

# The Thorium Trail Widens

Year in Review

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# The lady and the thorium



Baroness Bryony Worthington, the “Thorium Lord”. UK House of Lords. Leading political advocate, thorium. That’s her at Oak Ridge National Lab last year, just after this conference.

# DOE-China Collaboration



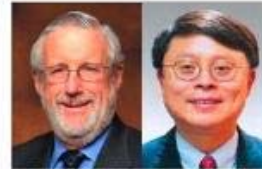
钍基核能系统

## Organizational Overview

The Chinese Academy of Sciences (CAS) and U.S. Department of Energy (DOE) Nuclear Energy Cooperation Memorandum of Understanding (MOU)

### MOU Executive Committee Co-Chairs

China – Mianheng Jiang (CAS) 江绵恒  
U.S. – Pete Lyons (DOE)



### Technical Coordination Co-Chairs

China – Zhiyuan Zhu (CAS) 朱志远  
U.S. – Stephen Kung (DOE)



### Nuclear Hybrid Energy Systems \*

- Zhiyuan Zhu (CAS) 朱志远
- Yuhan Sun (SARI, CAS) 孙予罕
- Steven Aumeier (INL)

\* Work scope governed by DOE-CAS Science Protocol Agreement

SINAP: Shanghai Institute of Applied Physics  
SARI: Shanghai Advanced Research Institute  
ORNL: Oak Ridge National Laboratory  
INL: Idaho National Laboratory  
MIT: Massachusetts Institute of Technology  
UC-Berkeley: University of California at Berkeley

### Molten Salt Coolant Systems

- Hongjie Xu (SINAP, CAS) 徐洪杰
- Weiguang Huang (SARI, CAS) 黄伟光
- Cecil Parks (ORNL)
- Charles Forsberg (MIT)



### Nuclear Fuel Resources

- Zhimin Dai (SINAP, CAS) 戴志敏
- Biao Jiang (SARI, CAS) 姜标
- Phil Britt (ORNL)
- John Arnold (UC-Berkeley)



2012/03/12

Xiaohan Yu

High temperature, molten salt COOLED. Not fuelled.

# Westinghouse - Commercial Adviser



Regis Matzie, retired Westinghouse CTO,  
chairs Westinghouse-led DOE-China  
commercial advisory panel. Molten salt  
COOLED. Where's the molten fuel? Answer...

# IN THIS CASE - CHINA

- The DOE-China collaboration looks at molten salt cooling of high-temperature, solid fuel reactors per se. For whatever reason, DOE is not looking at molten salt fueled reactors.





CHINA IS...  
HOWEVER.....

# This is a slide of a slide

China's expected molten salt cooled and fueled  
timeline as of Aug., 2012



## Expected Outcome of the TMSR Project

-  A 2MW molten salt-cooled research reactor built in 2015;
-  A 2MW molten salt research reactor built in 2017;
-  Gain the capabilities of building 10 to 100 MW-scale demonstration reactors;
-  Set up a comprehensive test facility for R&D.

Presentation by Kun Chen, Shanghai Institute of Nuclear Physics, U Cal Berkeley. This would change a few months later when in October....



# China's Xu Hongjie indicated “not so fast”



Xu Hongjie, director of the Thorium Molten Salt Research Center, Chinese Academy of Sciences, at the Thorium Energy Conference, Shanghai, Oct. 2012

# A slide of Xu Hongjie's slide, Oct. 30, 2012



Presented at Thorium Energy Conference, Shanghai, Oct 2012



# Taking the heat



Jiang Mianheng: China will use TMSRs for electricity AND heat. Will assist in coal gasification, hydrogen production, etc.

# Steenkampskraal Thorium Ltd



Trevor Blench, chairman, STL and RARECO (rare earth mining company). High temperature. pebble bed.

# STL

- Based in Centurion, South Africa
- Modular pebble bed thorium reactor
- 35 MWe, 100 MW thermal Th-100
- Helium-cooled. 750 degrees C
- Commercialize in “5-to-10 years”
- 20 percent owned by Canada’s Great Western Minerals Group. Sister company to RARECO rare earth mining company. Monazite mine in S. Africa a ready source of thorium.
- For those keeping score: Around this time last year the principals were with a company called Qpower
- Owns 15 percent of Thor Energy, the Halden, Norway thorium company
- Looking for consortium of industrial owners/ customers. Possibly from coal industry.

# Do they run Twitter?



No - It's Transatomic Power. Co-founders Mark Massie and Leslie Dewan, MIT PhD students. Good nuclear re-branding move - youth movement?

# Transatomic Power, Cambridge, Mass.

- Molten salt reactor, 500 Mwe
- All good reactors deserve an acronym: “WAMSR” (waste annihilating molten salt reactor)
- They also call it a “uranium molten salt reactor”
- Combines uranium with spent fuel
- Uranium first, thorium possible down the road.
- Young co-founders Mark Massie and Leslie Dewan are MIT PhD students
- CEO, co-founder Russ Wilcox, from the IT world - E-Ink (e-reader displays)



# Transatomic (con't).

- Other adults:
  - Advisor Richard Lester, MIT head of nuclear science and engineering
  - Regis Matzie - (there he is again; ex-Westinghouse CTO, commercial adviser to China-DOE molten salt project
  - Jess Gehin, Oak Ridge; Benoit Forget, MIT, Todd Allen, Idaho National Lab; Ken Czerwinski, University of Nevada LV; Michael Corradini, U of Wisc., president American Nuclear Society

FUNDING - trying to raise TK..

Worth noting: Won top prize in a DOE-backed future energy “pitch-off. Judges included Shell Oil’s “GameChanger” group.

# Fast talk



I've got a reactor for you. Russia will build and operate your reactor for up to 60 years. They're planning fast reactors at home, building water cooled reactors around world.

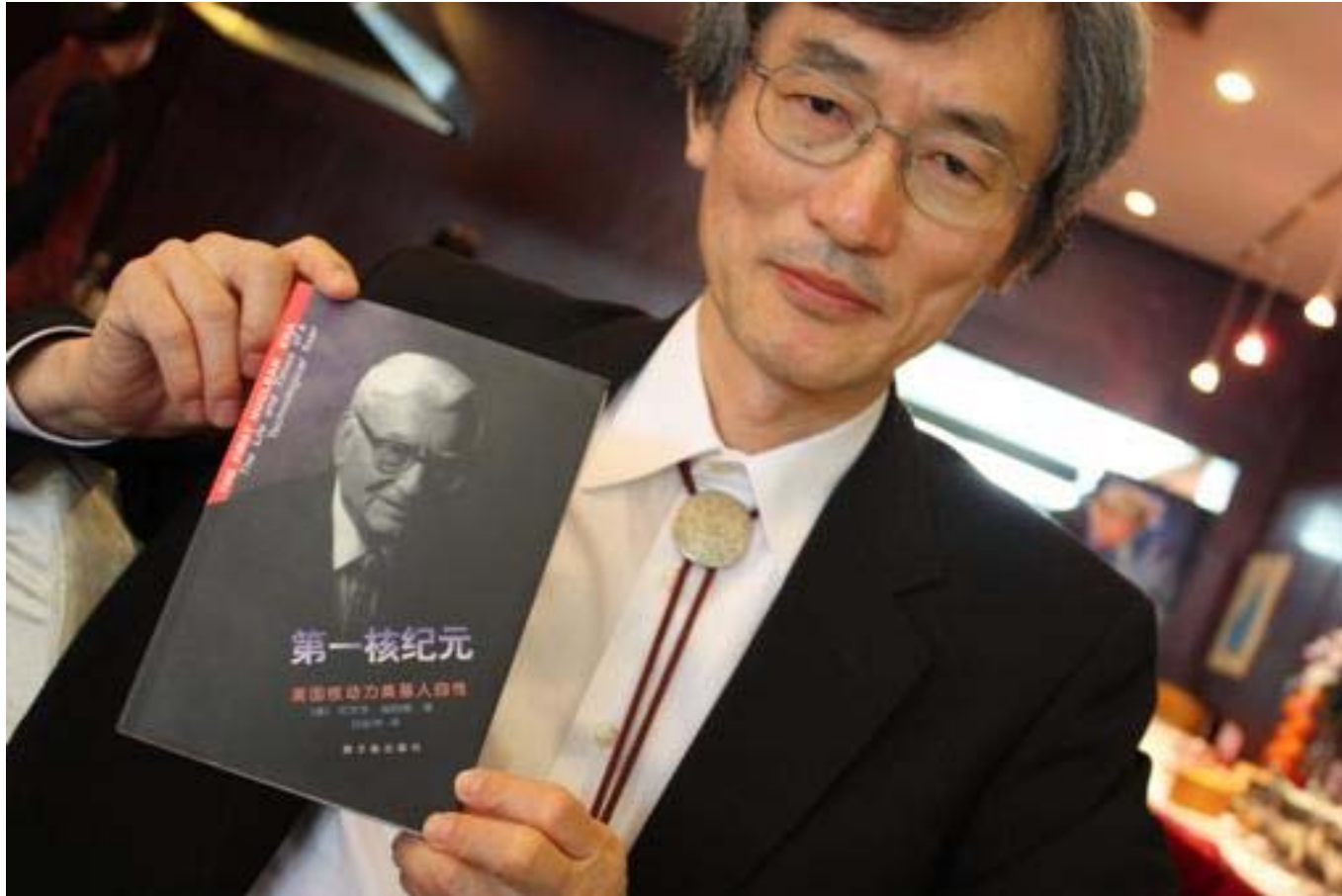
# Nuclear Power Icebreaker



Russian of course. Escorting liquefied natural gas to guess where? Japan, a country wracked by trade deficits and CO2 emissions since shutting down nuclear after Fukushima.



# Thorium Tech Solution (TTS)



Motoyasu Kinoshita goes to the source, Alvin Weinberg.

# TTS

- Tokyo, founded 2011 by the late Dr. Kazuo Furukawa, picking up from his former company ITheMS (International Thorium Energy and Molten Salt Technologies ).
- Principals: Masaaki Furukawa (brother), Kazuro Furukawa (son) Motoyasu Kinoshita, chief engineer.
- Thorium molten salt reactor. Thorium blended with plutonium to dispose of Japan's nuclear waste.
- Single fluid, not dual.
- “FUJI Reactor” 160 MWe. “miniFUJI” 7 MWe. Translation: “FUJI” implies “the only one” (the only CO<sub>2</sub>-free solution).
- Aim: small working prototype by 2018 (smaller than 7 MW). Commercial by 2025.



# TTS (con't)

- Evaluating which salt to use. Probably not FLiBe. Beryllium does not get along with plutonium. Considering sodium salts.
- \$300,000 for salt evaluation, to finish this year or next.
- \$5 million for next stage: Testing the waste's transuranic elements - plutonium, americium, etc. Could happen in Norway at Halden, in the Czech Republic, or Japan.
- Speaking of Norway.....

# Norwegian would



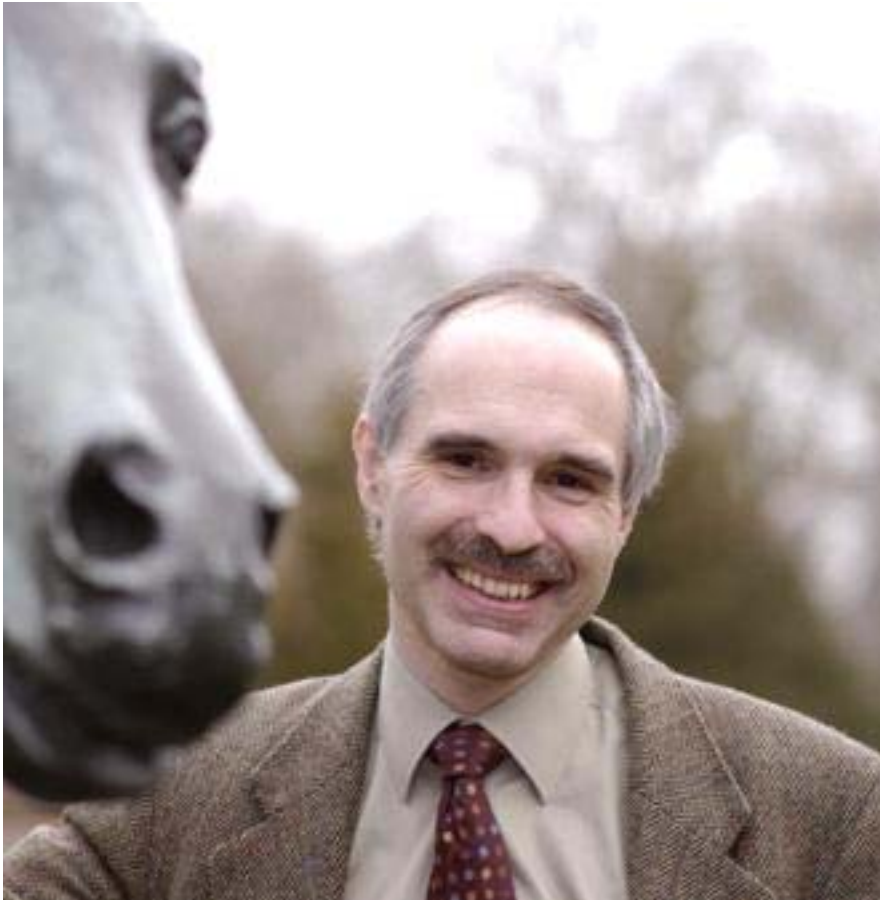
Norway's Thor Energy is getting ready to irradiate thorium/plutonium MOX at the country's Halden test reactor. WESTINGHOUSE backs the project. That's Julian Kelly, Thor's chief technology officer, announcing the upcoming test at the Shanghai thorium conference last October. The idea: These Norwegians would run solid-fuel thorium - and burn plutonium - in

# Nuclear heat: Good on paper



The Norske Skog paper mill next door to Halden uses heat from the test reactor for industrial processes. A lesson for heavy industry.

# Not so moderate



More solid fuel thorium along the conventional lines. Geoff Parks and Ben Lindley from the University of Cambridge say thorium will last a long time in a reduced moderation water reactor. They're in close touch with Halden too. And Westinghouse.



# Prague



Last year China. This year, the U.S. DOE ships molten salts to the Czech Republic for testing by Czech Nuclear Research Institute (Rez). Again, focused on “cooling” as opposed to “fueling.”



# Molten Man



Milo Hron, University of West Bohemia, Pilsen, Czech Republic presenting in Shanghai on molten salts.

# Good Advice



Sir John Beddington, the UK's freshly retired chief scientific officer, recommended more funds for nuclear R&D for a possible high nuclear scenario... The result so far? £15 million (\$23 million).

# Look for some thorium here

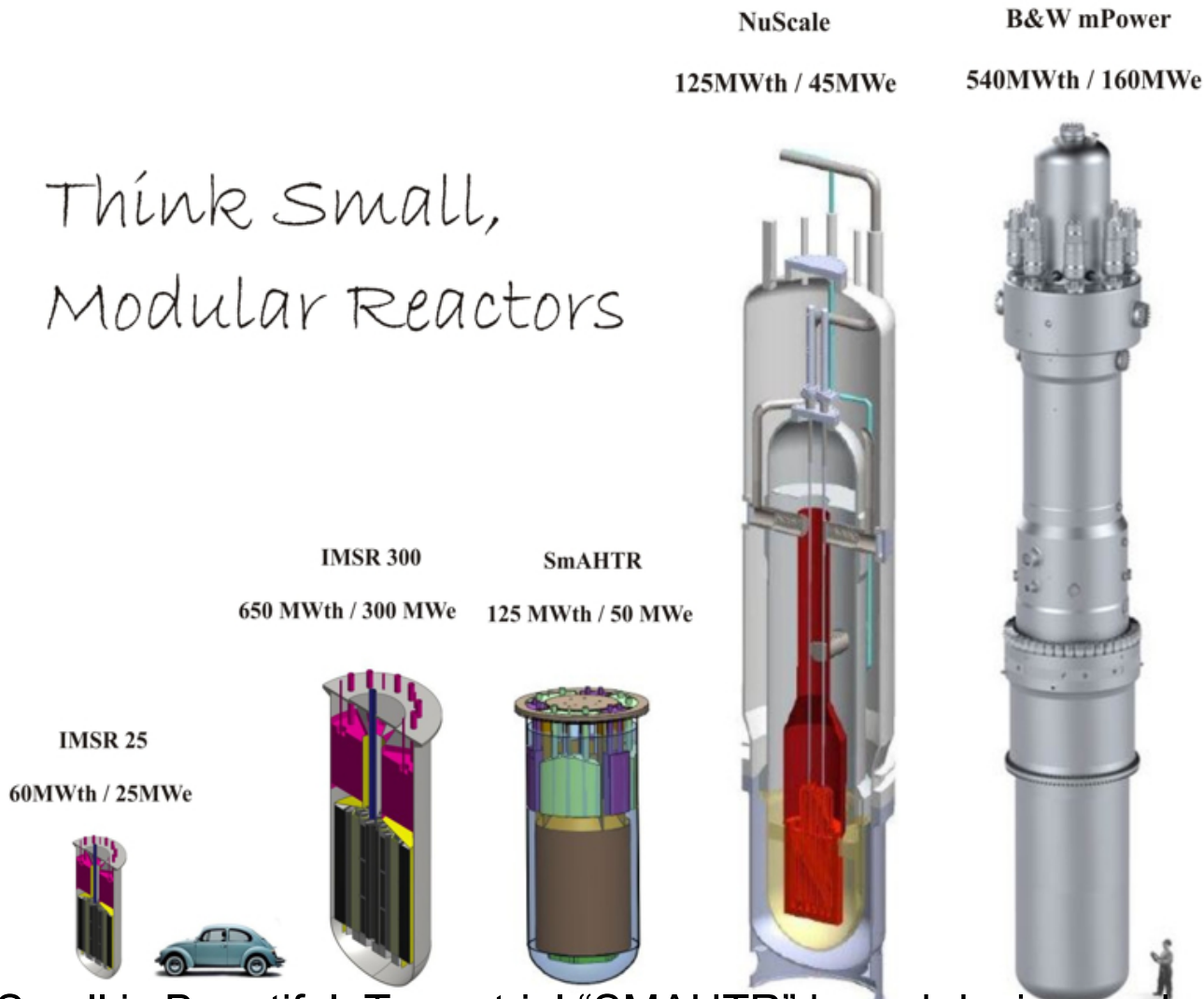


Irradiated thorium is on its way to the UK's Harwell nuclear facility, destined for storage.



# Terrestrial Energy

Think Small,  
Modular Reactors



Small is Beautiful. Terrestrial “SMAHTR” based design packs a wallop compared to other SMRs.

# Terrestrial

- Founded Dec. 2012, Ottawa, Canada, from David LeBlanc's Ottawa Valley Research Associates, an IP company
- "Integral Molten Salt Reactor" IMSR
- Single fluid, not dual. Easier. In dual, one fluid constantly feeds fuel to the other, adding complexity.
- Incorporates "SmAHTR" concepts developed recently at Oak Ridge for Small Modular Advanced High Temperature Reactor. SmAHTRs use liquid cooling instead of gas for solid-fuel high temp reactors. Terrestrial applying that to liquid fuel reactor. Result: High power density, smaller reactors for the same wallop as larger reactors.
- "Burner" not "breeder."
- Once through cycle last 30 years.
- David LeBlanc, co-founder, president, CTO: "Come for the thorium, stay for the reactor."
- Small modular. Size ranges from 25-MW electric to 300-Mwe
- Goal: commercialize by 2021



# Nuclear Growth Global

- 30 percent increase in global nuclear generation by 2020, according to London research firm GlobalData.
- Emerging countries, newcomers like Bangladesh, etc.



Wouldn't it make sense to introduce thorium and MSR's?

# Thorium Power Canada



That's not Canada. It's Kalimantan, Indonesia, where TPC could "soon" connect a thorium reactor to the grid or to a water desalination plant. Indonesia has the world's third fastest growing consumer economy. (Time to add an "I" to BRIC?)

# Remember to Water



TPC is also in advanced discussions to provide a small thorium reactor powering water desalination for Copiapo, Chile.

# TPC

- Thorium Power Canada acquired the reactor technology in Jan. 2012 from DBI Century Fuels, San Leandro, Calif.
- Toronto-based. CEO, David Kerr
- DBI founded decades ago by Chilean-born Hector D'Auvergne
- DBI now called DBI Ceramics and will serve as the reactor's manufacturer.
- Secretive about technology. Solid fuel thorium. Gas cooled. Graphite moderated. Won't say whether it's "high temperature." Won't reveal the fuel form or the gas, but not helium.
- Thorium fueled, last up to 60 years. A series of fuel cycles. First three use some amount of low enriched uranium for 18-to-36 months each. After that no more uranium.
- Modular, 10-to-25 Mwe and up to 100 Mwe.
- Claims low production costs of \$1.8 million per MW, so a 10 MW-plant = \$18 million.
- "Advanced discussions" with Indonesia and Chile, Indonesia would probably happen first.
- Needs \$50 million for the Indonesian project.
- Thinks DBI can build a reactor within 18-to-24 months after TPC raises the funds.



# Mining the Market



TPC has interest from Chilean and Argentine mining companies. Copiapo is near the San Jose mine that famously trapped 33 miners for 69 days in 2010. That's the leader of Los 33 and the president of Chile.

# TPC (con't)

- Also has interest from the Middle East including Saudi Arabia.



# Middle East



Saudi Arabia, UAE have announced significant nuclear plans. Export the oil, use nuclear at home. Saudi-China. UAE-South Korea. Thorium opportunities?

# Money

- From the oil industry?

# Kids say the darndest things



Thorium is the future. Even 13-year-olds such as Katie Hudek (12 in this picture) know that.

# Meet me in Cranberry



My next stop on the thorium trail - Westinghouse headquarters, Cranberry, Pa.



# Thank you

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