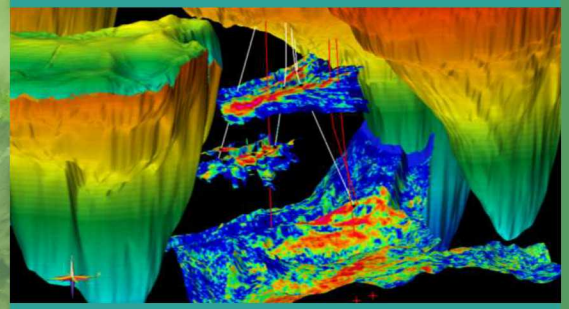
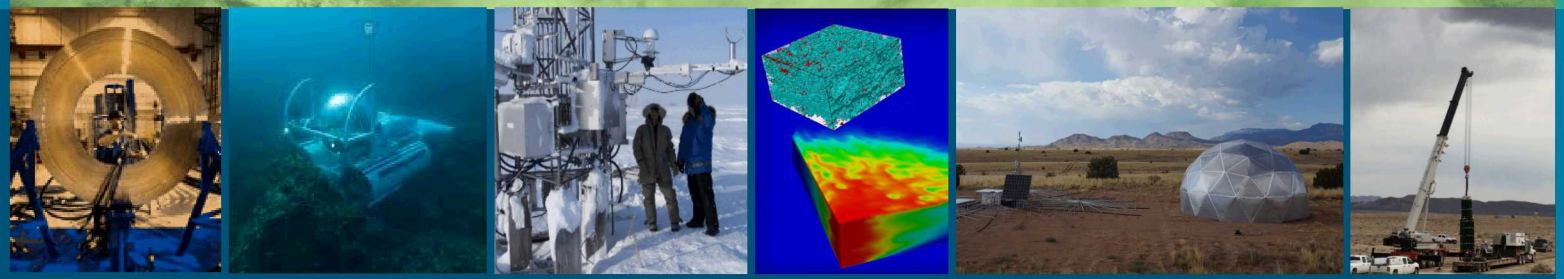
The Earth Science Research Foundation:
An Evolution





May 24, 2019

PRESENTED BY

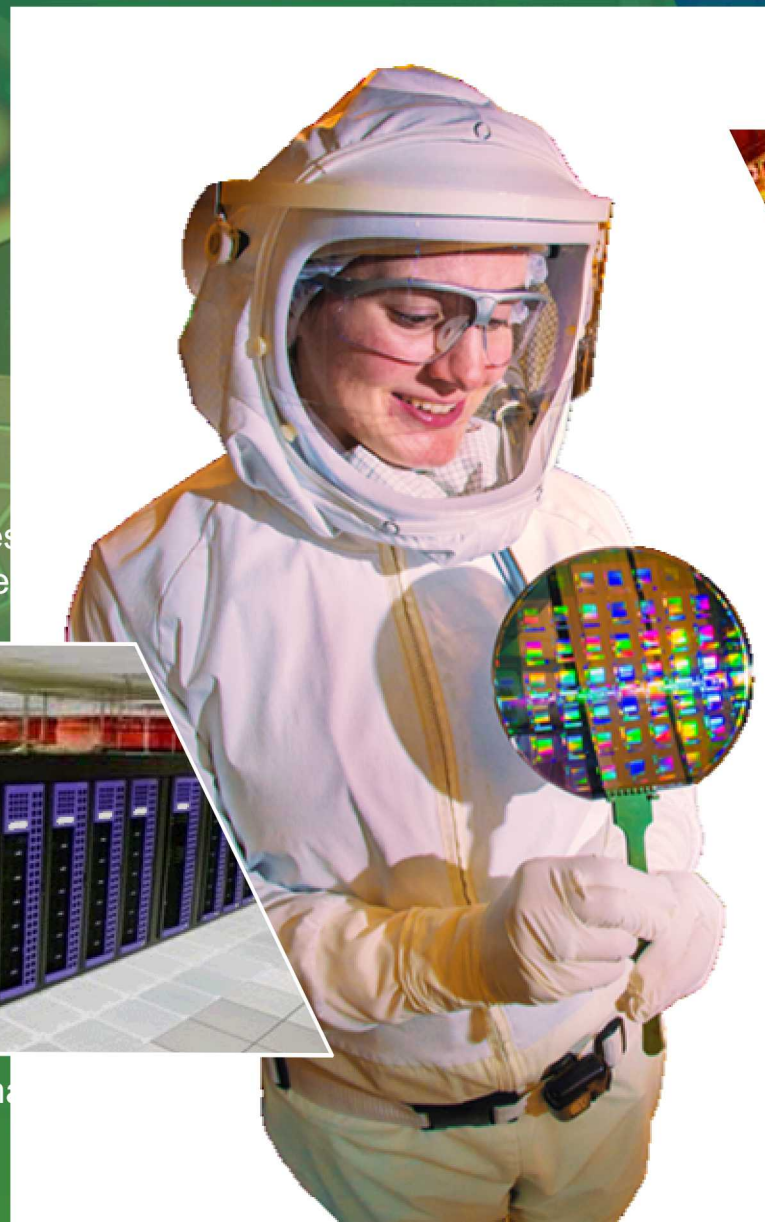
Erik Webb

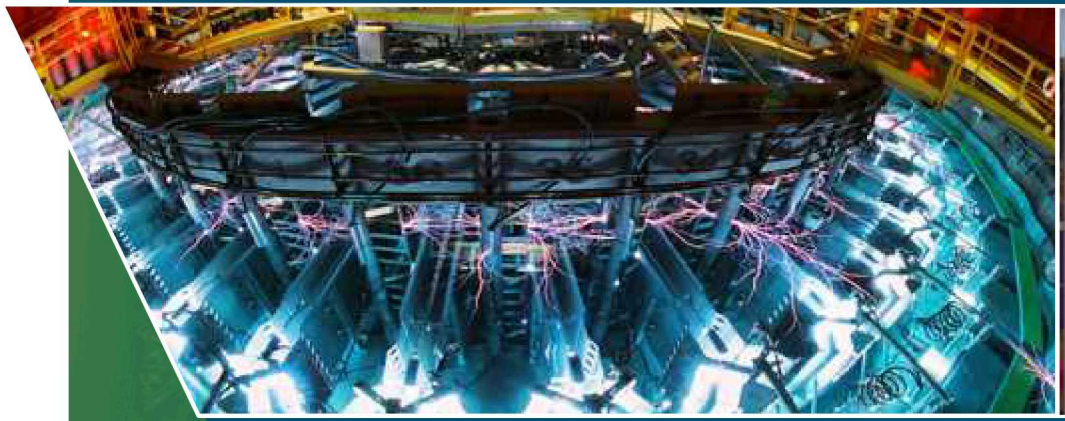
Senior Manager, Geoscience Research and Applications

SAND2019-6948PE

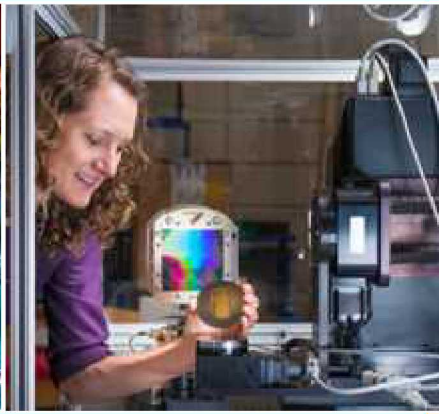
RESEARCH FOUNDATIONS ARE INTEGRAL TO MISSION EXECUTION

Nanodevices
Microsyste



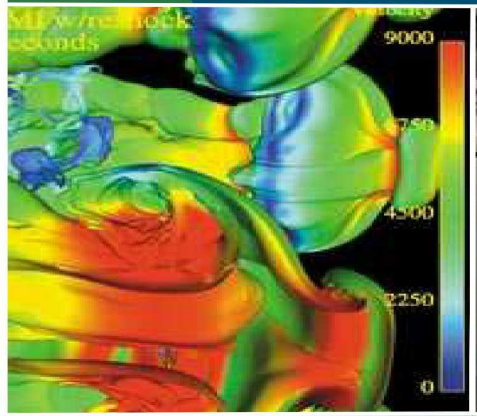


Radiation Effects & High Energy Density Science



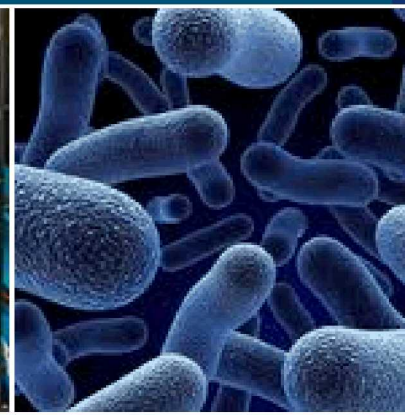
Materials Science

Computing & Informa



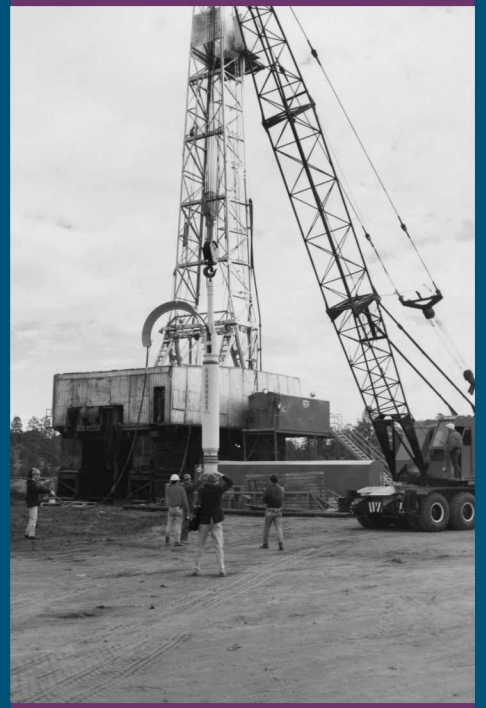
Engineering Science

Earth Science



Bioscience

ADVANCED SCIENCE & TECHNOLOGY



- Plowshare (peaceful uses of nuclear weapons
- Beginning in the 1970's, support of shock physics
- 1972: Sandia provided scientific packages and experiments for unmanned balloon studies for the Army's Atmospheric Sciences Laboratory
- 1980's: Rock Mechanics Lab installed

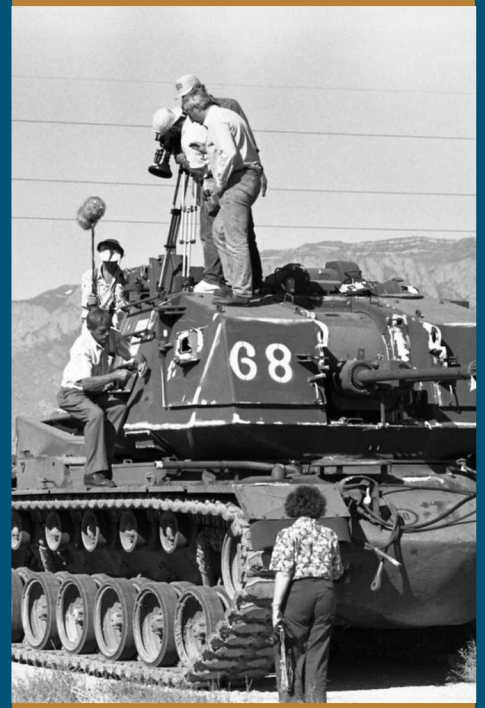
ENERGY & HOMELAND SECURITY

- Sensors for Vietnam (acoustic & seismic capability)
- Energy Programs
  - FY75 18 proposals in energy work, 8 of which directly evoked earth science capabilities
- Management of DOE's Multiwell Experiment
- Strategic Petroleum Reserve

NATIONAL SECURITY PROGRAMS

- International Arms Control Treaty Support
  - Since 1959, Sandia was involved in the VELA program which included satellite and underground testing of nuclear weapons
- U.S. Arms Control & Disarmament agency funded Sandia to develop unmanned seismic observatories

GLOBAL SECURITY



- Nuclear test detection
  - Unattended Seismological Observatory
  - National Seismic Station
  - Treaty Verification Research
  - Regional Seismic Test Network

NUCLEAR DETERRENCE

Sandia's earth science capability originated and grew with the original nuclear weapons mission. Activities include:

- Support of nuclear testing
  - Meteorology
  - Seismology
- Support of weapon design capability
- Readiness

EARTH SCIENCE IS EMBEDDED IN SANDIA'S FIVE MISSIONS

Understand nano-microscale to the macroscale, multi-physics view of the earth and its processes and climate change monitoring, modeling and geo-engineering

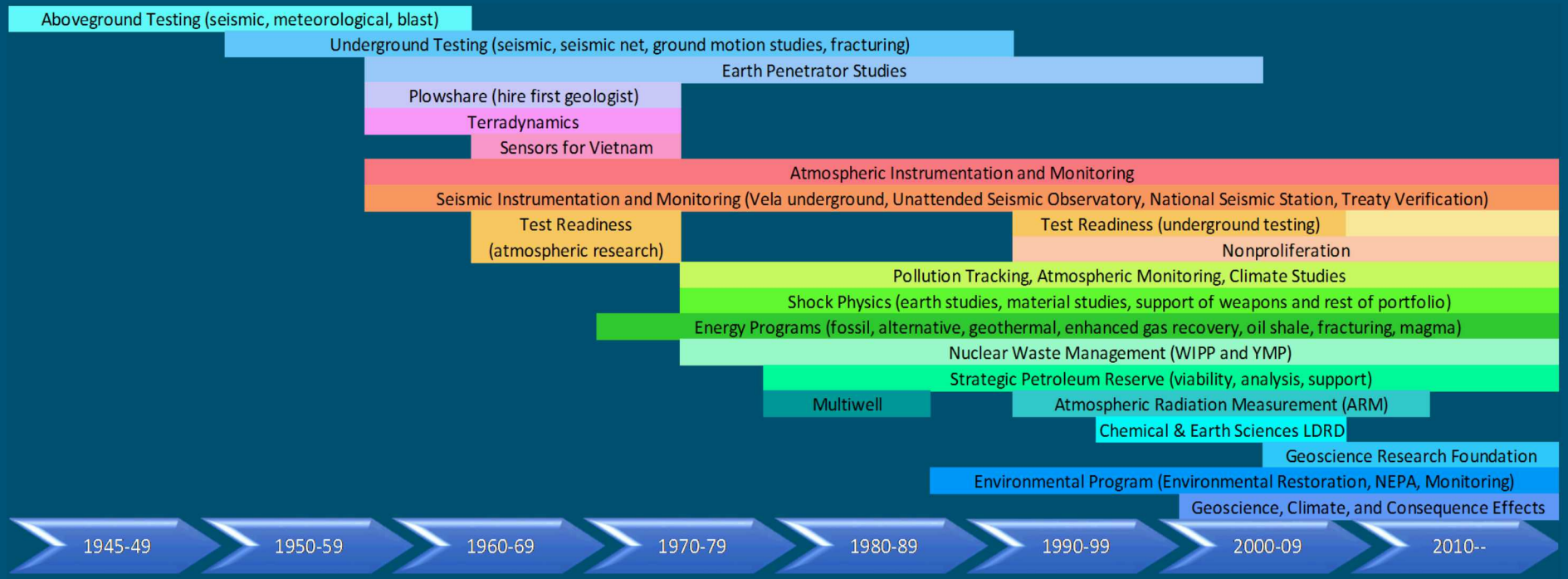
Emergency response activities for the Department of Homeland Security, nuclear waste disposal, geothermal energy and Fossil Energy production and optimization, managing deep subsurface energy storage

readiness and weapon to osphere, ocean and solid Earth raction

und-based nuclear detonation ection, determination of explosive d and burial conditions, and iferation assessments

ect and Characterize underground ctures and support effective ntermeasure planning; sea floor racterization; energy harvesting and ar accuracy

EARTH SCIENCE TIMELINE



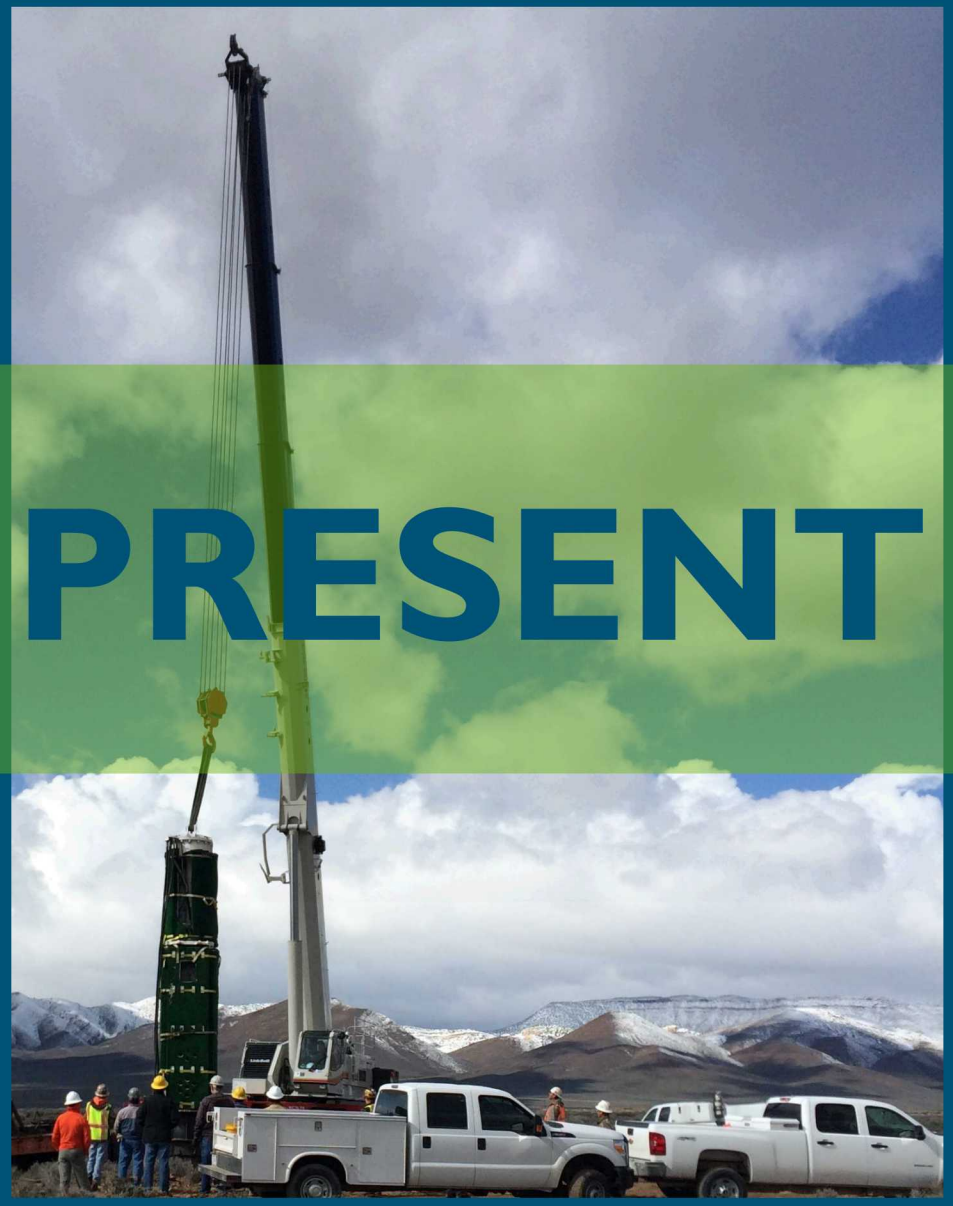
BRAND & FOCUS

Quantitative Earth Science for National Security

The Earth Science Research Foundation goals are to:

- Expand our basic understanding and reduce uncertainty of Earth systems
- Develop sensors and systems to interrogate Earth systems
- Analyze and experiment to characterize, quantify, and manipulate Earth properties
- Couple earth science and engineering tools
- Develop and test simulation tools for predicting Earth system behavior over orders of magnitudes in space and time for solid earth, oceans, hydrosphere, or atmospheric materials at *in situ* conditions.

EARTH SCIENCE AT SANDIA: A RETROSPECTIVE



FY20 Investment Objective

Quantitative Earth Science for National Security

The Earth Science Research Foundation investment goals are to:

- Expand our basic understanding and reduce uncertainty of Earth systems
- Develop sensors and systems to integrate Earth system data
- Analyze and experiment to characterize, quantify, and manipulate Earth processes
- Couple earth science and engineering models
- Develop and test simulation tools for predicting Earth system behavior over orders of magnitudes in space and time for solid earth, oceans, hydrosphere, or atmospheric materials at in situ conditions.

New start investments will have a strong bias to projects with value to multiple Sandia missions.

Arctic Science R&D Sponsorship

SNL has multiple sponsors that underpin the projects we undertake:

Two critical funding sources are:

- Laboratory Directed Research and Developiment
  - Earth Science Research Foundation
  - Energy and Homeland Security
  - Advanced Science and Technology
  - Global Security Programs

- Department of Energy, Office of Science, Biological and Environmental Science (BER)

FY19 Seedlings

Arctic Tipping Points Triggering Global Change

- **Not funded as a Baby Grand but funded in FY19 and FY20 by**
  a special $500K plus-up from the LDRD Office
- Develop computational methods to enable Arctic-focused tipping
  event prediction to support early warning of critical transitions
  and evaluation of impacts. Arctic changes impact the e
  Earth
  system and have significant national security consequences
- Would position SNL to be a leader in Arctic systems analysis
- Mission Connections: AS&T, CIS and E/HS
- Partnering Opportunities: Office of Naval Research Arctic & Global Prediction Program, U of Alaska – Fairbanks

Ideas Going to Full Proposal	Comments
Releasing, Detecting, and Modeling Trace Aerosols and Gases in Earth's Stratosphere	Geoengineering focus
Seismic Spatial Gradients as a Machine Learning-Based Classifier for Explosion Monitoring	
Uncertainty Quantification of Geophysical Inversion Using Stochastic Partial Differential Equations	
Physically Rigorous Reduced-Order Flow Models of Fractured Subsurface Environments without Explosive Computational Cost	
A Frontier, Validated Reactive Gas Transport Simulator for Global Security	
Adsorbent Materials for High Ionic Strength Disposal Environments to Sequester Anionic and Cationic Contaminants	
Predicting Gas Transport in the Subsurface	
Computational Analysis of Coupled Geoscience Processes in Fractured and Deformable Media	
Other ideas submitted -- not advancing to full proposal	**Comments**
Borehole Optical Strain Measurement and Hydraulic Fracture Tool	
Optimizing Measurement Networks for Permafrost Emissions	Arctic potential
A Novel Neutron Interrogation Sensor for Non-Intrusive Measurements of Carbon, Nitrogen and Oxygen in Degrading Permafrost and for Detecting Explosives and Contraband	Arctic potential
Aftershock Identification using One-Shot Learning for Seismic Monitoring Applications	
Capturing Acoustic Radiation Patterns over Volcanoes to Constrain Eruption Volume Flow Rate	Climate, geoengineering
In Situ Spectroscopy Sensing and Quantification of Geomaterial Fluid Interfacial Reactions	
A Novel Solid Mechanics-Based Formulation of Iceberg Fracture and Calving for Improved Prediction of Climate-Change-Induced National Security Threats	Arctic and Antarctic potential
Automated Integration of Multiscale Imaging Data for a Realistic Representation of Heterogenous Geomaterials using Deep Learning	
Effects of Aerosol-Atmosphere Interactions on Climate	Climate
Advanced Testing of Autonomous Sampling Capsule System for Seasonal Volatile Organic Compound Collection in Harsh Environments	
Novel Chemical Tool for Manipulating Colloidal Particle Movement in the Subsurface	
Deep Learning Framework for Structure-Properties Relationships in Transport Through Porous Media	
Improving Avalanche Forecasting Using Infrasound	Arctic, Antarctic potential

Title	Principal Investigator	Time
Attribution of Methane Emissions in the Arctic and Continental US	Ray Bambha	FY17-FY19
Deciphering Atmospheric Ice Nucleation Using Molecular-Scale Microscopy	Konrad Thuermer	FY17-FY19
High Resolution Measurements and Modeling in the Arctic	Erika Roesler	FY16-FY18
A Predictive Model for Arctic Coastal Erosion	Diana Bull	FY18
		FY19
		FY20 (potential)
Arctic Tipping Points Triggering Global Change	Kara Peterson	FY18
		FY19
		FY20 (potential)
Forecasting Wave Energy	Annie Dallman	FY18
High Heliotrope: Evaluating the Capability of High Altitude Infrasound Platforms to Cover Gaps in Existing Networks	Daniel Bowman	FY17
Developing Fugitive Emissions Sensor Networks: New Optimization Algorithms for Monitoring, Measurement and Verification	Katherine Klise	FY17-FY18
Forecasting Marine Sediment Properties On and Near the Arctic Shelf with Geospatial Machine Learning	Jenn Frederick	FY19
		FY20 (potential)
		FY21 (potential)
AeroMine and Hydromines - motionless integrated extraction for distributed wind and tidal energy in Alaska and the Arctic – Exploratory Express	Brent Houchens	FY20

Sandia Arctic LDRD Investment Strategy

Sandia's Arctic LDRD strategy focuses on three areas with the potential to have the greatest impact on national security and provide much needed data which will lead to more robust global climate models.

Ice Migration: Melting sea ice increases access to natural resources and impacts multiple sectors.

Coastal Erosion: Arctic Coastal erosion rates in the US have doubled since the middle of the 20th century.

Permafrost: Melting permafrost leads to the release of methane, causes erosion and damage to infrastructure.

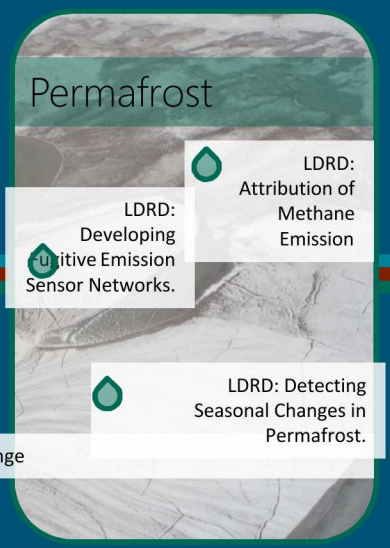
Ice Migration

LDRD: Deciphering Atmospheric Ice Nucleation Using Molecular-Scale Microscopy

Coastal Erosion

LDRD: A Predictive Model for Coastal Erosion

Permafrost



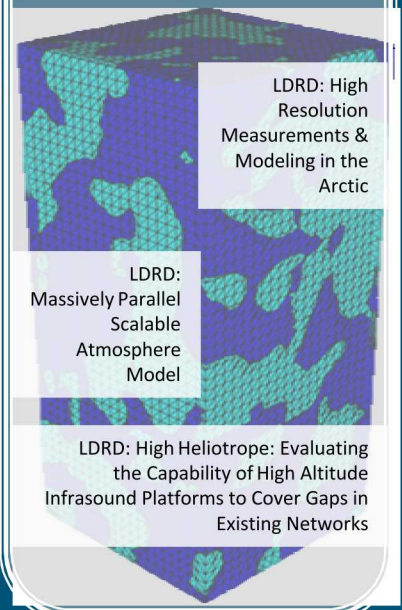
LDRD: Developing Fugitive Emission Sensor Networks.

LDRD: Attribution of Methane Emission

LDRD: Detecting Seasonal Changes in Permafrost.

LDRD: Arctic Tipping Points Triggering Global Change

Climate Models



LDRD: High Resolution Measurements & Modeling in the Arctic

LDRD: Massively Parallel Scalable Atmosphere Model

LDRD: High Heliotrope: Evaluating the Capability of High Altitude Infrasound Platforms to Cover Gaps in Existing Networks

Security Issues

- Territorial disputes
- Increased access for parties with commercial and political interests
- Potential conflict due to impact on economies and cultures of the peoples in the Arctic regions
- Increased foreign and domestic maritime and aerial transportation

Security Issues

- Over 178 Arctic communities are at risk from coastal erosion. As a result, many native villages must relocated and compete for state and federal assistance.
- Heightened competition over increasingly scarce resources (land, indigenous food sources, state and federal aid)

Security Issues

- Subsidence and damage of critical road infrastructure
- Coastal erosion, infrastructure damage, and military and civilian site relocations, and
- Methane and other trapped underground gas release to the atmosphere lead to greater rates of global climate change and ice melt.

2015

Sandia provides MAAI funding for Arctic Science & Security Initiative. A cross-laboratory innovation tournament is held which results in eight white papers and three roadmaps on Arctic Security, Science and Infrastructure.

2016

In addition to MAAI funding for 2016, Division 6000 allocates funding for the development of a U.S. High Arctic Research Station and the Alaska Infrastructure Simulation Analysis Center. Joint Sandia (8800 & 6500) capability being leveraged to fly UAS systems at Oliktok Point.

2017

Engagement with LDRD IATs to have Arctic-related issues represented in GNAS, EC and Geoscience Research Foundation calls. 17 LDRD ideas submitted, 3 funded and 1 emerging GC concept is maturing

2018

Active engagement and program opportunities sought with external stakeholders and sponsors.

Arctic Capabilities Working Group established to articulate lab strategy and guide outreach.

PORTFOLIO

Type	PM	PI	Title	E&HS	AS&T	GS	NSP	ND
Continuing	LEE, MOO	YOON, HONGKYU	Integrated Geomechanics and Geophysics in Induced Seismicity: Mechanisms and Monitoring	⧖		⧖		
Continuing	PARROTT, LORI	BAMBHA, RAY	Attribution of Methane Emissions in the Arctic and Continental US	⧖	⧖		⧖	
Continuing	VIGIL,STEVE	WEISS, CHET	Prediction and Inference of Multi-scale Electrical Properties of Geomaterials	⧖	⧖			
Continuing	MCMAHON, KEVIN	MATTEO, ED	Monitoring and Repair of Damaged Cement-Geomaterial Interfaces in High Pressure High Temperature Repository and Borehole	⧖		⧖		
Continuing	GILLICH, DON	ALBERT, SARAH	Unlocking Real Time Infrasound Event Classification Abilities using Machine Learning	⧖		⧖		
Continuing	MACKINNON, BOB	KUHLMAN, KRIS	Characterization and Sampling of Ultralow Permeability Geomaterials using Electrokinetics	⧖	⧖	⧖		
New	MACKIINON, BOB	FREDERICK, JENN	Forecasting Marine Sediment Properties On and Near the Arctic Shelf with Geospatial Machine Learning	⧖	⧖		⧖	
New	BETTIN, GIORGIA	SU, JIANN	Direct Subsurface Measurements through Precise Micro Drilling	⧖		⧖	⧖	
New	NEWCOMER, JUSTIN	SHAND, LYNDSAY	Marine Cloud Brightening	⧖			⧖	
Baby Grand Challenge	BETTIN, GIORGIA	TBD	Real-Time Subsurface Event Assessment and Detection	⧖	⧖	⧖	*	*
Continuing	PARKS, MIKE	PETERSON, KARA	Arctic Tipping Points Triggering Global Change	⧖	⧖	*		

Legend

*	Building Connections
⧖	Expand

ACADEMIC ALLIANCE UNIVERSITIES

- For FY19, four ES LDRDs received an additional $443K in (above and beyond the amount funded by the ES Research Foundation (RF)) to partner with five designated Academic Alliance universities

PURDUE UNIVERSITY

(1 LDRD)

ILLINOIS

(1 LDRD)

Georgia Tech

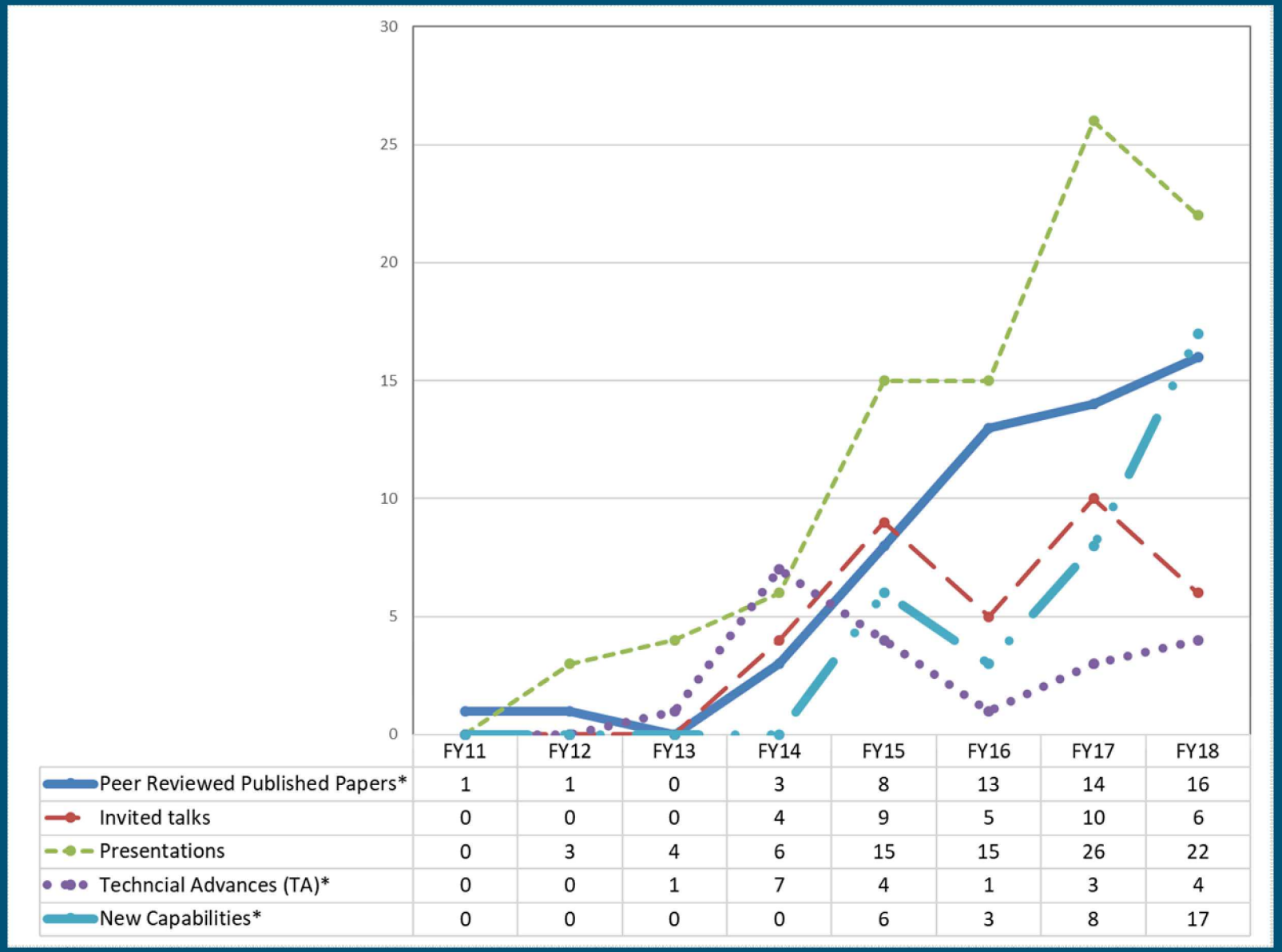
TEXAS
The University of Texas at Austin

(2 LDRDs)

UNM

(1 LDRD)

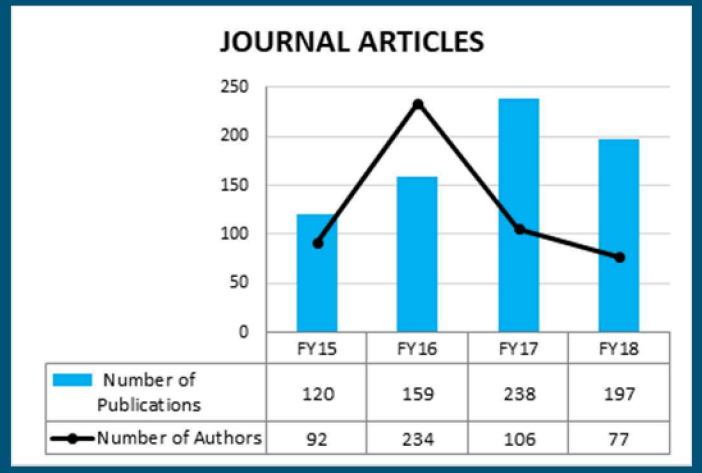
LDRD ACCOMPLISHMENTS

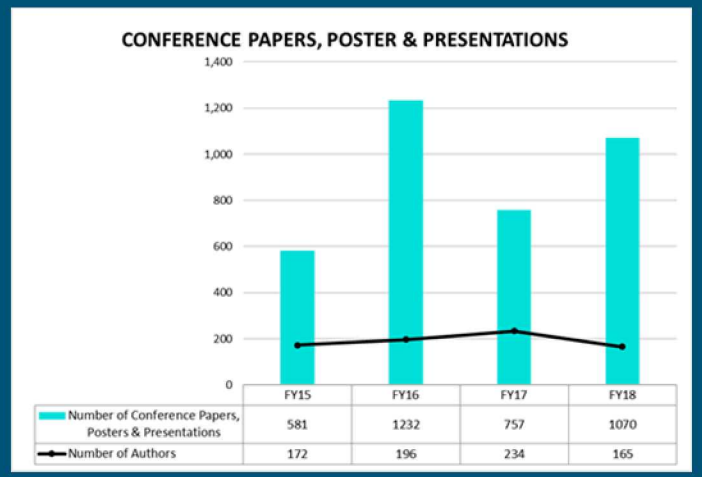


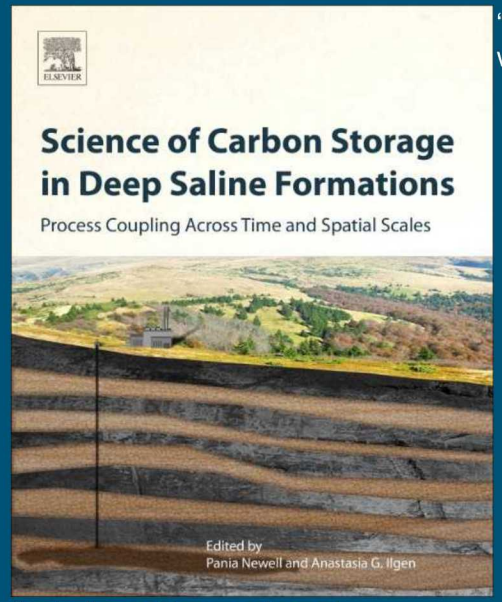
	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
Peer Reviewed Published Papers*	1	1	0	3	8	13	14	16
Invited talks	0	0	0	4	9	5	10	6
Presentations	0	3	4	6	15	15	26	22
Techncial Advances (TA)*	0	0	1	7	4	1	3	4
New Capabilities*	0	0	0	0	6	3	8	17

EARTH SCIENCE IMPACT

PUBLICATIONS/POSTERS/PRESENTATIONS/JOURNALS

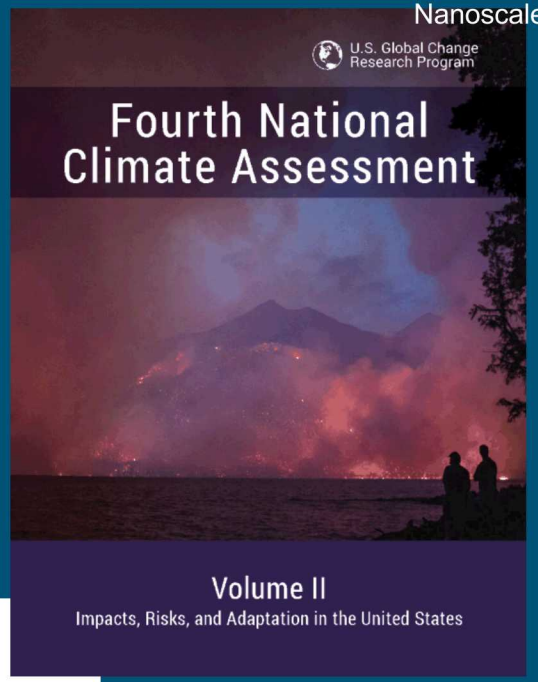






Anastasia Ilgen: Peer-reviewed book published by Elsevier, September 2018

Yifeng Wang, Anastasia Ilgen, Louise Criscenti, and Craig Tenney: Manuscript entitled: "Supercritical CO2-induced atomistic lubrication for water flow in a rough hydrophilic nanochannel" has been accepted for publication in the journal Nanoscale.



Vincent Tidwell: Lead author for Energy, Water and Land Use Chapter of the Fourth National Climate Assessment, November 2018.

Institution of MECHANICAL ENGINEERS

Jason Heath and Richard Jensen: co-authors of a paper that was the winner of the 2017 Thomas Lowe Gray Prize from the Institution of Mechanical Engineers for the Paper "Verification of a rapid mooring and foundation design tool" in Proceedings of the Institution of Mechanical Engineers.

EARTH SCIENCE IMPACT

Sandia recently celebrated twenty years of the Sandia-managed Atmospheric Radiation Measurement (ARM) Center in Utqigvik (formerly Barrow), Alaska Atmospheric Science in the Arctic.

Sandia successfully executed a first-of-its-kind fireball test to measure the burn properties of crude oils.

Seminar pursuing the understanding of pollution from combustion engine systems to help improve energy efficiency and safety, and reduce environmental impact.

Sandia is taking part in the Year of the Polar Prediction (YOPP), a large international effort 2017-2019. YOPP seeks to collect atmospheric observations to help improve modeling and forecasting capabilities around the poles.

KOGAS

Sandia successfully uses sensor placement optimization tool, Chama, for collaboration with KOGAS.

WELCOME BOARD MEMBERS

Dr. Kaye Shedlock – Chair, Independent Consultant

Dr. Thomas Ackerman – Director, Joint Institute for the Study of the Atmosphere and Ocean

Dr. Lawson Brigham – Distinguished Fellow, Center for Arctic Policy Studies

Dr. Darryl P. Butt – Dean, College of Mines and Earth Sciences, University of Utah

Dr. Sean McKenna – Senior Research Manager, IBM Ireland Research Lab

Dr. Joaquin Ruiz – Thomas R. Brown Distinguished Professor, University of Arizona

Welcome new Earth Science Research Foundation board member, Dr. Darryl Butt!

- Dean, College of Mines & Earth Sciences, University of Utah
- Distinguished Professor of Materials Science & Engineering, Boise State University
- Dr. Butt has held numerous leadership positions in academia, industry and R&D including A.P. Green Industries, LANL & University of Florida
- Ph.D., Materials Science, Penn State University

THE UNIVERSITY OF UTAH

one color red