# CHANDLER: Lessons Learned from Interactions with Industry

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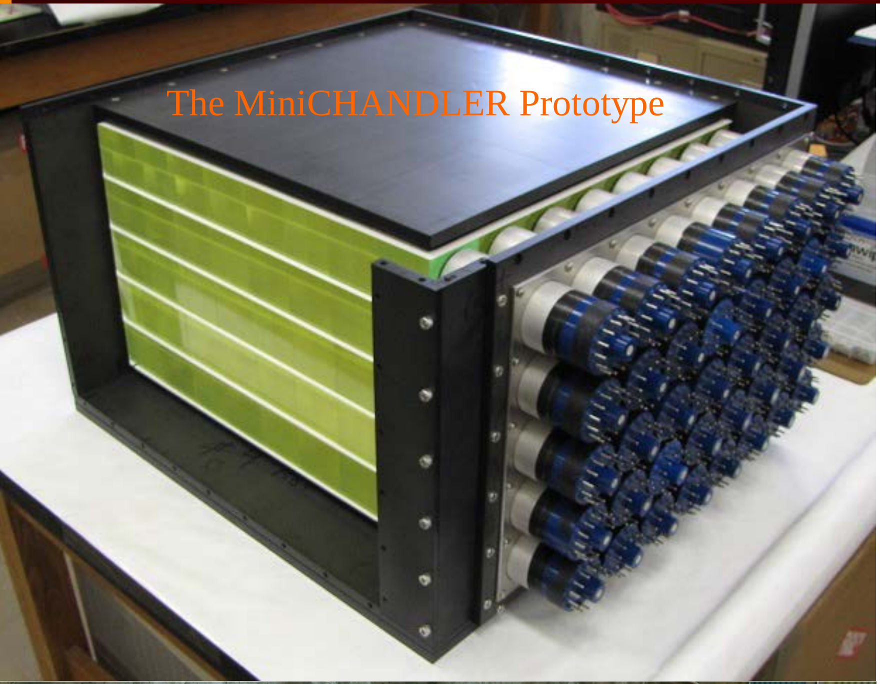
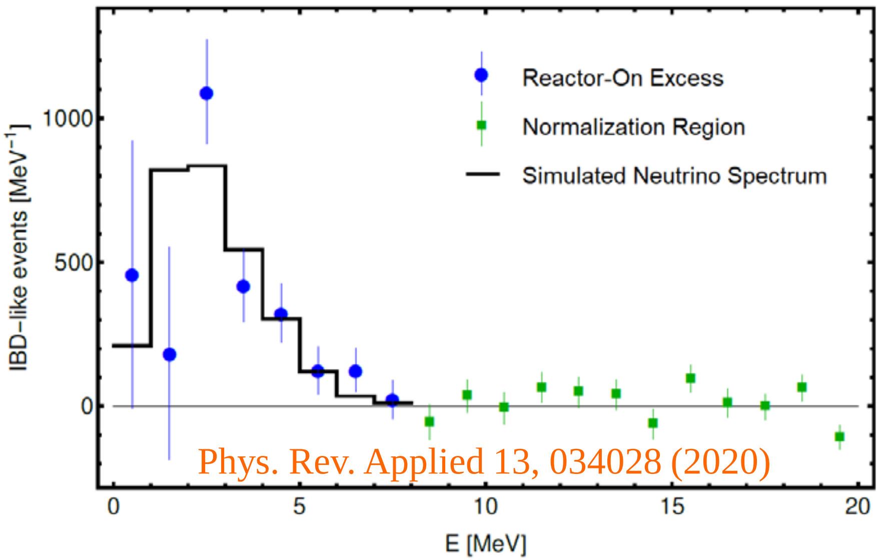
# The CHANDLER Technology




CHANDLER is constructed of alternating layers of optically linked cubes of wavelength-shifting plastic scintillator and thin sheets of lithum-6 doped ZnS scintillator. (US Patent No. 10,429,526).

It uses a clean neutron tag and high spatial resolution to tag IBD events. It has an energy resolution of 6.5% at 1 MeV.

The detector is highly mobile and our MiniCHANDLER prototype has successfully demonstrated neutrino detection.

# NSF Innovation Corps

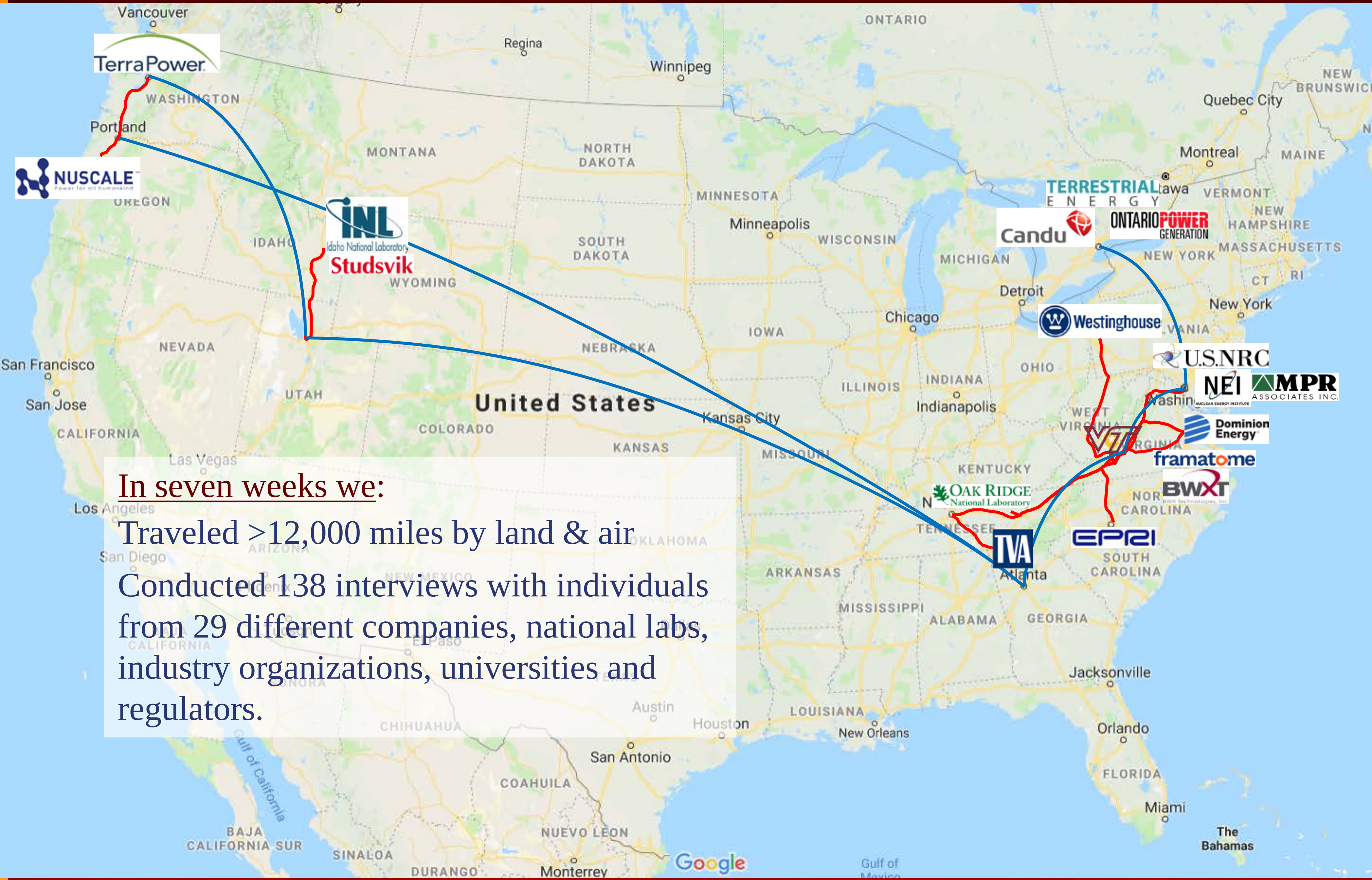
The purpose of the I-Corps program is to identify NSF-funded researchers to receive entrepreneurial education, mentoring and funding to accelerate the translation of knowledge derived from fundamental research into emerging products that can attract subsequent third-party funding.

During the seven-week cohort, each team is expected to spend significant time doing active customer discovery work, interviewing potential customers and potential partners.  A minimum of 100 interviews are required, and most should be conducted in person.

Each I-Corps team consists of three roles: the Entrepreneurial Lead (typically a student of postdoc), the Technical Lead (usually the PI), and an Industry Mentor.

Our goal was to identify potential market opportunities for reactor neutrino detector technology, with a particular focus on reaching beyond our preconceived notions of utility.

# I-Corps Customer Discovery




<u>In seven weeks we</u>:

Traveled >12,000 miles by land & air

Conducted 138 interviews with individuals from 29 different companies, national labs, industry organizations, universities and regulators.

# Lessons Learned

## Post Incident Criticality Detector

This application was raised independently by several individuals.

Following a nuclear accident it would be nice to be able to confirm that the core is no longer critical, particularly with the media asking this question.

*But who would pay for this application?*

In the US, the Strategic Alliance for FLEX Emergency Response (SAFER) operates two equipment pool centers for nuclear emergencies.

This is an industry group founded after Fukushima to head-off new regulatory mandates.

It's unlikely they would voluntarily add expensive new equipment to their inventory when there is no requirement in law or regulation.

# Lessons Learned

## To Improve Operational Efficiency of Existing Reactors

There are operational uncertainties, such as peaking factors, that limit the efficiency of existing reactors, through conservative safety margins.

A reduction in these safety margins could be achieved with highly local power measurements that reduce the uncertainties.

A 50% reduction in the uncertainty would more than pay for the cost of neutrino detectors in each fuel cycle.

Significant progress on reducing safety margins would require power measurement spatial precision at the fuel assembly level.

This is beyond the current state-of-the-art of neutrino detectors.

# Lessons Learned

## Neutron Flux Detector Calibration

Reactors use neutrons to monitor power as part of their critical safety systems.

Ex-core neutron detectors must be able to detect a 5% spike in power and scram the reactor within two seconds. They are also used to detect core tilt.

*Neutrino detectors are unlikely to accomplish these tasks.*

Most reactors insert movable in-core neutron flux detectors, every 30 to 90 days, to calibrate the ex-core system.

Anything in-core is expensive to operate and repair, and new reactors would benefit from reducing or eliminating core vessel penetrations associated with them.

Can a neutrino detector be used to continuously calibrate ex-core neutron detectors?

# Lessons Learned

## Advanced Reactors without Fixed Fuel

IAEA monitoring relies heavily on tagging and tracking spent fuel assemblies.

Many advanced reactor designs use fuel that is dissolved in the moderator or coolant, therefore the tag and track approach may not work.

In these designs the fuel is well mixed, so an overall measurement of the isotopic concentrations would be sufficient to characterize the state of the whole reactor.

Neutrino detectors may be able to ensure that fuel is only removed when the isotopic mix is incompatible with a chemical conversion to weapons grade.

Or at a minimum, neutrino assay could be used to rank the proliferation risk associated with each batch of spent fuel at the time it's removed.

# Lessons Learned

## Advanced Breeder Reactors

Breeder reactors will require a better understanding of the time evolution of fissionable isotopes.

The baseline assumption is that this will be done with chemical assay of spent fuel (or fuel samples in liquid fuel reactors).

Chemical assay represent both an environmental and proliferation risk.

Neutrino detectors would have to match the precision of chemical assay to be considered as an acceptable replacement.

Alternatively…

Neutrino detectors could be used in the R&D stages of advanced reactors to better understand the fuel cycle.