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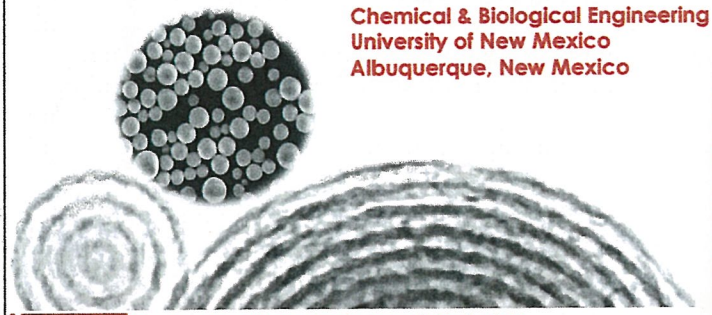
Carbon Capture/Sequestration Research
at The University of New Mexico

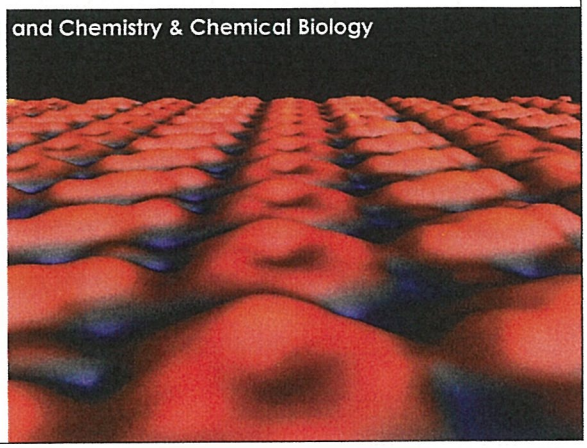
Plamen Atanassov

Chemical & Biological Engineering
University of New Mexico
Albuquerque, New Mexico



CMEM Center for Micro-Engineered Materials

and Chemistry & Chemical Biology



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OVPR Research Centers & Institutes

UNM's research centers & institutes facilitate interdisciplinary collaboration among researchers & provide opportunities for their research to influence public policy & contribute to New Mexico's economic development.

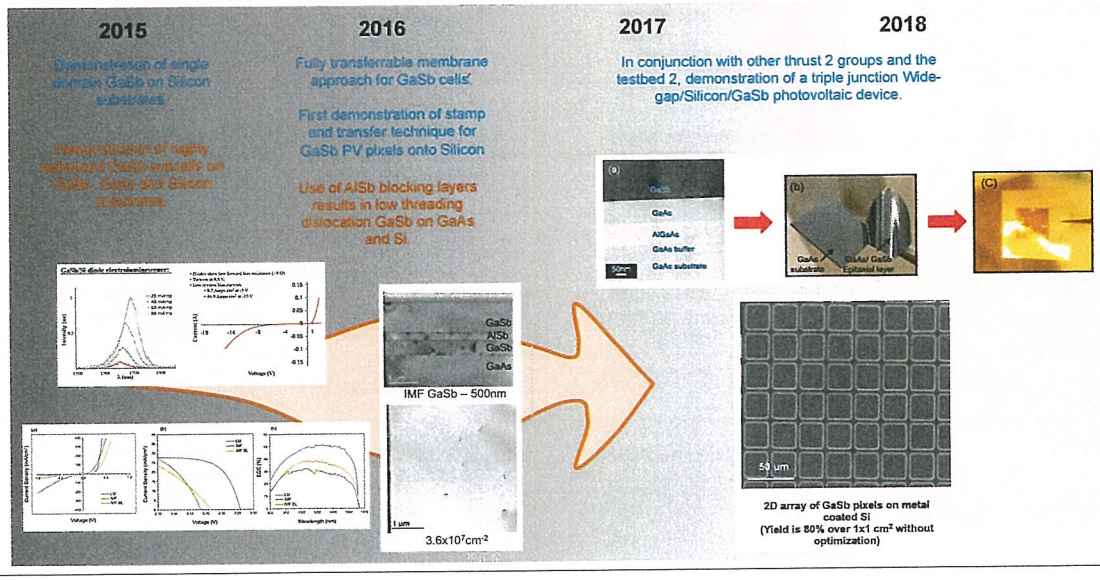
Listed are the research centers & institutes at UNM overseen directly by the Office of the Vice President for Research.

http://research.unm.edu/centers-institutes

- Bureau of Business and Economic Research (BBER)
- Center for Advanced Research Computing (CARC)
- Center for High Technology Materials (CHTM)
- Center for Micro-Engineered Materials (CMEM)
- Center for Water Governance Studies (CWGS)
- Center on Alcoholism, Substance Abuse, & Addictions (CASAA)
- Data Observation Network for Earth (DataONE)
- Established Program to Stimulate Competitive Research (EPSCoR)
- GeoSpatial and Population Studies (GPS)
- Institute for Policy, Evaluation, And Applied Science (IPEAR)
- Land Grant Council (LGC)
- Southwest Hispanic Research Institute (SHRI)

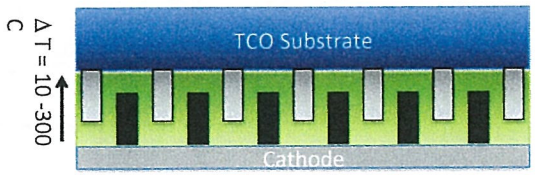
- CHTM/UNM is part of the QESST (Quantum Energy and Sustainable Solar Technologies) NSF/DOE joint engineering research center on photovoltaic development for meeting the nation's terawatt challenge.
- CHTM in the past decade has been involved in prominent photovoltaic research efforts including the Army MAST project and a DOE MURA project, both towards the development of thermophotovoltaics.
- Strong collaborative ties with the AFRL space vehicles directorate for use of UNM epitaxial reactors.
- CHTM is fully capable of realizing wafer to solar cell fabrication and subsequent testing/characterization of solar cells and thermophotovoltaics. Four molecular beam epitaxy reactors in place for PV growth.
- Currently **Prof. Balakrishnan, Prof. Cavallo and Prof. Busani** are involved in photovoltaic/thermophotovoltaic research at CHTM.

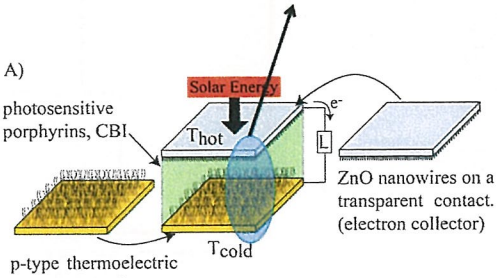
Current UNM Effort on the QESST Program: Realization of III-Sb PV cells on GaAs and Silicon substrates

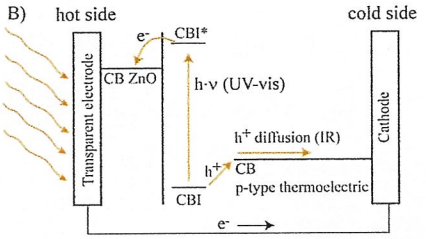


Combining Photovoltaic and Thermoelectric Generators

A hybrid solar device targets a larger region of the solar spectrum and increases its overall efficiency by reabsorbing heat generated by other chemical components.





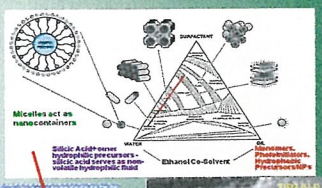


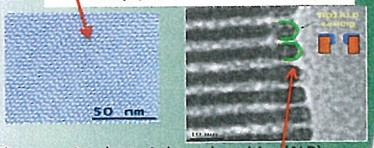
CHTM

Nano-stabilized Enzymatic Membrane for CO_2 Capture Meets DOE Standard for CO_2 Sequestration (UNM/SNL) by C. Jeffrey Brinker and Susan Rempe

Basic Science | Applied R&D | Manufacturing/ Commercialization

Evaporation-induced self-assembly (EISA) enabled for the first time the formation continuous large scale nanoporous silica films with uniform ordered porosity (*Nature '97, '00, Science '00*)

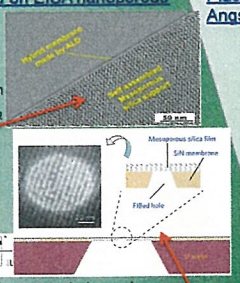




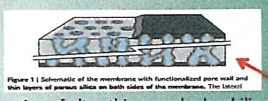
Plasma-assisted atomic layer deposition (ALD) enabled sculpting of pore entrances with 0.1-nm resolution and ~4-nm depth, creating ultrathin nanoporous membranes (*JACS '06*)

Membrane platforms based on EISA nanoporous films modified by ALD

Template removal from ultra-thin hybrid ALD membrane resulted in high flux membrane with He/N_2 selectivity exceeding 10^3 (*JACS '07*)



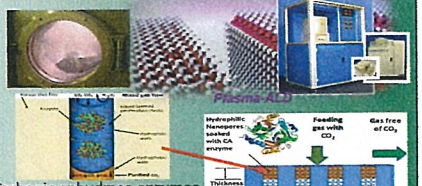
ALD modification of freely suspended membrane composed of 'kinked' nanopores resulted in separation of ss and dsDNA and single channel recordings of DNA translocation (*Nature mater '10*)



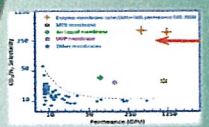
(*Nature nano '10*)

Creation of ultra-thin superhydrophilic proton exchange membrane resulted in proton conductivities 100-1000X greater than Nafion at low humidity

Plasma-Assisted ALD membrane technology transferred to Angstrom Thin Film LLC



Carbonic anhydrase enzymes stabilized within ultra-thin hydrophilic membrane



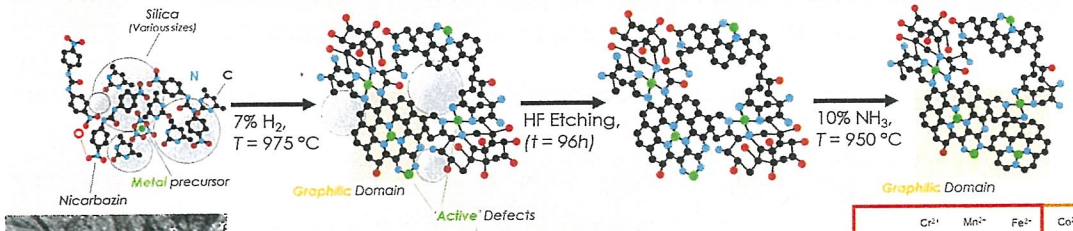
Combined CO_2 permeance and CO_2/N_2 selectivity meet for the first time the DOE standard for CO_2 sequestration

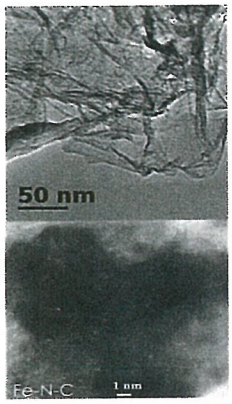
2015 R&D 100 WINNER — First R&D 100 Gold Medal for Green Technology

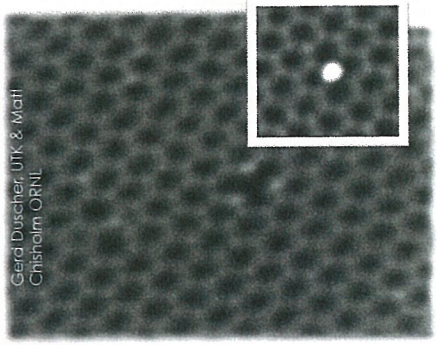
CO_2 Electro-reduction to CO

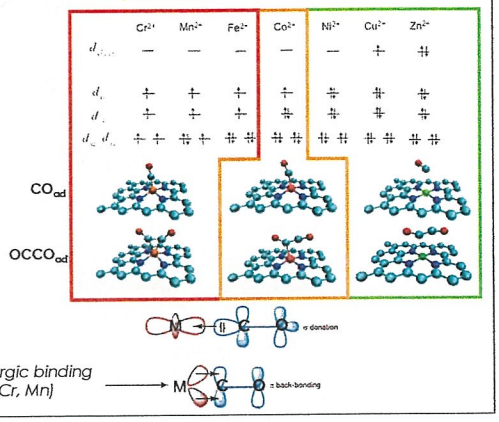
Plamen Atanassov, Center for Micro-Engineered Materials

2nd pyrolysis
(increase graphitic content, decrease oxide content and leads to the active sites diffusion to the surface)





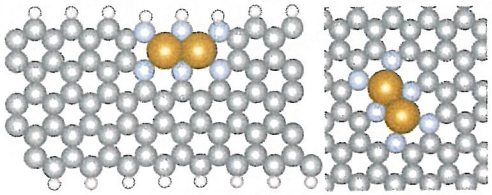




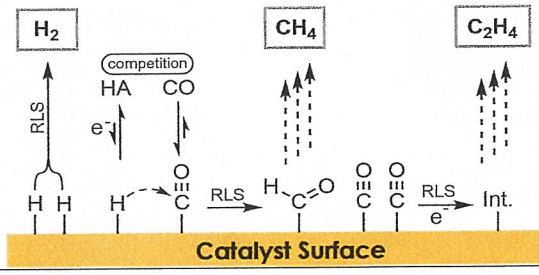
CO_2 Valorization to Chemical and Fuels

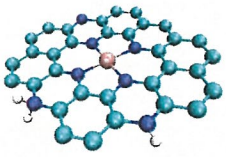
Outlook

- **Co** is the best electrocatalyst for the **HER** and **CO_2RR** + ability to reduce CO to C_1 alcohols.
- **Ni** present a high activity for CO_2RR + weak CO_{ad} binding, high selectivity.
- **Fe**, **Mn** and **Cr** present high activity for **CO_2RR** + strong CO_{ad} binding (**Cr** also stabilize C adsorbed species).



Synthesis of a dual metal site
- *Higher metal loading.*
- *Mono (**Co**) or Bi (**Fe-Ni, Fe-Cr**) electrocatalysts.*





Theoretical questions
- *Can C – C bond be formed on a single M atom ?*
- *Can a second site be a N – containing moiety ?*

Detecting, characterizing and repairing leaky wellbores for geologic CO_2 sequestration

John Stormont and Mahmoud Reda Taha

Sandia National Laboratories

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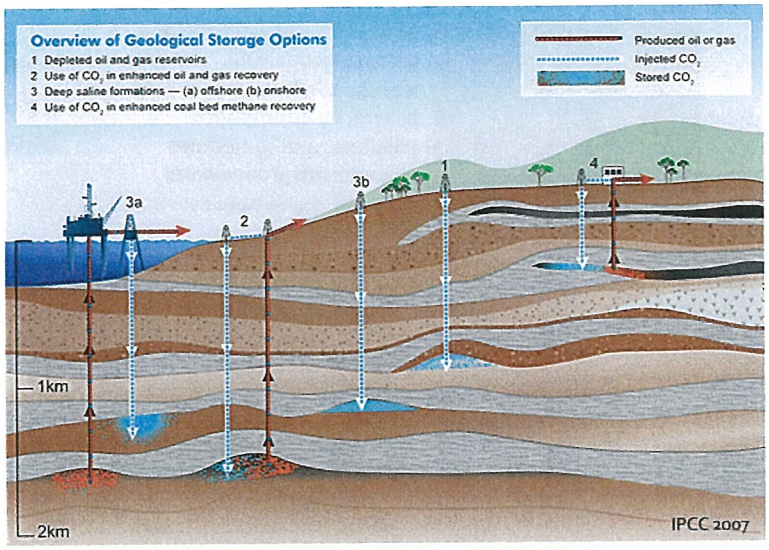
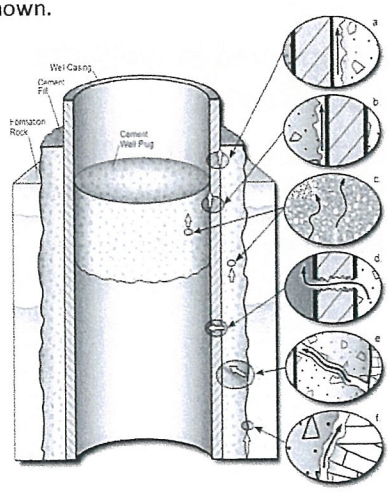


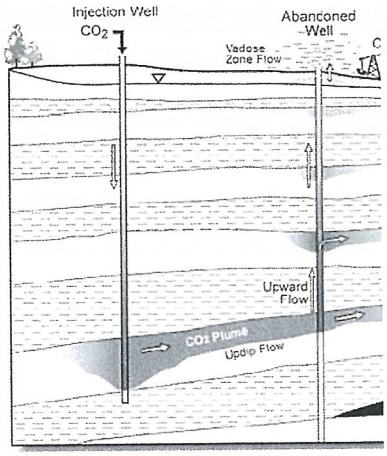
Wellbores can and do leak!

Schematic of wellbore consisting of steel casing surrounded by cement. Typical leakage paths are shown.

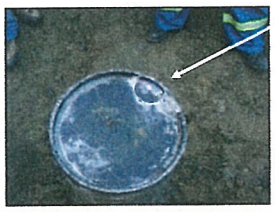


from Gasda et al., 2008

There are typically numerous wellbores associated with a CO_2 sequestration facility. Leakage from these wellbores significantly reduces the functionality of these facilities.



Most evidence for wellbore leakage comes from oil and gas wells



Gas bubbles at wellhead of a gas production well. This gas leakage can be a surface safety hazard, an atmospheric pollutant, and sometimes contaminate groundwater supplies. Source: Watson and Bachu, 2009.

Somewhere between 1 to 15% of all oil and gas wells have this issue.

Leakage can be catastrophic

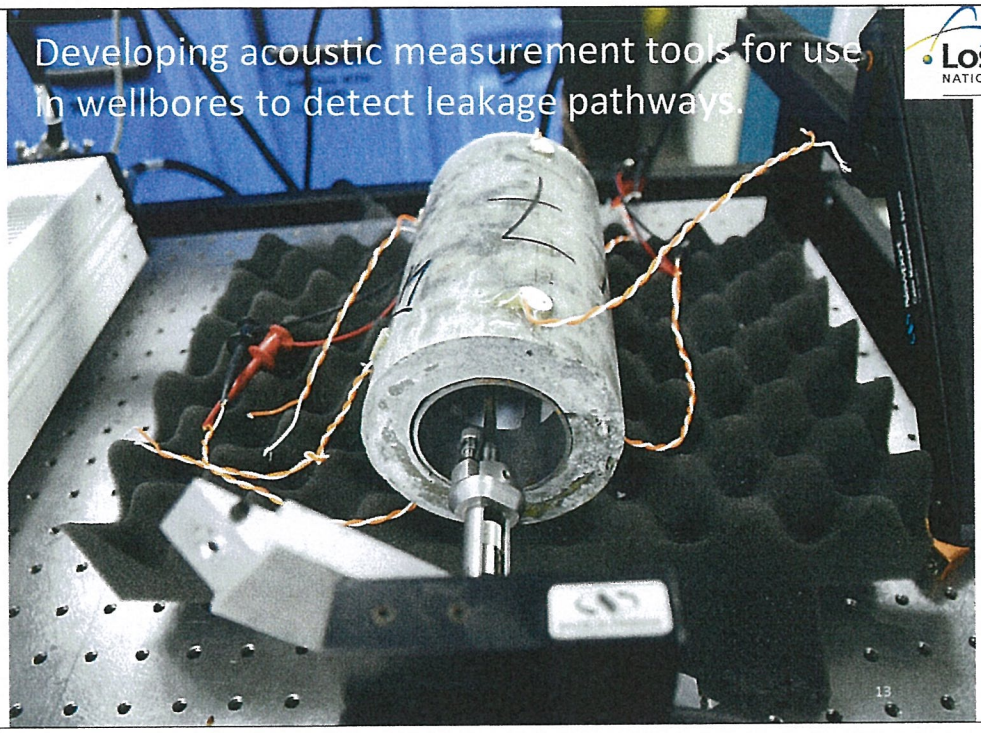
Aliso Canyon, CA. Wellbore leakage from an underground storage facility released more than half as much greenhouse gas as the entire State of California in a year. Source: PBS.org

11from PBS.org

UNM is conducting research to **improve wellbore integrity** for CO_2 sequestration applications.

- **Detecting leakage pathways** by developing improved in-wellbore acoustic measurements to detect fractures and flaws.
- **Characterizing leakage pathways** by measuring flow in novel experiments through wellbore systems under realistic conditions .
- **Remediating leakage pathways** by developing special repair materials that can penetrate and seal very small fractures and survive in downhole conditions.

Developing acoustic measurement tools for use in wellbores to detect leakage pathways.



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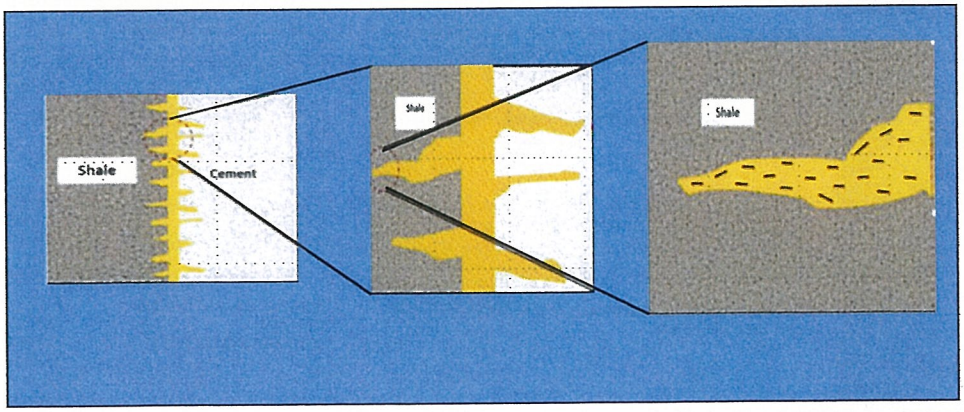
By adding special nanomaterials to cementitious materials, we can **improve the acoustic contrast of wellbore cements** to make it easier to detect leakage pathways.

Sandia National Laboratories



Patent application #62/489,829

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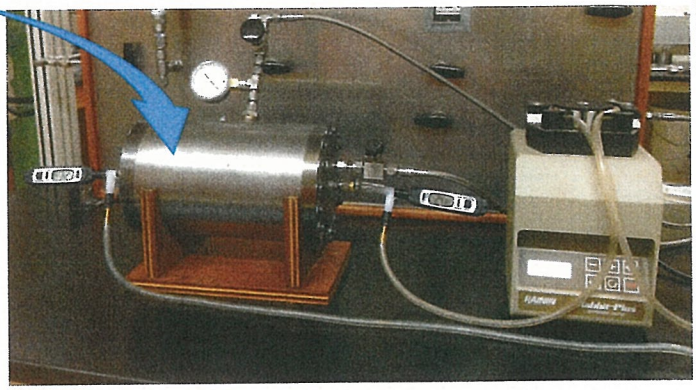
Measure flow through damaged wellbore specimens under varying stress and temperature conditions.

Sandia National Laboratories

We first create wellbore samples (cement sheath on steel casing) includes typical small flaws that allow flow under field conditions.

We then place the samples in a special pressure vessel and measure fluid flow through the sample while samples exposed to stress and temperature conditions expected in the field.



RESEARCH

Understanding the effects of rising CO_2 on climate change and the environment.

*Project Title	Funding Agency, Award Dollars, & Project Period	Principal Investigator & Collaborations
Sevilleta (SEV) Long-Term Ecological Research (LTER): Climate Variability at Dryland Ecotones Predicting ecological futures of drylands as a consequence of climate change	National Science Foundation $6,432,997 7/15/2018-12/31/2023	Jennifer Rudgers
Quantifying the effects of species range shifts and management of post-fire recovery on regional carbon dynamics in a changing climate	US Dept of Agriculture $850,000 7/1/2017-6/30/2020	Matthew Hurteau
Collaborative Research: Partnership for Geoscience Education and Research, Watershed Science and Climate Change in the Southwestern United States	National Science Foundation $799,939 10/1/2016-9/30/2021	Mark Stone Collaborations with Southwestern Indian Polytechnic Institute
Central New Mexico Climate Change Scenario Planning Project	Department of Transportation Ecosystems Management, Inc. $103,869 3/24/2014-12/31/2014	Greg Rowangould
Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands: From characterization to solutions	**US Dept. of Agriculture 335,000 03/01/2015-02/29/2020	David Gutzler Collaboration with University of Texas at El Paso **UNM is the subawardee
Collaborative Research: Responses of Endotherms to Rapid Recent Climate Change	National Science Foundation $231,400 09/0102015-08/31/2019	Blair Wolf Collaborations with San Diego Society of Natural History, University of California-Berkley, University of California – Santa Cruz

*Selected research projects at UNM