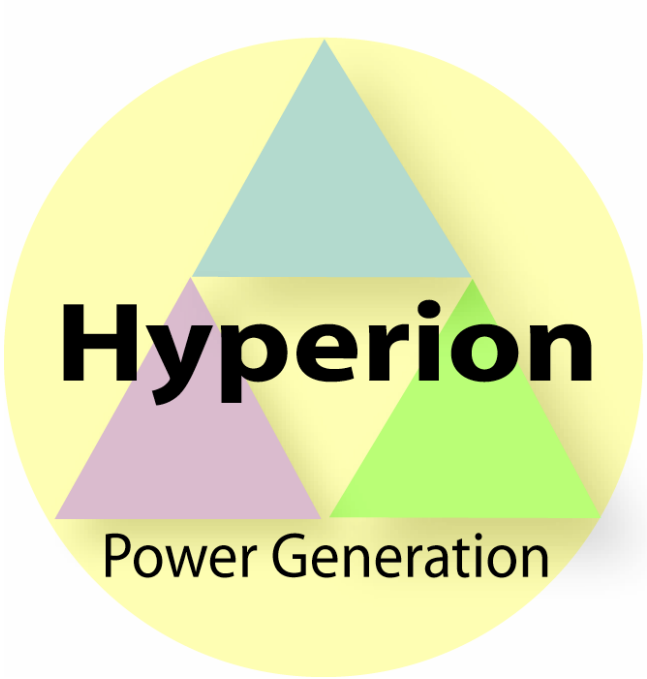


NRC Pre-application Meeting

22 August 2007

Agenda

- **Introduction**
- **Applications**
- **Technical Overview**
- **Design & Testing**
- **NRC Licensing & Commercialization**



Introduction

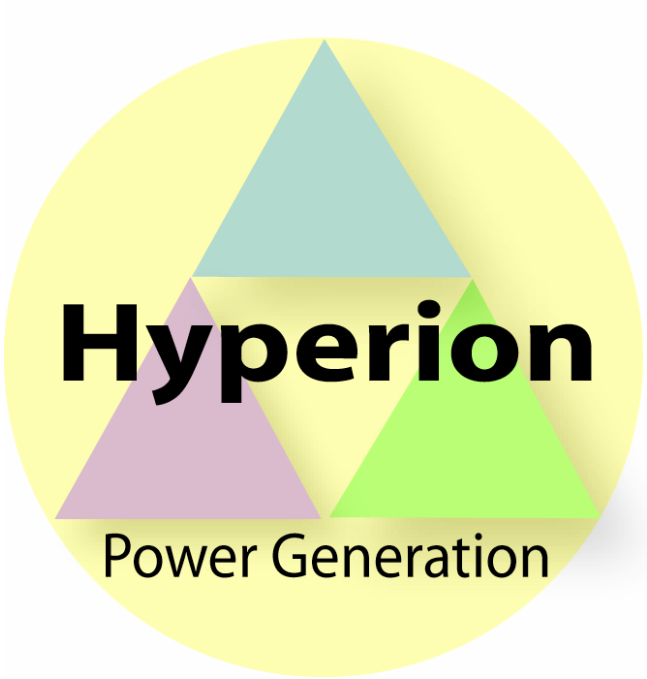
John R. Grizz Deal
CEO
Hyperion Power Generation, Inc.

Hyperion Team

- **Purple Mountain Ventures (PMV)**
  - **Commercialization & Management**
- **Altira Group**
  - **Capital**
- **Los Alamos National Laboratory (LANL)**
  - **Technology**

HPG, Inc. Team

- **John R. (Grizz) Deal**
  - **CEO HPG, Inc., & PMV Managing Director**
- **Deborah A. Blackwell**
  - **VP HPG, Inc. & Program Manager, PMV Director**
- **L. Robert (Bob) Libutti**
  - **VP HPG, Inc. & PMV Director**
- **Otis (Pete) Peterson**
  - **Hyperion Inventor (LANL Retired)**



Motivation

Why are we here?

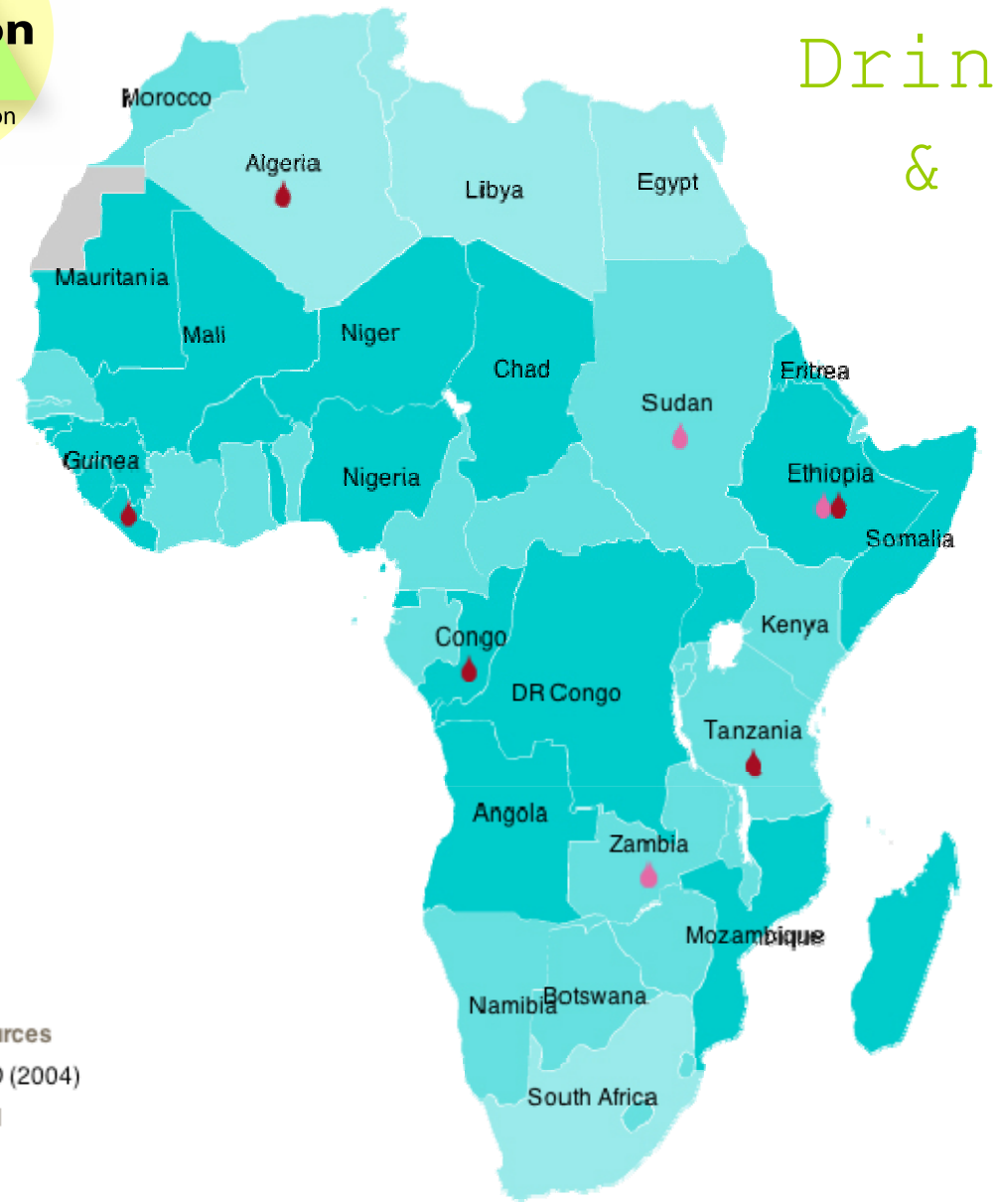
PMV Motivation

- **Purple Mountain Credo**
  - **Invest our time and money into projects that have a significant positive impact**
  - **Focus on "bleeding" edge, emerging technologies that ordinarily wouldn't see the light of day**
  - **Acquire that difficult-to-establish first market segment/first customer**

LANL & Altira Motivation

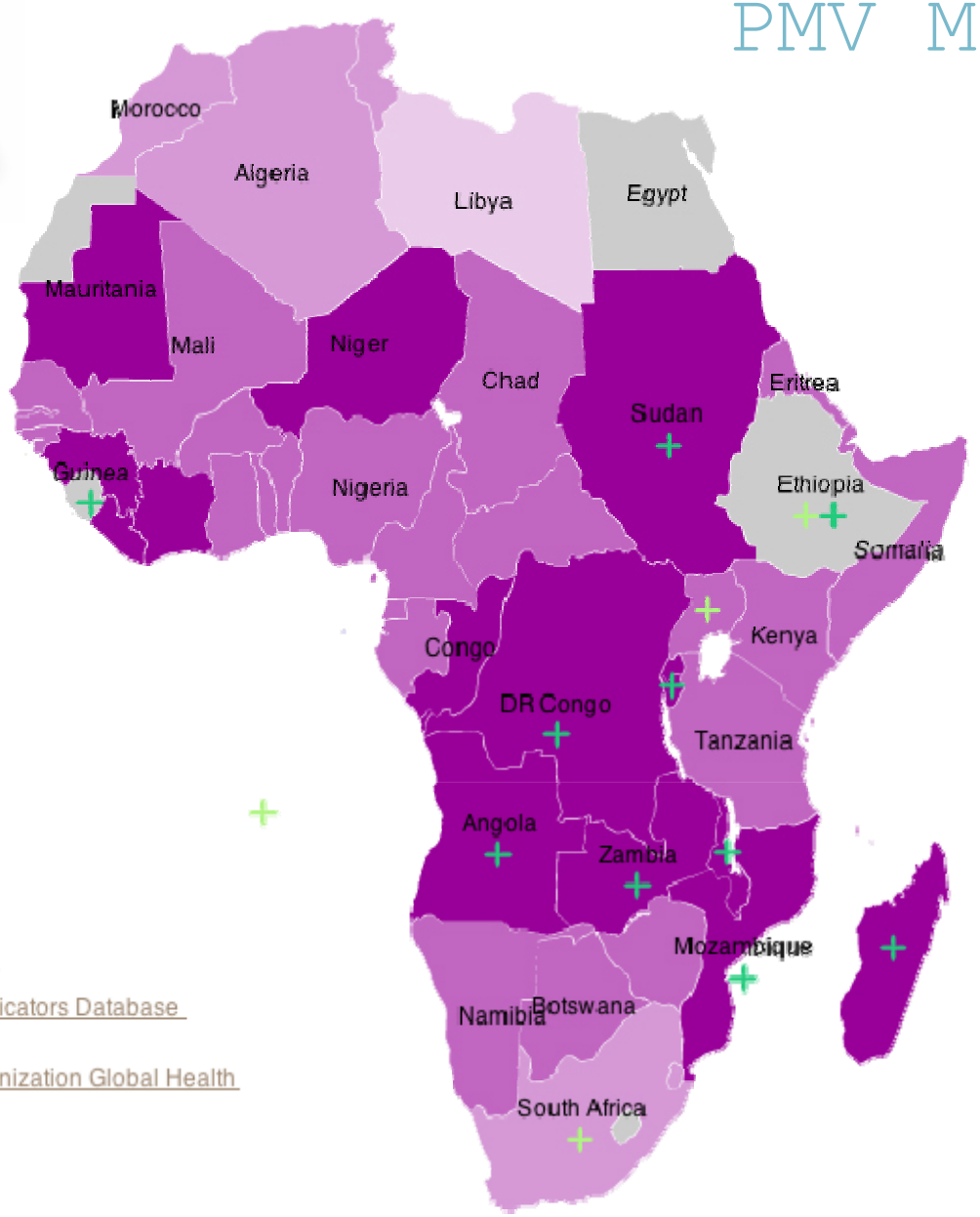
- **LANL**
  - **See taxpayer-funded technologies reach broadest market**
  - **Make positive impact on U.S. economy**
- **Altira**
  - **Generate wealth form alternative energy industries**

PMV Motivation
Drinking Water & Sanitation



Courtesy DATA.org

PMV Motivation
Malaria



Malaria Index (MI)
- Extreme (0-2.5)
- High (2.5-5.0)
- Medium (5.0-7.5)
- Low (7.5-10)
- No reported cases
- No data

Icons
- Flashpoints
- Hotspots

Key data sources

UN Millennium Indicators Database (2004)

World Health Organization Global Health Atlas (2002)

Last updated

January 2007

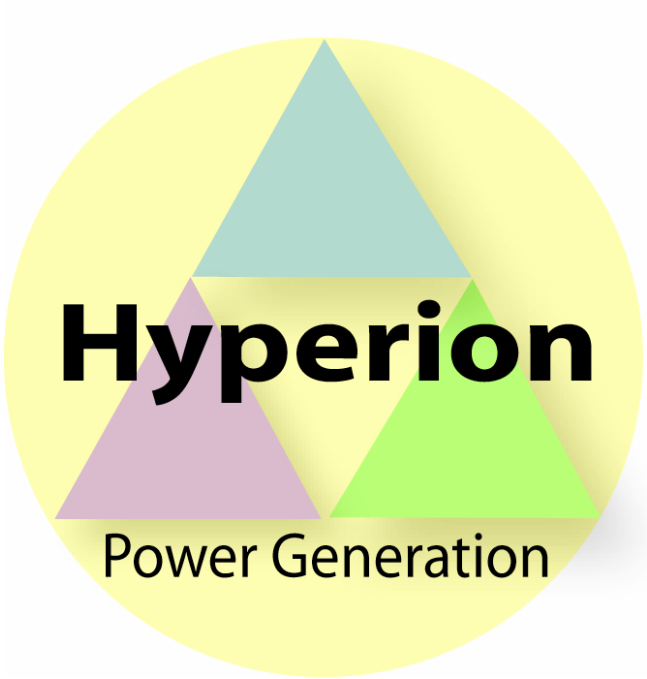
Courtesy DATA.org

Power for Remote Communities

- **Enormous power disparity between developed and developing regions**
- **Disparity exists even between mainland U.S. and its "off-shore" protectorates**
- **Healthcare, economic growth, food supply…all impacted by this power disparity**

PMV Motivation
Efficient Hydrocarbon Recovery

- **Oil sands & shales**
  - **Up to 35% of energy recovered is lost in recovery itself**
  - **Inefficiencies create additional greenhouse gases, waste, and have a destabilizing impact on prices**



Applications

Deborah A. Blackwell

VP HPG, Inc.

Hyperion: a New paradigm for Nuclear Power

- **Small reactors instead of giants**
  - **Distributed production (wave of future)**
- **Self regulating**
  - **Inherently safe**
  - **No mechanical moving parts**
- **Bury underground**
  - **Safe from threats**
  - **Radiation shielded**
  - **Out of sight**
- **Economy of mass production instead of economy of scale**
- **Standardization of design reduces certification to a single event**

…Hyperion continued

- **25 MW of electrical power each (25,000 homes)**
- **Sealed modules**
  - **Factory refueling greatly hampers proliferation attempts**
- **Replace oxide fuel and aqueous reprocessing**
  - **Minimizing instead of expanding waste**
  - **Recycle actinides**
- **Use all fissile & fertile elements: U, Pu & Th**
- **Reduces investment risk**
- **Reduces time to market**

The Economics of Hydride Reactors is Very Attractive

- **Capital costs (estimates provided by a member of the nuclear industry):**
  - **Thermal power: 68 MW_{th} for $20,000,000**
  - **Electrical power: 27 MW_e for $37,000,000 ($1380/kW_e)**
    - **Conventional plants estimated $2000/$kW_e$ (MIT study)**
- **Operating fuel costs:**
  - **Fuel for 5 years of operation: $12.7 million**
- **Small size and cost minimizes financial risk**
- **5 year investment for steam generation:**
  - **Hydride nuclear: $3/M BTU - $33 million per unit**
    - **Natural gas comparison costs: $7-$14 per M BTU.**
  - **5 year savings for heavy oil field: approx.** $2 billion

Hyperion is Needed

- **By remote communities**
- **To access unconventional hydrocarbons**
- **To meet the growing energy problem**

The Energy Problem

- **Global energy demand increased 60% in last 25 years**
- **Forecasts for the next 25 years project same**
  - **rapid development in China & other developing countries**
- **National Petroleum Council* recognizes that ALL types of energy sources are needed**
  - **not just oil and gas**
  - **includes nuclear, solar, wind**
- **International Energy Association's 2006 World Energy Outlook – predicts massive new investments in large scale projects will be required to develop and deliver energy**
  - **$20 trillion will be required over the next 25 years;**
  - **$3,000 per person alive today**

* *National Petroleum Council, Draft Report – "Facing the Hard Truths about Energy" July 18, 2007*

The Water Problem

Basic Human Rights and Survival affected by the Energy-Water Nexus

- ***Remote, independent (off the grid) power and water is needed**
  - **hospitals, schools, sanitation, irrigation, industry, drinking, cooking**
- **Technologies and abilities sufficient to ensure food supply**
  - **~ 13% of the world's population does not have access to enough food and water to live a healthy and productive life**
  - **could produce enough food for every man, woman and child in the world do currently exist.**
- **Poverty is driven by**
  - **lack of health, financial, & natural resources**
  - **lack of skills to link productive activities with remote markets and ensure employment**

*United Nations

The Water Problem

Basic Human Rights and Survival affected by the Energy-Water Nexus

- **An accessible supply of clean water is essential to improving health, education and overall productivity around the world**
- **Population growth and economic expansion**
  - **placing huge demands on coastal and freshwater ecosystems**
  - **water withdrawals have increased 6X since the 1900s**
    - **twice the rate of population growth**
- **Over one billion people lack access to a basic supply of clean water**
  - **~25% (311 million) in sub-Saharan Africa**
  - **~45% of Africa's population lacks access to clean water**

Access to Clean Water is Essential

- **Water related illnesses affect more people on earth than any other disease**
- **Sanitation coverage in developing countries (49%) is only half that of the developed world (98%)**
- **Unsafe water and poor sanitation**
  - **cause intestinal worms, cholera, & diarrhea**
    - **diarrhea is the 3rd biggest child killer in Africa (after pneumonia and malaria)**
    - **kills over 700,000 children a year**
- **A baby born in Africa is over 500 times more likely to die from diarrhea than a baby born in a G8 country**
- **A child dies every 15 seconds from water-related diseases**
  - **+5,700 deaths a day**
- **Improving water and sanitation would save $ millions in patient treatment cost**

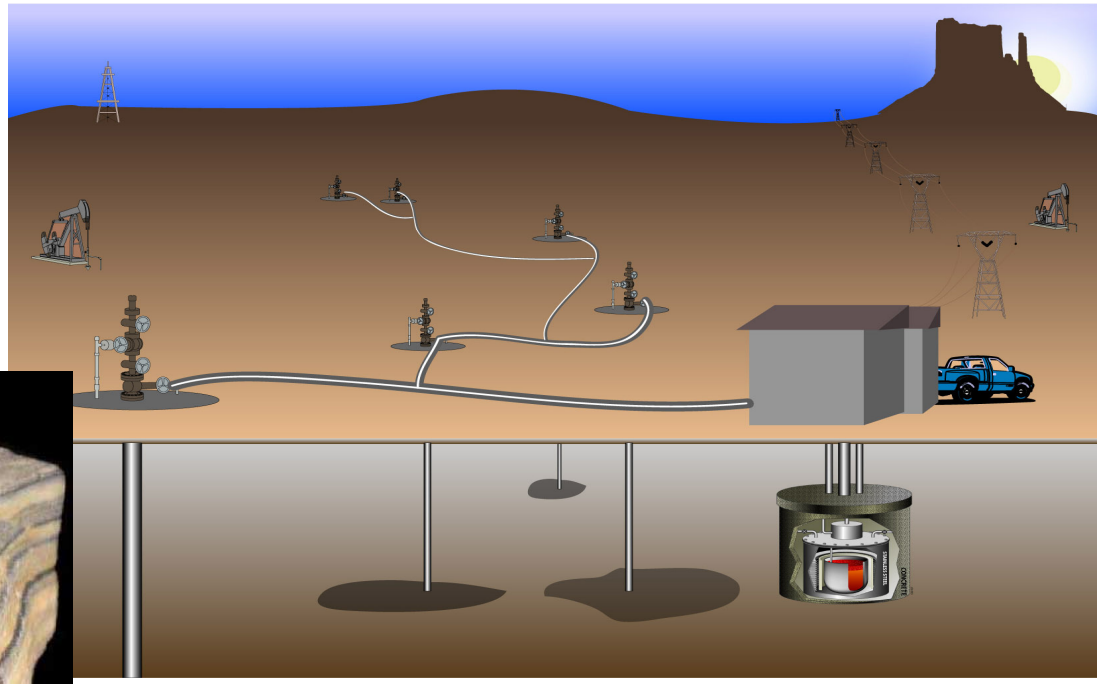
Hyperion is the Solution to the Clean Water Problem

- **No CO2 emissions**
  - **clean power is needed as global warming will only increase human misery**
- **Tamper resistant**
  - **nonproliferation**
- **Effective cost-ratio**
- **No human interface with its chemistry**
- **Portable**
  - **Ideal for remote locations**

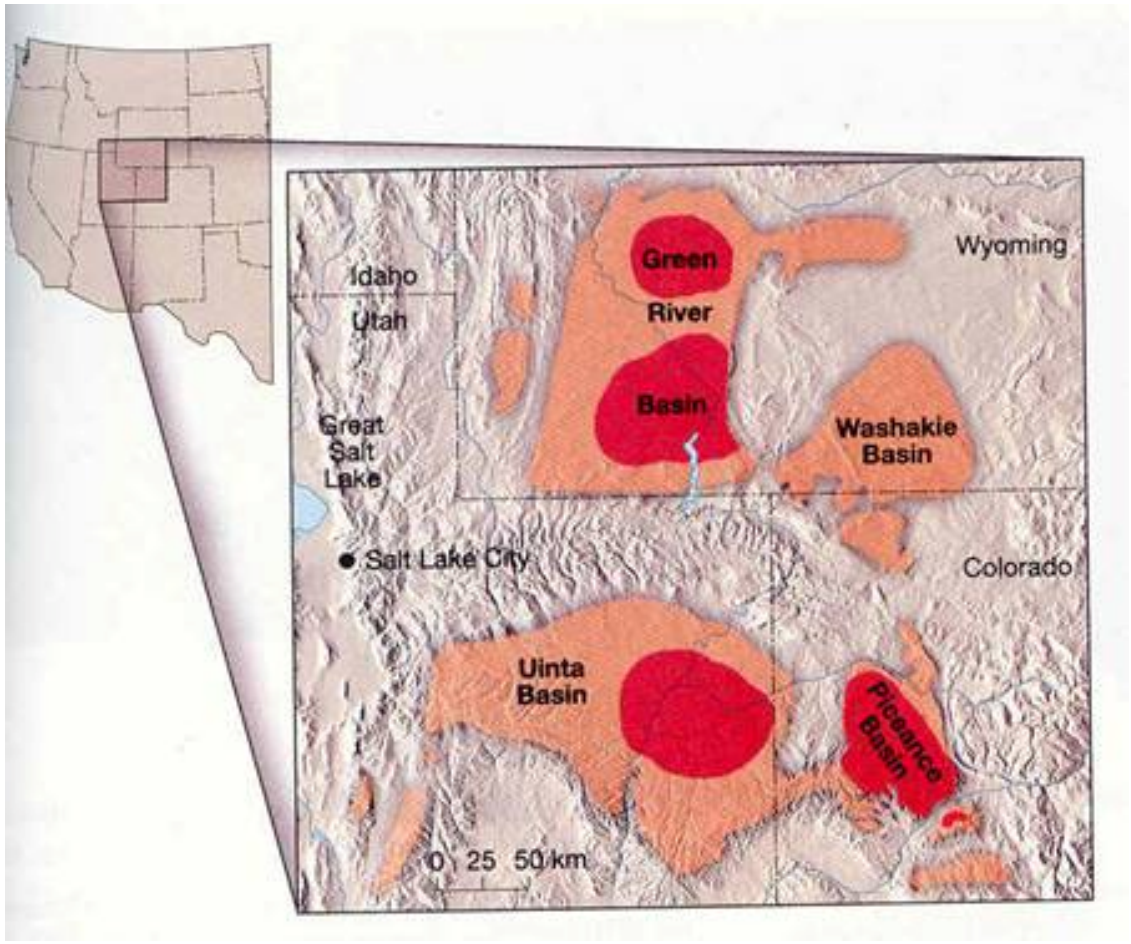
Hyperion Economically Assists in Heavy Oil Extraction

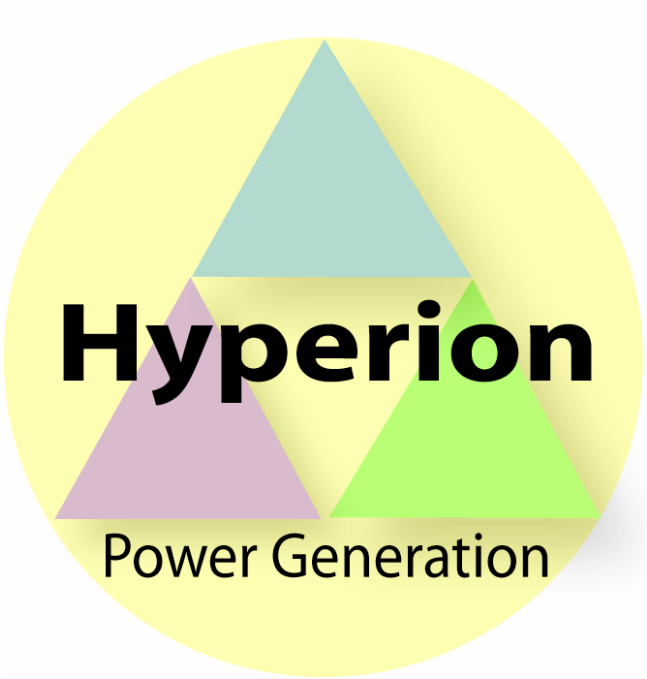
- **Heavy hydrocarbons (oil, shale, sands, etc.) require heat to liberate.**
- **Single oil field can consume over 1000 megawatts of thermal power.**
- **If powered by natural gas, consumption is over 100 million cubic feet per day.**
- **Costs of natural gas range from $0.5 to 1.5 million per day depending on gas price.**
- **Nuclear power costs approx. $250k per day.**
- **Cost savings for 5 year life of power sources is between $1 and 2 billion.**

Hyperion Will Dramatically Reduce the Cost of Recovering Oil from Shale & Sand



The Western U.S. has Trillions of Barrels of Oil Trapped in Shales & Sands

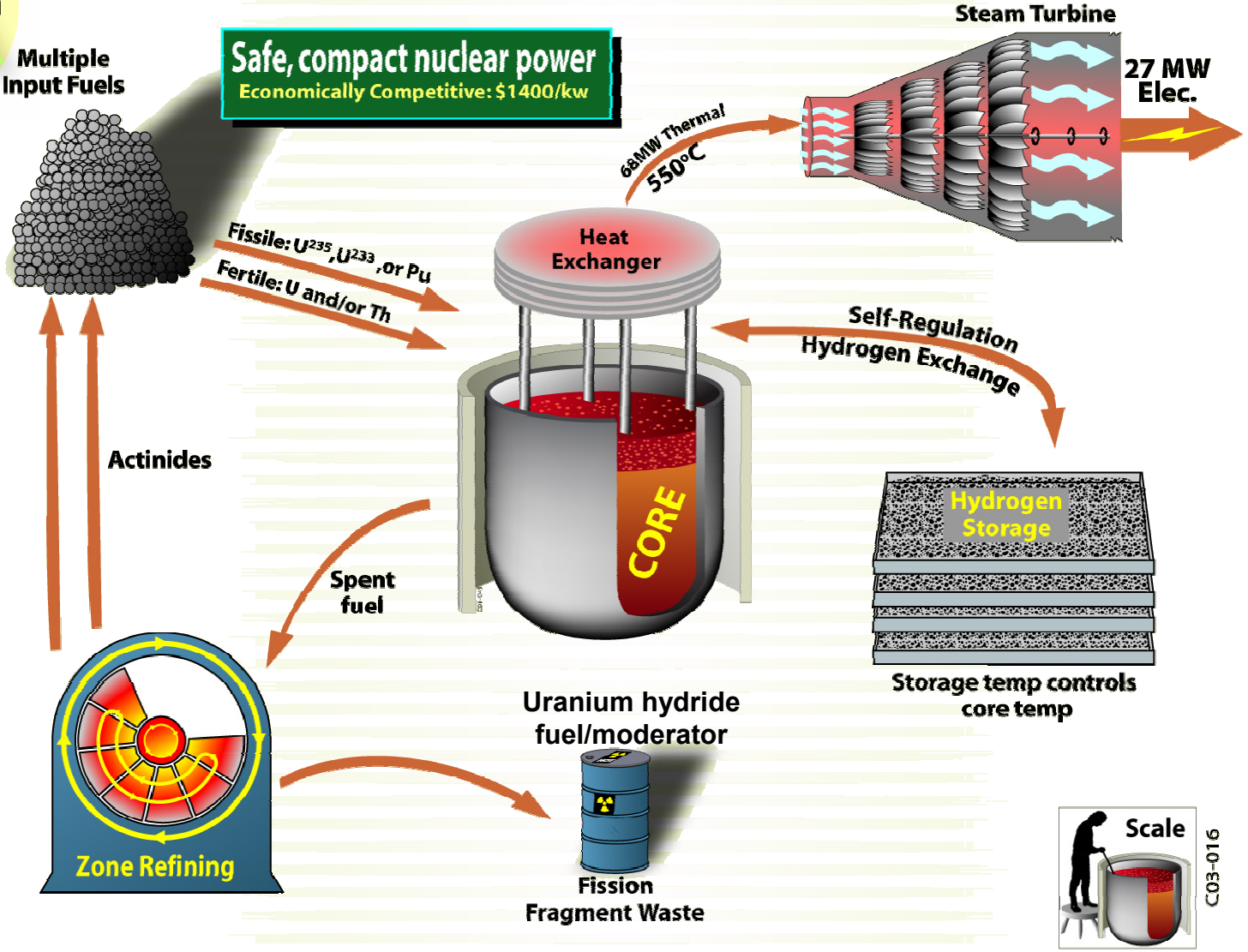




Technical Overview

Otis (Pete) Peterson

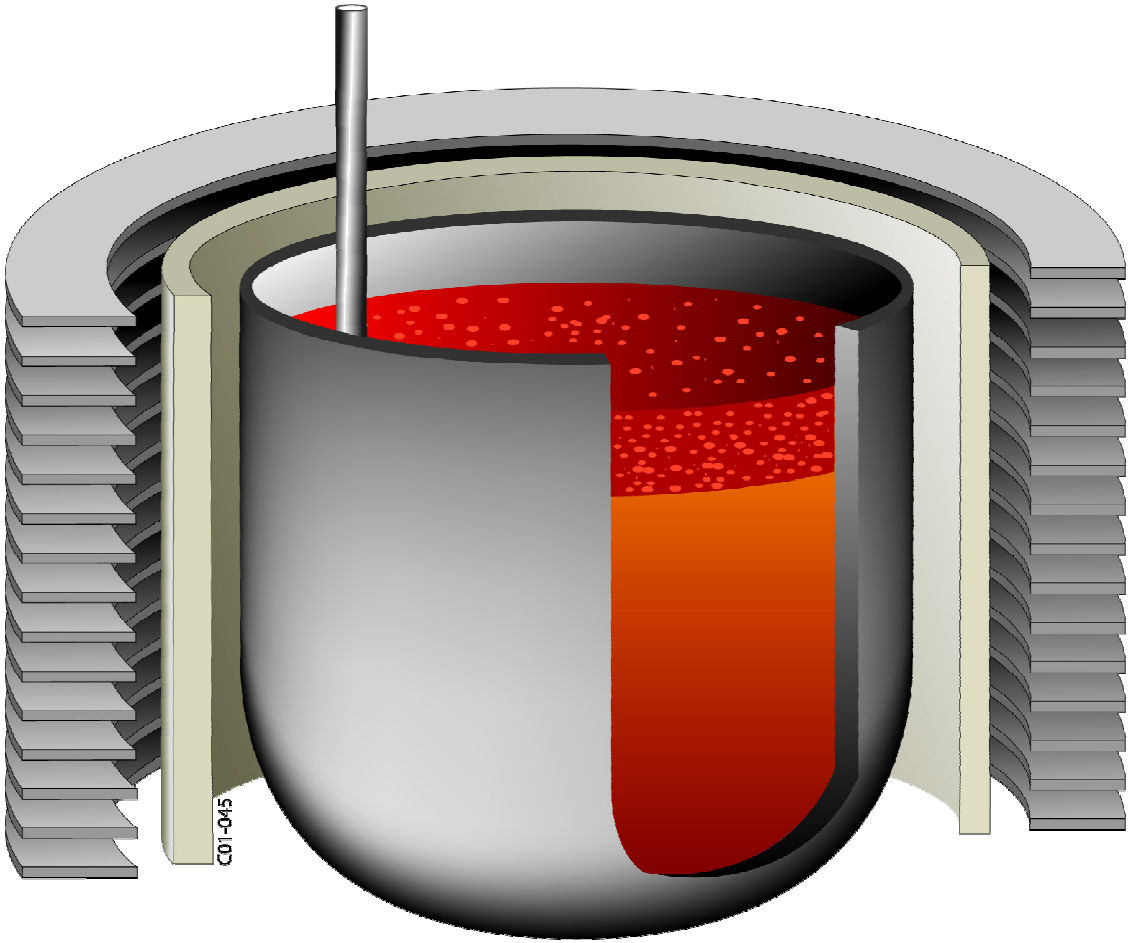
Hyperion Overview



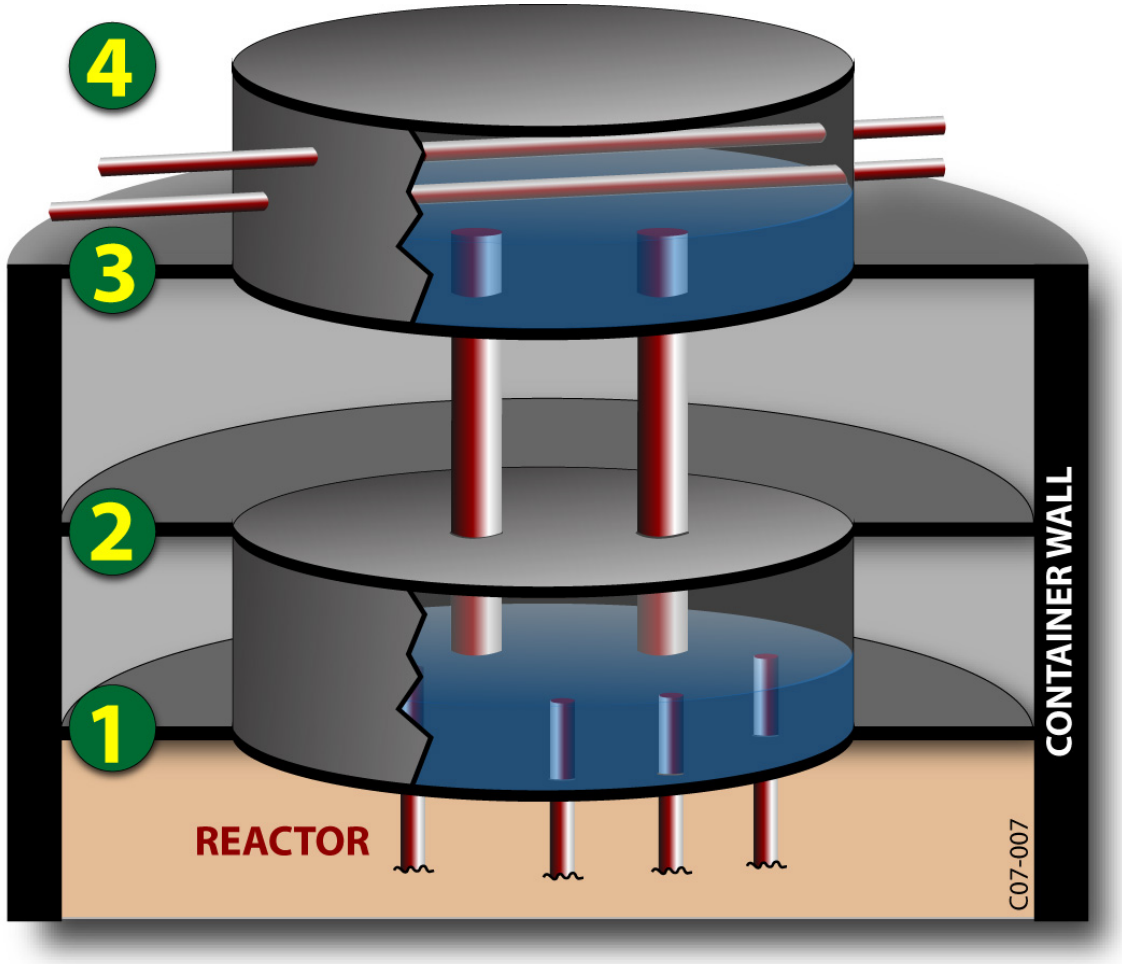
Hyperion
Power Generation

Hydride reactor safely stored underground in sealed vault

Hydride Reactor Size



Heat Extraction Includes Multiple Containment

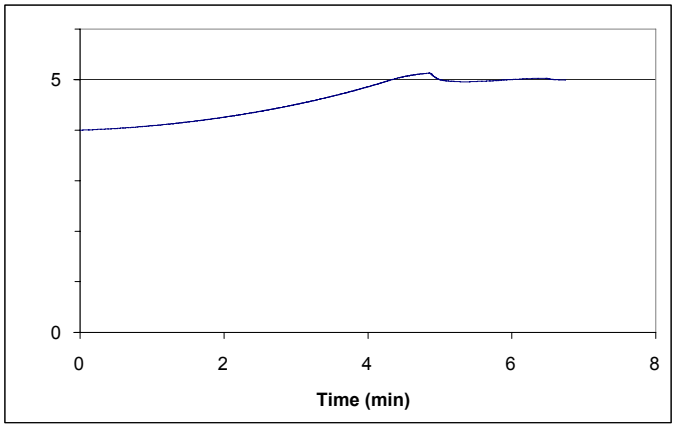


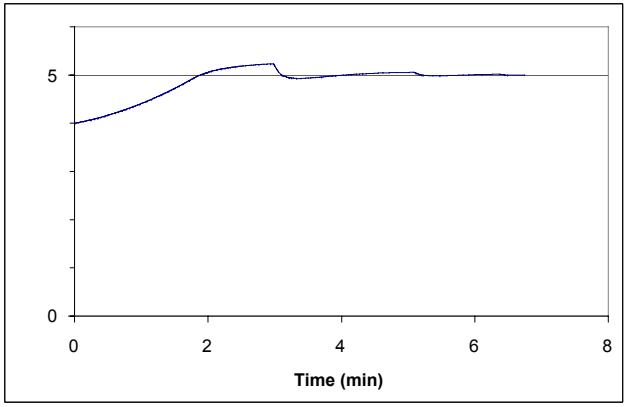
Hyperion Breaks the Paradigm

Characteristic	IRIS	PBMR	4S	ENHS	Hyperion
Fuel	UO_2	UO_2/U_2C_3	U	U	**UH_3**
Coolant	H_2O	He	Na	Pb-Bi	**K**
Volume (m^3)	760	1500	110	160	**10**
Power (MW_e/MW_{th})	100/300	100/260	50/120	50/120	**30/75**
Factory fueled	No	No	No	Yes	**Yes**
Safety + control elements	40	24	7	7	**zero**
Internal pumps	6	2	1	zero	**zero**

The Hyperion Reactor Is Stable

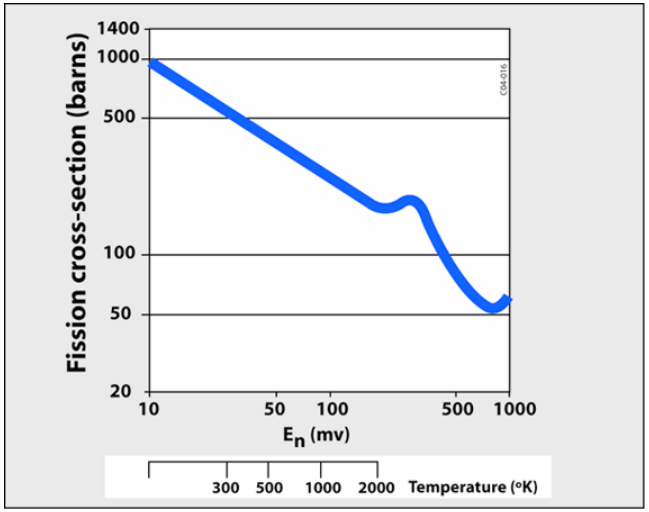
- **Transients damp out in a few minutes**
- **Rapid changes in power generate transients**
  - **5°C/min.: top figure**
  - **50°C/min.: bottom figure**
- **Order of magnitude rate changes do not affect stability101**

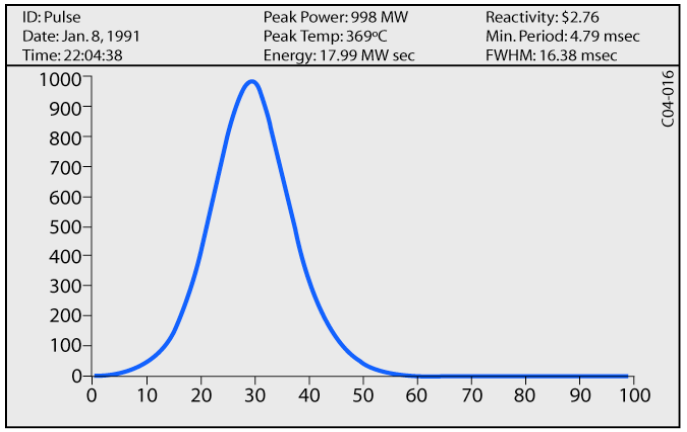




Hydride Fuels Have a Half Century of Demonstrated Safety

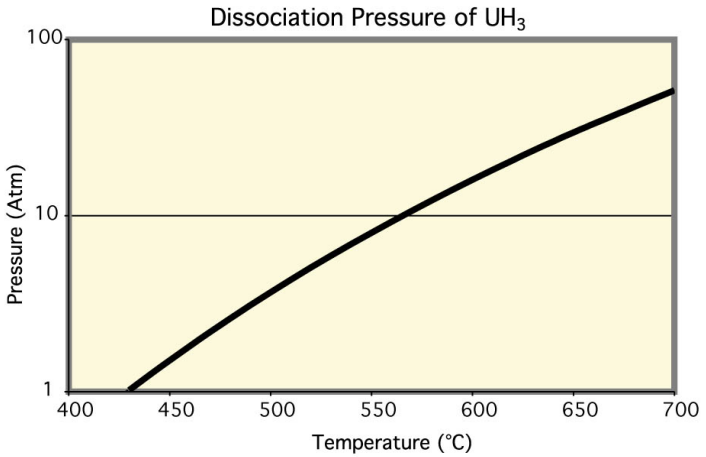
- **Hydride fuels are safe from temperature over-excursions**
  - **Common fuel/moderator yields warm neutrons**
  - **Fission cross-sections decrease as 1/velocity**
  - **Safe above prompt critical**
  - **Self-terminated pulses from 1 MW to 20 GW in 10 to 20 ms**
  - **Temperature rise up to 200°C**
- **Safety demonstrated at over 60 installations**
  - **Safety proven by TRIGA and SNAP reactors**
  - **TRIGA certified for unattended operation**





Uranium Hydride Was Created for Nuclear Reactor Applications

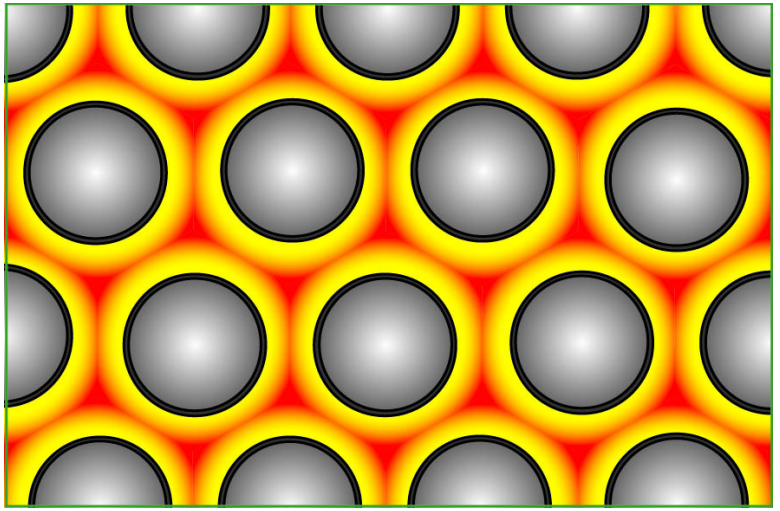
- Hydrogen is most effective moderator
- High storage density for hydrogen moderator: comparable to water and liquid hydrogen
- High dissociation pressure (8 atm) at high temperature (550ºC)
  - Enhances gas and thermal transport
  - Improves power conversion (40%) using supercritical water (superheated steam)
- UH_3 inherently forms as a powder
  - Particle size is very small (<75 microns)
  - Does not fuse under 900ºC
  - Enhances diffusion escape rate (<30 ms)
- High mobility of hydrogen enhances difusion and gas flow

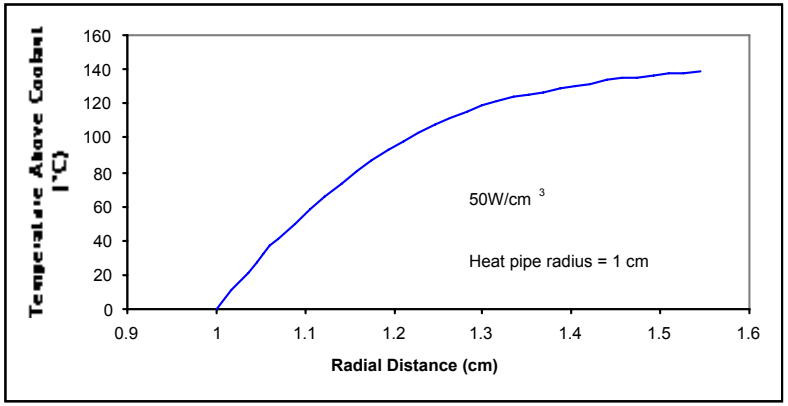


Core Property	Bare Core	Half Heat Pipes
U^{235} enrichment	4.94%	5 %
Final enrichment	4.94%	3.5%
UH_3 powder density	7.5 g/cm^3	7.5 g/cm^3
Void fraction	0.32	0.32
U^{235} critical mass	30 kg	440 kg
Total critical mass	0.61 MT	8.8 MT
Critical volume	83 liters	2400 liters
Critical diameter	0.54 m	1.44 m
Energy content	Zero	340 MW yrs
Electrical power	Zero	27 MW
Number of heat pipes	Zero	1600

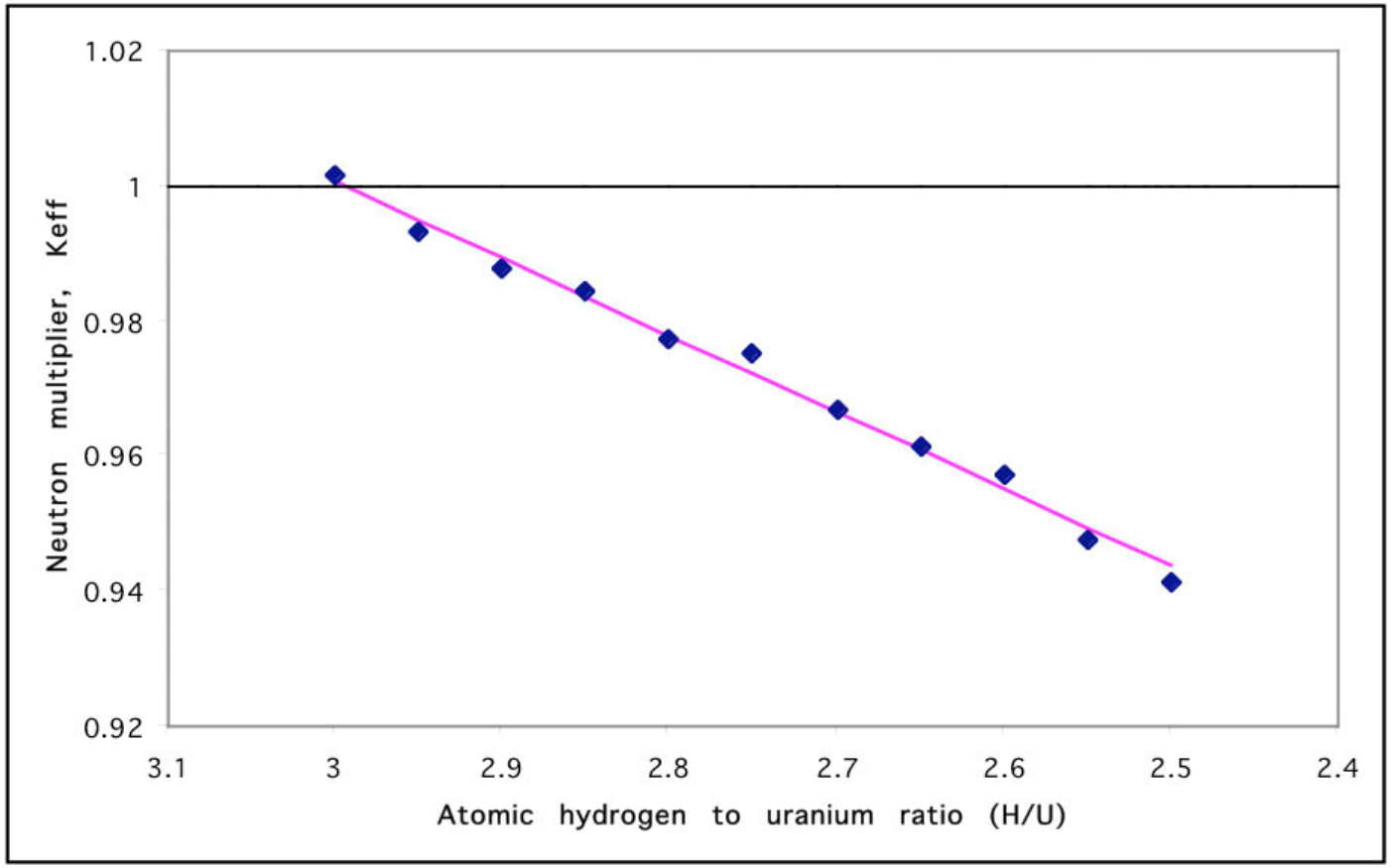
Practical Deployment Requires Power Extraction

- **Coolant must be non-moderating:**
  - **Potassium heat pipes**
- **Reserve half of volume for cooling**
  - **1600 heat pipes (1 inch) in 1.4 m OD core**
  - **Pipe diameter = 3/4 of spacing**
- **Temperature gradient extracts power**
  - **Five year operation permits 50 W/cm^3**
  - **Powdered fuel has low conductivity: 0.04 W/cm/°C**
- **Effective temperature is above coolant**
  - **Mass averaged $\Delta T = 90$ °C**
  - **H_2 reservoir temperature equals highest of fuel -- safer operation**



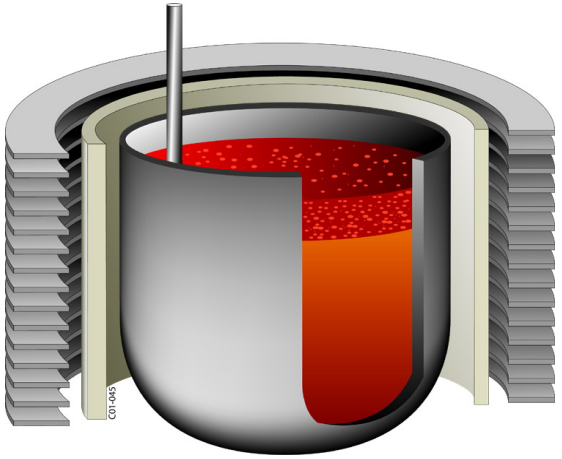


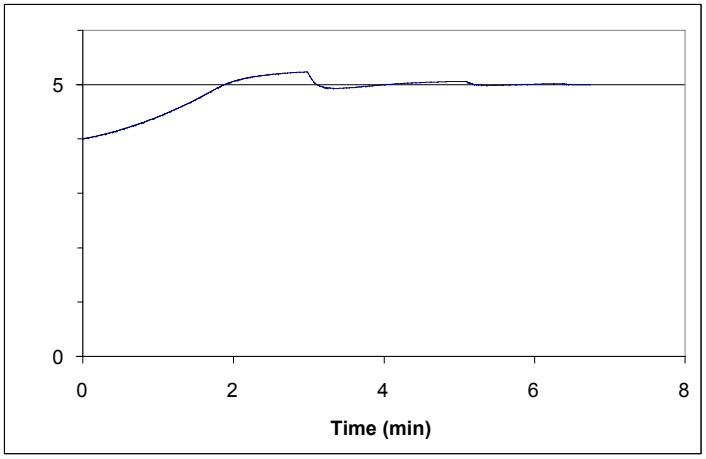
Moderator Depletion Reduces Neutron Multiplication

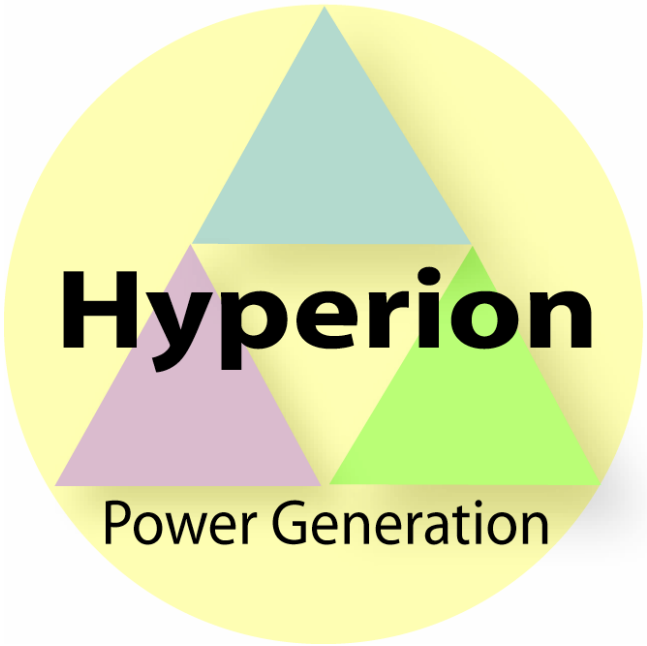


Compact, Self-Stabilizing Nuclear Power Source

- Based on uranium hydride
  - **Both fuel & moderator**
  - **Hydrogen volatility stabilizes reactor**
  - **Power transients damped by H transport**
- Change power production paradigm
  - **Many dispersed & redundant sources**
  - **Source sited and controlled locally**
- Economically competitive ($1400/kw) from inherent safety and stability
  - **Power transients damped out**
  - **Mass produced**
  - **No mechanical moving parts**
  - **Minimum human oversight**
  - **High (550ºC) operating temperature**
  - **Constant temperature: load following**
- Minimize investment risk
  - **Compact 1 to 2 m diameter core**
  - **Multi-10s of megawatt production**
  - **Multi-year use from factory sealed unit**
- Spent fuel easily processed
  - **Zone refining separations**
  - **Only power added to spent fuel**





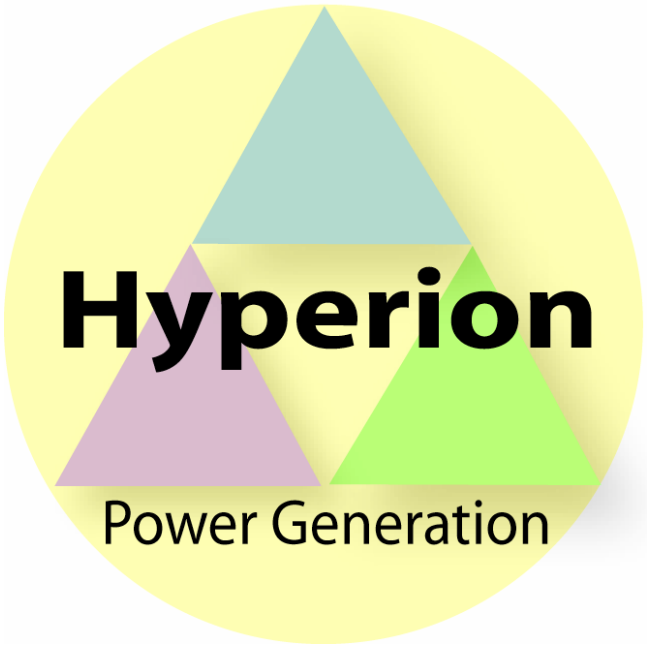


Design & Testing

Otis (Pete) Peterson

Hyperion Testing

- **Gas Flow Dynamics Modeling**
- **Experimental Demonstration**
- **Material Capability**



NRC Licensing & Commercialization

Deborah A. Blackwell

VP HPG, Inc.

Draft License Schedule

- **Now – Summer 2009: Validation**
- **October 2009: Turn over documentation of tests to NRC for pre-application review**
- **October 2011: Pre-app review completed, application for manufacturing license completed and submitted**
- **March 2015: Manufacturing license issued**
- **March 2016: Hyperion online**
  - **Assuming User/Operator has requested ESP or COL**

Contacts

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