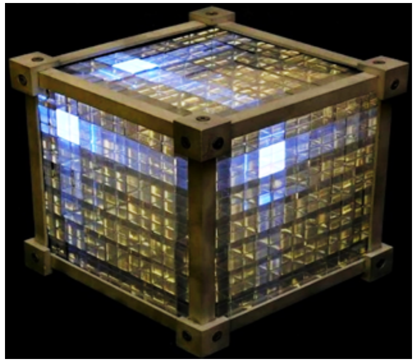
MTV Kickoff Meeting

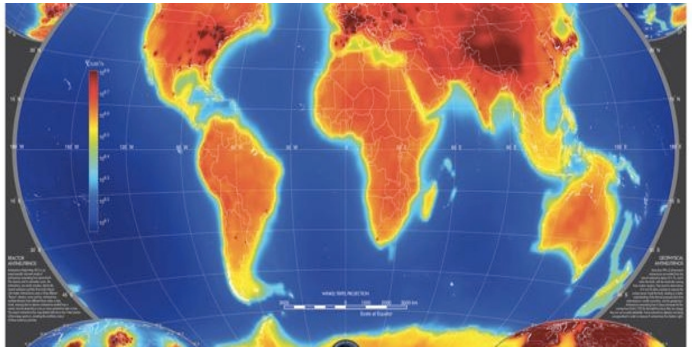
20 May 2019, Ann Arbor



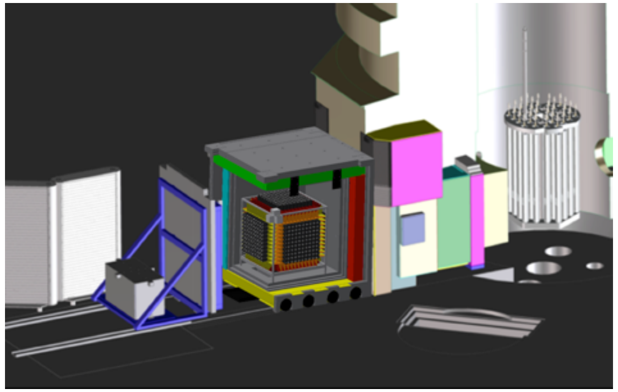
Electron Anti-Neutrinos for Long Range Reactor Monitoring

John G. Learned

University of Hawaii



With collaborators Bruce Vogelaar and others at Virginia Tech, plus UH Collab's Ryan Dorrill, Kurtis Nishimura, Jelena Maricic, and others.



Motivation

- **Reactor monitoring at long range... Reaching towards >100km**
  keep track of activity of known reactors,
  find unannounced reactors

- **Fundamental problem trying to solve?**
  Our previous work highlighted need for new detectors
  and particularly, observing neutrino direction

- **Strategy: develop small close-in detectors and work upwards**

Mission Relevance to NNSA

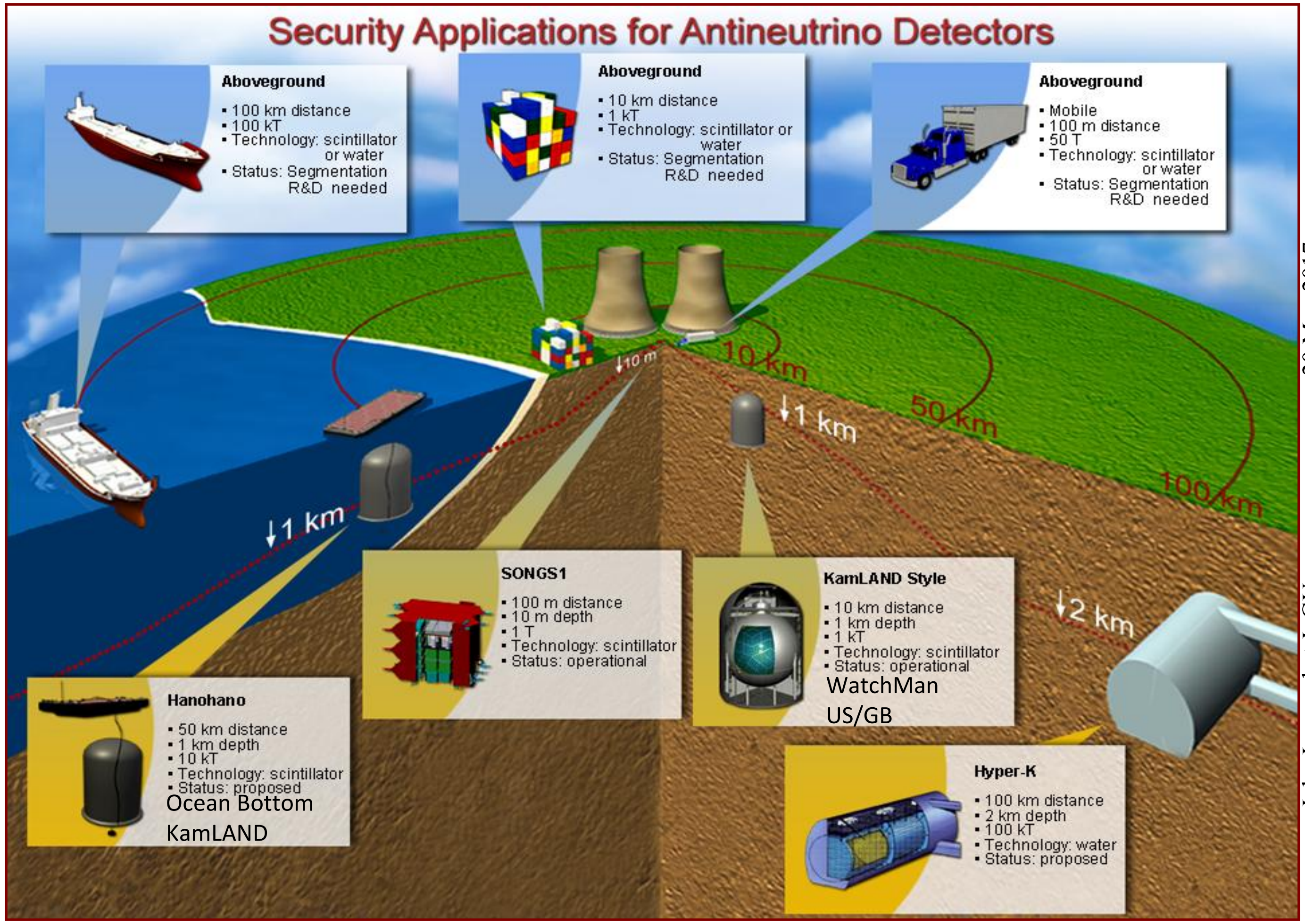
Nuclear reactor monitoring (and bomb test detection)

Only neutrino monitoring is
- **independent of information from operators**
- **non-contact**
- **not possible to fake**
- **not possible to hide, depends only on reactor power and fuel mix**

Can be done at various ranges
- **few meters from cooperative site with ~1 m^3 detector, remotely operated**
- **easily from outside site to a few km distance with 10-100 ton scale**
- **long range 100-1000 km much harder but doable, with hundred kiloton scale**

Nuclear Reactor Monitoring for Anti-Proliferation

- **Series of Workshops over last 10 years about reactor monitoring (Hawaii, Palo Alto, Paris, Brazil, Livermore, Maryland, Japan, Italy, DC, Liverpool and India).**
- **Near reactor core: ~1m^3, ~20m out, cooperative site => IAEA application… being pursued.**
- **Small scale demonstrations in Japan, US, France, Russia, Brazil, Italy, and more.**
- **Standoff: 1-1000 km, possibly clandestine reactor, look at location and operation patterns, huge detectors needed at long dist. (1/r^2 inescapable)**
- **Developing new techniques to utilize all possible information from multiple detectors.**



Hanohano -> Ocean Bottom KamLAND Detector

John Learned at JpGU 20 May 2017

Classic $\bar{\upsilon}_e$ Signature

Inverse Beta Decay   IBD

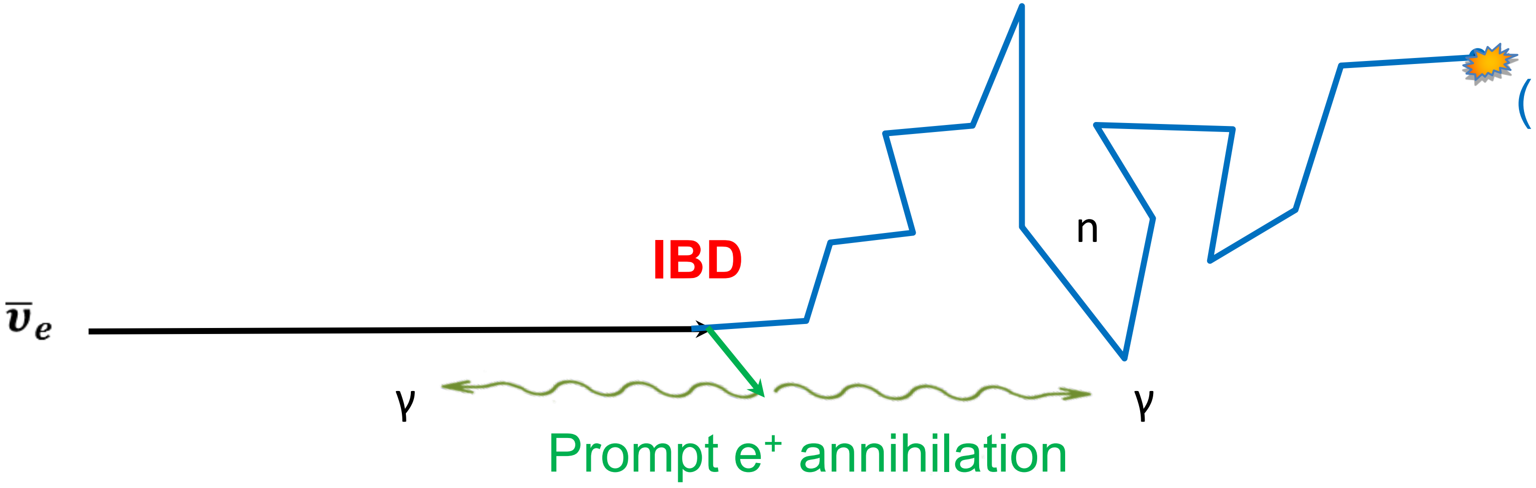
Beautiful double pulse signature

Prompt

$$\bar{\nu}_e + p \rightarrow e^{+} + n$$

Delayed

$$\xrightarrow[\tau\sim7\mu s]{} n + {}^6Li \rightarrow \alpha + {}^3H$$

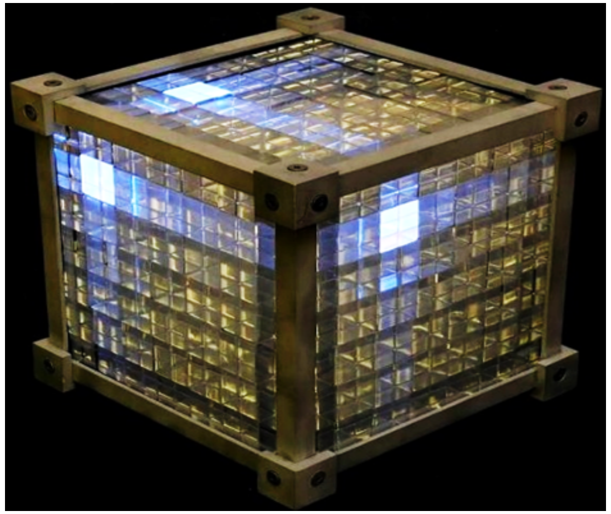


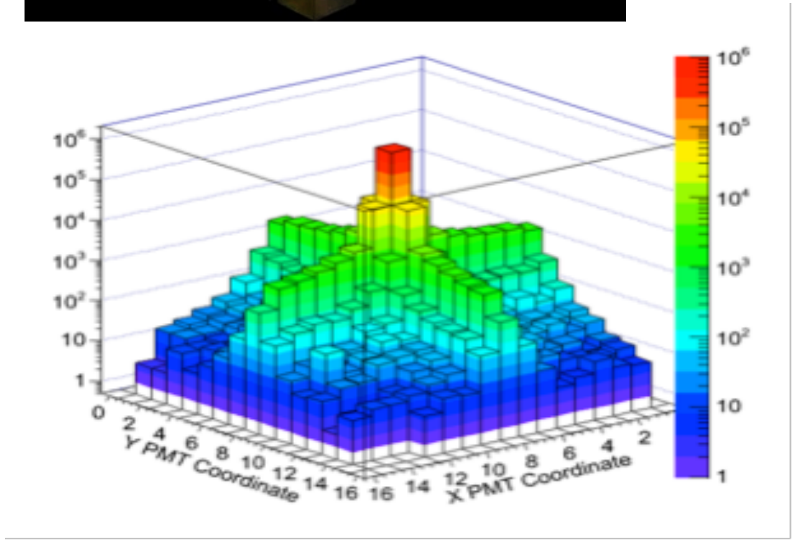
Delayed Neutrino Capture

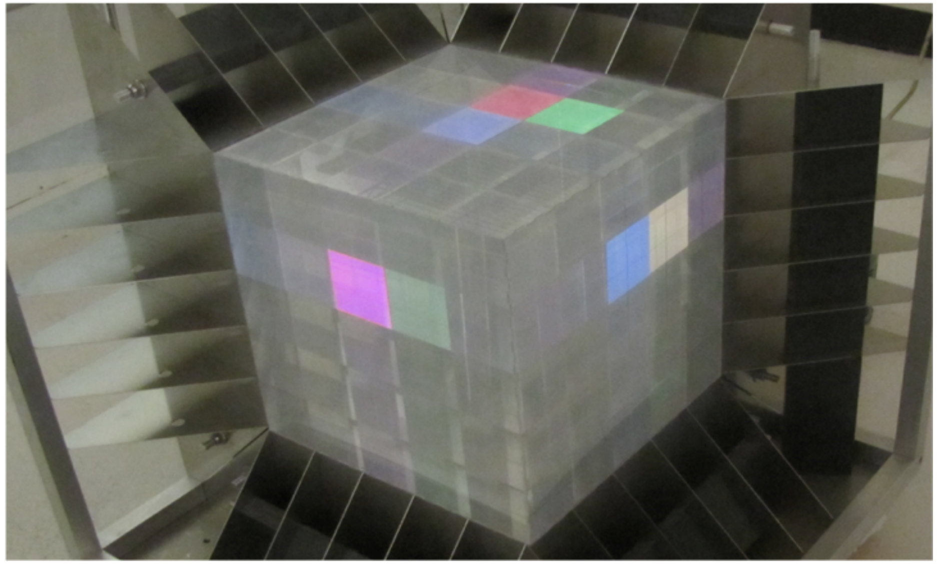
($n + {}^6Li \rightarrow {}^4He + {}^3H + 4.8$ MeV)

localized 400 keV$_{ee}$

Raghavan Optical Lattice



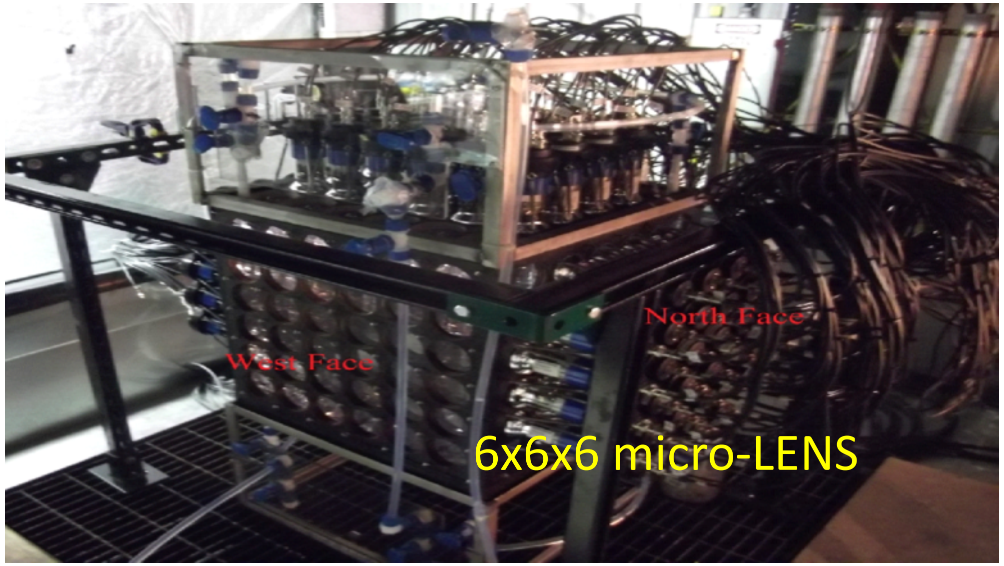




- light channeling via total internal reflection
- full 3D light collection along principle axes
  - <u>Breaks degeneracies present in other detection schemes and rejects backgrounds</u>

Segmentation

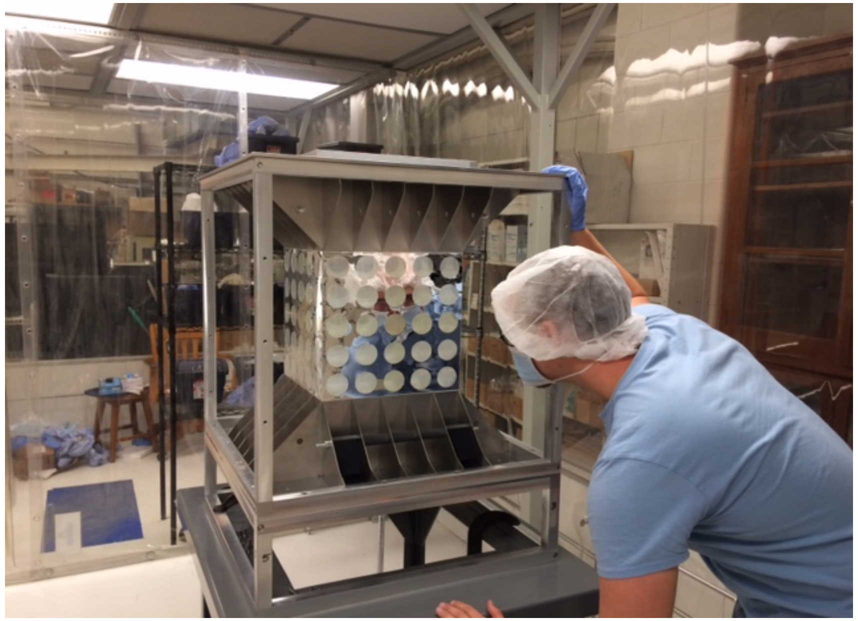
- proven technique: micro-LENS at VT
  - operated liquid scintillator ROL detector located at KURF
  - Cell size = $(3.25'')^3$
  - thin Teflon walls (0.002")
  - partial light channeling (n=1.34 and 1.49)



- NuLat (solid scintillator)
  - Aim for 10x10x10 cubes
    - effectively 1000 individual detectors
  - 2.5 inch polished plastic scintillator cubes
  - 0.5% ^{6}Li wt. loading (Eljen or other)
  - VM2000 reflective film 'dots' to maintain air-gap
  - ***Total*** light channeling (n=1 and 1.54)
  - Easily scalable to larger mass
  - True zero-mass wall – no energy loss
  - (Have some very preliminary schemes for kiloton scale.)

Technical Work Plan

- We are currently focused on two designs
  - Scintillating plastic rods with SiPM detectors on both ends
    - Being developed for neutron camera application, but good for nu’s as well
  - NuLat demonstrator, focused on high resolution and background suppression
- NuLat 5x5x5 ready summer 2019 for test at reactor
  - Schedule evolving
- Working with various projects directly associated with LLNL, SNL and peripherally with ORNL, BNL, FNAL, PNNL and NIST



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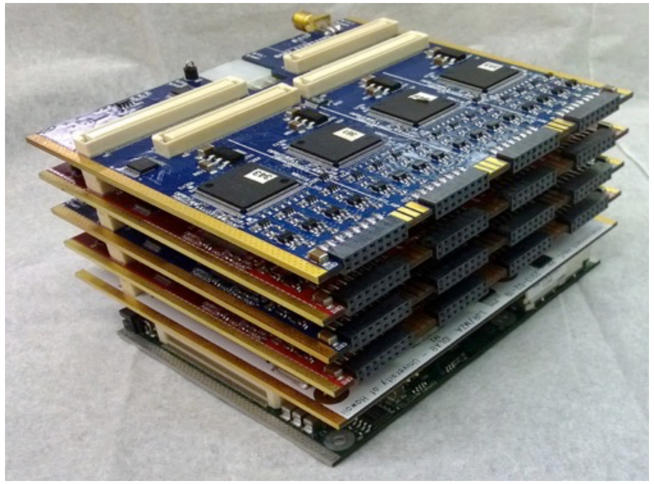


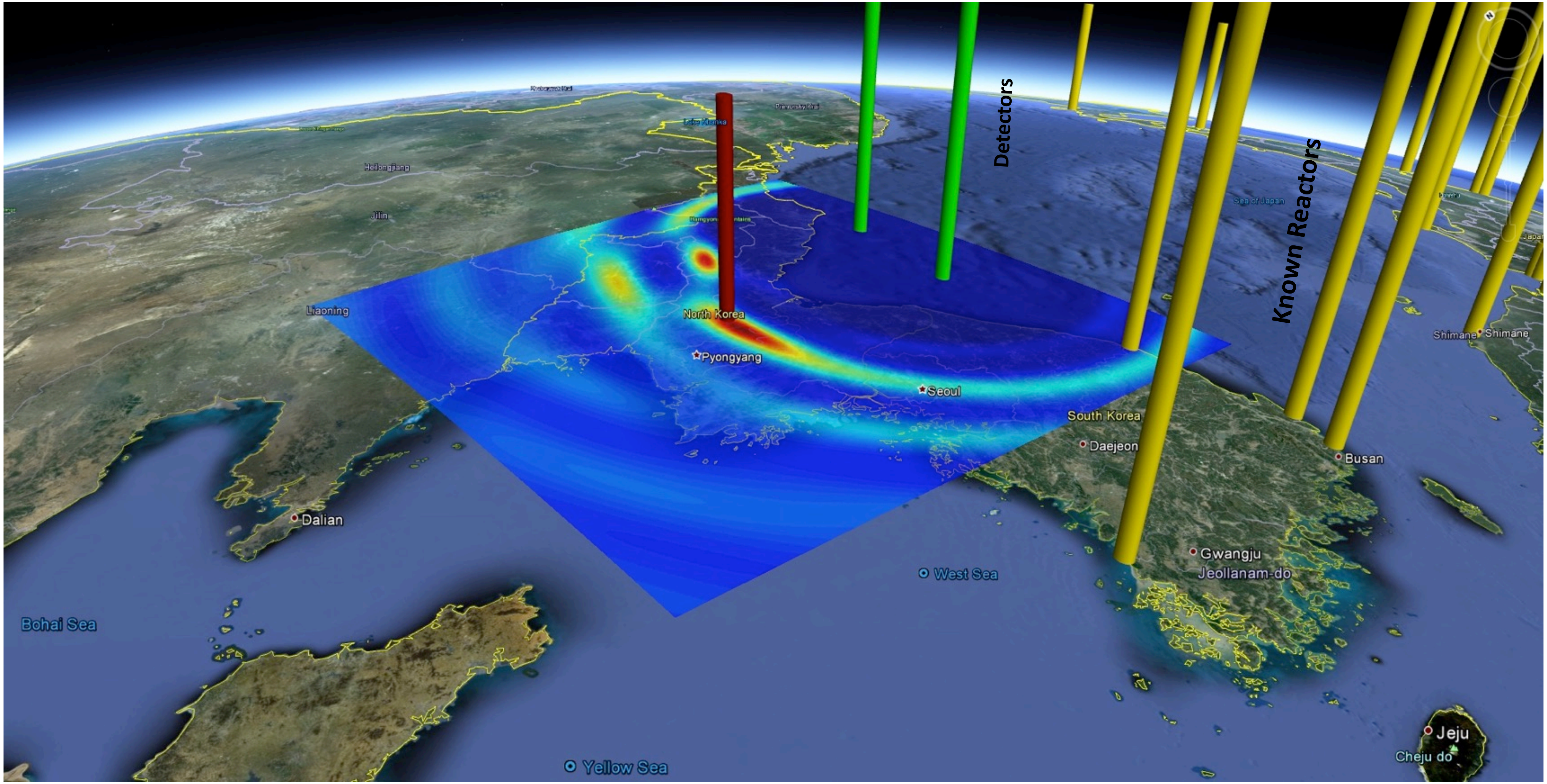
@UH

Expected Impact

- Success will point towards **development of larger, less expensive per unit volume and more sensitive Inverse Beta Decay detectors.**
- Very active field and **training young scientists** will benefit future national laboratory staffing, and support larger science community.
- Parallel **non-interfering studies can have huge science payoff**
  - And while not directly benefiting NNSA goals, provides larger societal interest and motivation for new practitioners.
  - Examples: Supernova detection, hunt for sterile neutrinos, etc….
  - Can have revolutionary impacts benefitting smaller and larger goals

win-win-win program

NeUtrino Direction & Ranging (NUDAR)

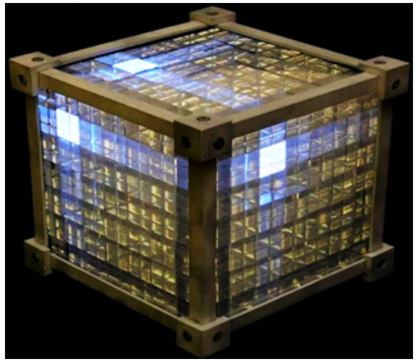


MTV Impact

- **Impact of the MTV on our development?**
  - Examples: Internships, workshop participation, networking, connections, and related technology development
- **Personnel transitions**: We have long standing good relations with LLNL, SNL, LANL, ANL, and others, with **UH graduates at all**.
- **Technology transitions**… long tradition with our group
  - We are at **forefront of neutrino detection technology pushing new scintillators, optical detectors, digitization electronics**
  - **Collaborating on new scintillators with SNL, LLNL, and Eljen ; photodetection with Incom (LAPPDs), SiPMs (SenSL), and Hamamatsu (PMTs)**; **UH builds ultrafast digitizing electronics (UH IDL)**
  - **UH Group has long experience in neutrino detectors and involved in several Nobels**

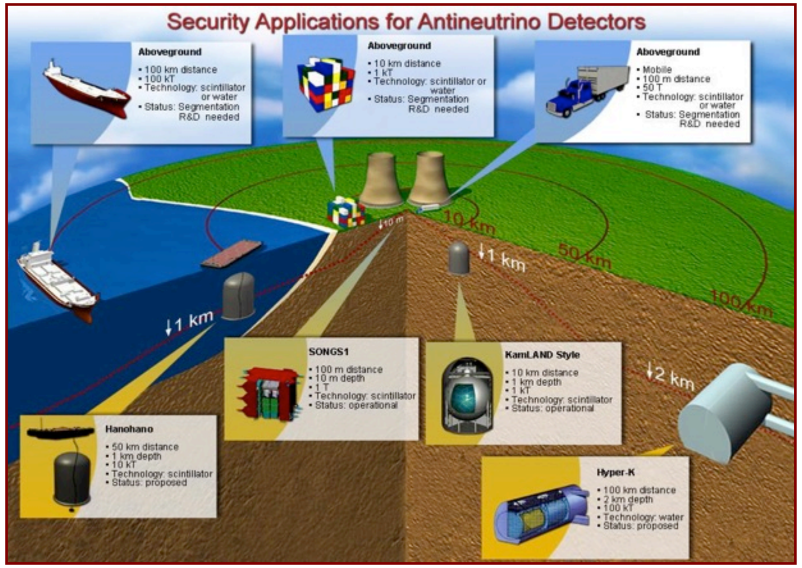
National Nuclear Security Administration

Summary



- **Program at UH to study various means of detection of reactor born electron anti-neutrinos, in motion for some years now and proceeds along several lines**
  1) **development of compact neutrino detectors which have application in clean reactor monitoring from safe distances**
  2) **development of detectors and strategy for long range monitoring.**
- **Focus upon developing methods for low energy neutrino direction measurement… very tough but making progress.**

- **Synergy of developing such detectors with neutrino science, producing new PhDs who can work at national labs, and introducing attractive scientific and technical spinoffs.**



Acknowledgements

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