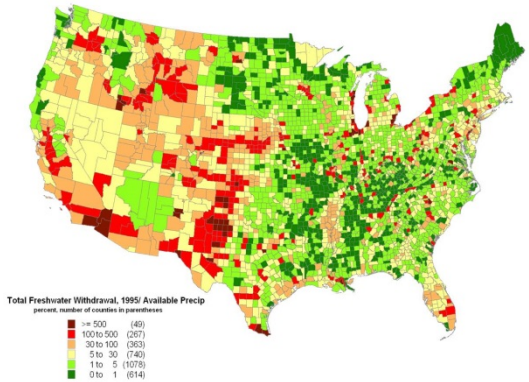
SAND2017-5500PE

Exceptional service in the national interest

Sandia National Laboratories



Sandia Water Treatment & Desalination Research, Development & Demonstration

Susan J. Altman, Ph. D.
Manager, Geochemistry Department

May 23, 2017

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525

water.sandia.gov

Sandia National Laboratories

Energy & Climate

Secure & Sustainable Energy Future

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Stationary Power | Climate & Earth Systems | Transportation Energy | Energy Research | About EC

R&D 100

THE FRANZ EDELMAN AWARD
Achievement in Operations Research

COIN|OR
COMPUTATIONAL INFRASTRUCTURE FOR OPERATIONS RESEARCH

FLC
Federal Laboratory Consortium for Technology Transfer

Decision Modeling and Analysis | Energy and Water program

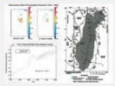
Sandia National Laboratories

Contact: Stephanie Kuzio
Energy & Water Program Manager
spkuzio@sandia.gov

2001-2003 — Middle Rio Grande Regional Water Planning Model

2002 — Middle Rio Grande EIS Support

2004-2006 — Water Management Toolbox



2005 — Borders as Membranes

2005-2007 — Modeling the Gila-San Francisco Basin

2006-present — Upper Rio Grande Simulation Model

2005-2006 — Water Quality Monitoring in the Jordan River Valley

2007 — Libyan Workshop

2007 — Water Resources Decision Making

2007 — Algae Testbed Project

2007 — New Mexico Dairy Project

2009 — Study of the Willamette Basin, Oregon

2010 — State-wide Climate Study through 2050

2011-2014 — Hydropower Optimization

20011-2014 — Model for Geothermal Energy Development

2013 — Spatially Variant Process Models

2014-present — Energy Water in the Eastern Interconnect

2015 — Climate Change Impacts in the Southeast US

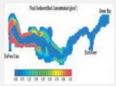
2015-2016 — Water Atlas

2000 | 2005 | 2010 | 2015 | Present

2001-2010 — NMSBA Projects Providing Technical Support to New Mexico Small Businesses

2001-2008 — Water Quality Monitoring in Central Asia

2002 — Evaluation of Contaminants in Rivers



2003-2005 — Tool to Evaluate Sediment Transport in Western Streams and Rivers

2005-2006 — Water Resource Management for the Rio Grande

2005 — Global Water Futures

2006 — Rainey River Basin Project

2007 — Water Leasing Market Design for Mimbres River

2007 — Nambe Pueblo Project

2007-2008 — Model for Iraqi Water Planners

2008 — Algae Biofuels Project

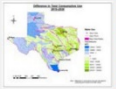
2008 — Sandia-GM Biofuel Deployment Model

2010-2014 — Energy-Water Planning in the Western and Texas Interconnections

2010 — Algae Biofuels Technology Roadmap

2011-2013 — WECSim Model

2012-2013 — ERCOT Climate Study



2012 — Upper Rio Hondo Water Availability Model

2014-2016 — High Plains Aquifer Analysis

2014-present — SWaRMS Regional Partnership

2014 — National Climate Assessment Energy-Water-Land Chapter

2015 — Water Consumption for Energy Production Around the Pacific Rim

2016-2017 — Water Sustainability in the Permian Basin Region of New Mexico

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Sandia Water Security Software

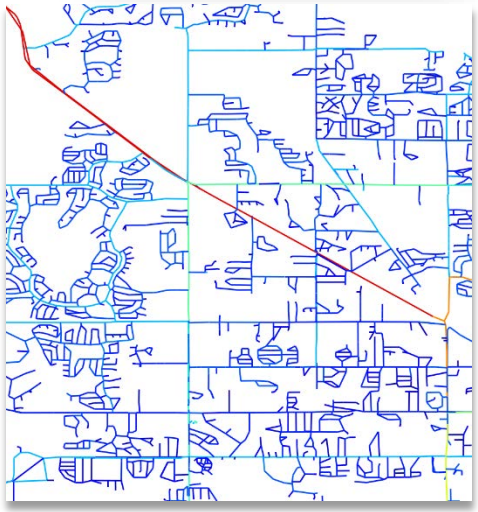
Sandia has developed a wide range of simulation and optimization software tools to improve security and resilience of water distribution networks. These tools include:

SPOT – Sensor placement optimization tool

Optimize sensor placement locations in the network to minimize impact. (2008 Edelman Prize, 2008 COIN-OR Cup, used to place sensor in 4 US cities)

CANARY – Real time event detection

Event detection algorithms for online sensors, alerts water utilities if water quality becomes anomalous. (2010 R&D100 Award, running at Metropolitan Water District of Southern California, and on the Singapore national system)



WNTR – Water Network Tool for Resilience

Simulate and analyze water distribution networks under disaster scenarios. (Release October 2016 on the USEPA GitHub site)

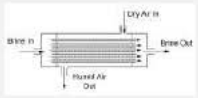
Sandia National Laboratories

Sandia has been actively working in a broad range of water treatment technical challenges for over a decade

2000 — ADVANCED CONCEPTS WATER-TREATMENT PROGRAM BEGINS

2001 — DESALINATION TECHNOLOGY ROADMAPS

2002 — DEVELOPMENT OF SWEEPING GAS MEMBRANE DESALINATION USING COMMERCIAL HYDROPHOBIC HOLLOW FIBER MEMBRANES

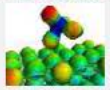


For more information contact:

Susan J. Altman, Ph.D.
Geochemistry Department
sjaltma@sandia.gov

2003 — ARSENIC WATER TECHNOLOGY PARTNERSHIPS FORMS

2004 — DEVELOPMENT OF NOVEL ARSENIC TREATMENT APPROACHES



2005 — FRONTIERS OF INTERFACIAL WATER RESEARCH WORKSHOP

ARSENIC PILOT DEMONSTRATION PROJECTS

UV ULTRAVIOLET WATER PURIFICATION SYSTEMS FOR RURAL ENVIRONMENTS AND MOBILE APPLICATIONS

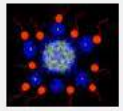
2006 — JOINT WATER REUSE & DESALINATION TASK FORCE

WATEREUSE

METHOD FOR SYNTHESIZING LAYERED DOUBLE HYDROXIDE CAPABLE OF SORBING ANIONIC AND IONIC CONTAMINANTS FROM FLUID

2007 — PRODUCED WATER PILOT SAN JUAN BASIN

CAPACITIVE IONIZATION FOR COAL-BED NATURAL GAS PRODUCED WATER



PATENT FOR NEXT-GEN COAGULENT FOR THE REMOVAL OF BACTERIA AND VIRUSES

2008 — COMMERCIALIZATION OF ZERO LIQUID DISCHARGE PROCESS FOR BRACKISH WATER DESALINATION

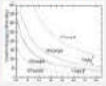
BRACKISH GROUNDWATER NATIONAL DESALINATION RESEARCH FACILITY

2009 — IMPLEMENTATION OF THE NATIONAL DESALINATION AND WATER PURIFICATION TECHNOLOGY ROADMAP

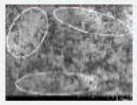
EXPLOITING INTERFACIAL WATER PROPERTIES FOR DESALINATION & WATER PURIFICATION APPLICATIONS

2010 — MEMBRANES & SURFACES NANO-ENGINEERED FOR PATHOGEN CAPTURE & DESTRUCTION

LOW COST ARSENIC TREATMENT SYSTEM FOR SMALL COMMUNITIES



SELF-SEALING EVAPORATIVE POND LINER



BIOMIMETIC MEMBRANE R&D 100 AWARD

MEMBRANE DISTILLATION WATER TREATMENT USING POWER PLANT WASTE HEAT

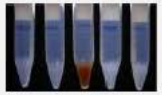
2011 — MICRO-MIXERS FOR MITIGATING MEMBRANE FOULING

NOVEL SILICA REMOVAL STRATEGIES BY WARM LIME SOFTENING

BIO-FOULING RESISTANT CERAGENIN-MODIFIED WATER TREATMENT MEMBRANES

MEMBRANE TREATMENT OF SIDE-STREAM COOLING TOWER FOR REDUCTION OF WATER REUSAGE

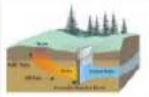
2012 — CRYSTALLINE SILICOTITANATES FOR RADIOACTIVE CESIUM REMEDIATION



COAGULATION CHEMISTRIES FOR SILICA REMOVAL FROM COOLING TOWER WATER

2013 — PATENT ON METHOD FOR RECOVERING ALKALI METALS

APATITE PERMEABLE REACTIVE BARRIERS FOR IN SITU REMEDIATION OF URANIUM IN SUBSURFACE OF UMTRA SITE



2014 — USE OF FLUE GAS TO CONTROL SILICA AND CALCITE SCALE IN COOLING TOWERS

NMSBA

MEMBRANE DISTILLATION PROJECT FOR SMALL NEW MEXICO BUSINESS

2015 — WASTE WATER FOR POWER GENERATION VIA ENERGY EFFICIENT SELECTIVE SILICA SEPARATIONS

GRAPHENE OXIDE/POLYMER MEMBRANES

2016

U.S. DEPARTMENT OF ENERGY | NNSA

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Sandia National Laboratories

Sandia has been active … water treatment technical challenges for over a decade

ADVANCED CONCEPTS WATER-TREATMENT PROGRAM BEGINS

DESALINATION TECHNOLOGY ROADMAPS

DESALINATION AND WATER PURIFICATION TECHNOLOGY ROADMAP

A REPORT OF THE EXECUTIVE COMMITTEE

Discussion Facilitated by Sandia National Laboratories and the U.S. Department of Interior, Bureau of Reclamation

Desalination & Water Purification Research & Development Program Report #95

Sandia National Laboratories

…OMMERCIALIZATION …F ZERO LIQUID …SCHARGE PROCESS …OR BRACKISH …ATER …ESALINATION

…RACKISH …ROUNDWATER …ATIONAL …ESALINATION …ESEARCH FACILITY

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SELF-SEALING …

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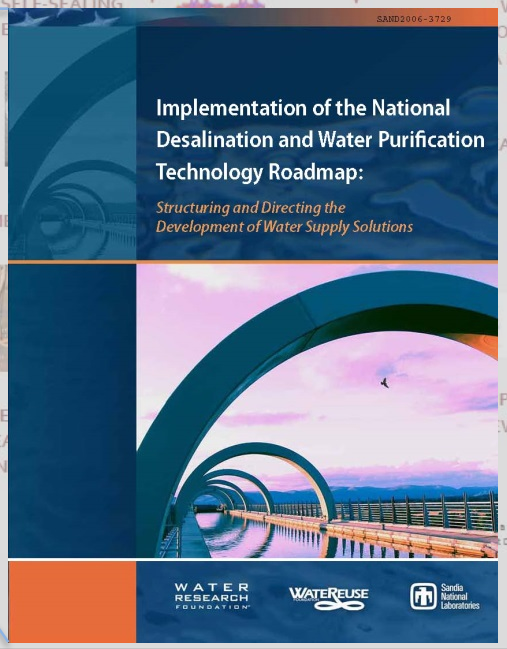
…PROJECT …W MEXICO



U.S. DEPARTMENT OF ENERGY NNSA

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Roadmapping

Efforts to Accelerate Brackish Water Desalination Technology Development

Sandia National Laboratories

Brackish Groundwater National Desalination Research Facility (BGNDRF) Alamogordo, NM

- Led effort with Bureau of Reclamation on a Report to Congress for the conceptual design of a national brackish water desalination research facility - 2003
- Supported BOR on final design, construction, and operation - 2004 - 2009

Clients:

UTEP
NM State University
Texas Tech
Atlantis Technologies
Cost-effective Wastewater Desalination
GE
OASYS WATER
University of Nevada, Reno
VEOLIA
Voltea
LG
LG WATER STANDARD
A global water solution in partnership with nature

Fundamental Research

Sandia National Laboratories

road range of water treatment technical challenges for over a decade

JOINT WATER REUSE & DESALINATION TASK FORCE

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CAPACITIVE IONIZATION FOR COAL-BED

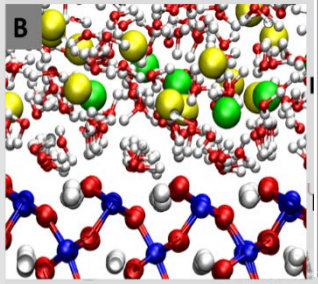
IMPLEMENTATION

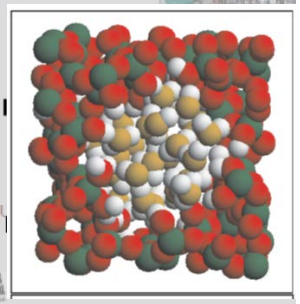
EXPLOITING INTERFACIAL WATER PROPERTIES FOR DESALINATION & WATER PURIFICATION APPLICATIONS

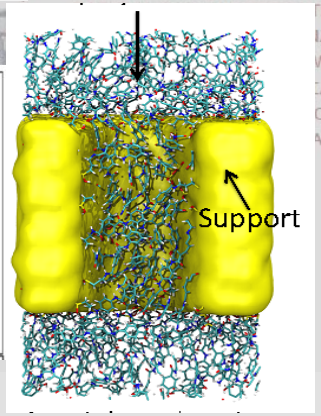
SELF-SE EVAPOR POND

BIOM MEMBRAN 100 A

MEMBRANE DISTILL WATER TREATMENT POWER PLANT WAST







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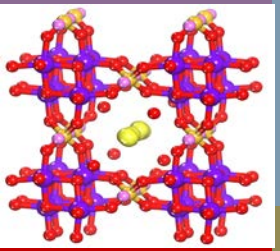
Sandia Designer Sorbents 1993-2016

Sandia National Laboratories

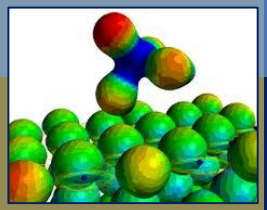
1993

Target: Cs^+
Sorbent: Crystalline-silico Titanate
Application: Radwaste Separations



1996

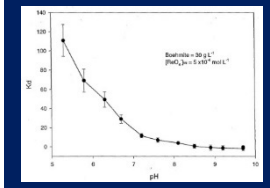
Target: I^-
Sorbent: HgS, Cu_2S, Bi-doped Clays
Application: Radwaste Backfills / Separations



1998

Target: T_CO4^-
Sorbent: AlOOH, Ca-phosphates
Application: Radwaste Backfills / Separations

Target: Sr^{++}
Sorbent: CST, Ca-Phosphates, Calcite
Application: Radwaste Backfills / Separations

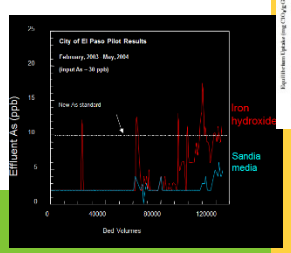


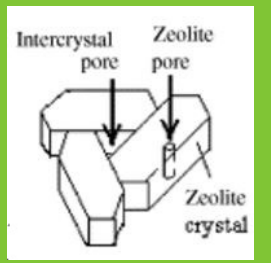
2004

Target: As(V)
Sorbent: Spinels, MgO
Application: Drinking Water

Target: Salts
Sorbent: Zeolites
Application: Desalination

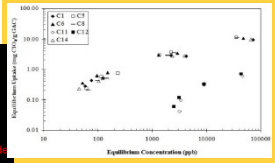
Target: Cr(VI)
Sorbent: Spinels
Application: Drinking Water





2005

Target: ClO_4^-
Sorbent: Metal-doped GACs
Application: Drinking Water

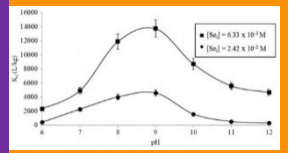


2009

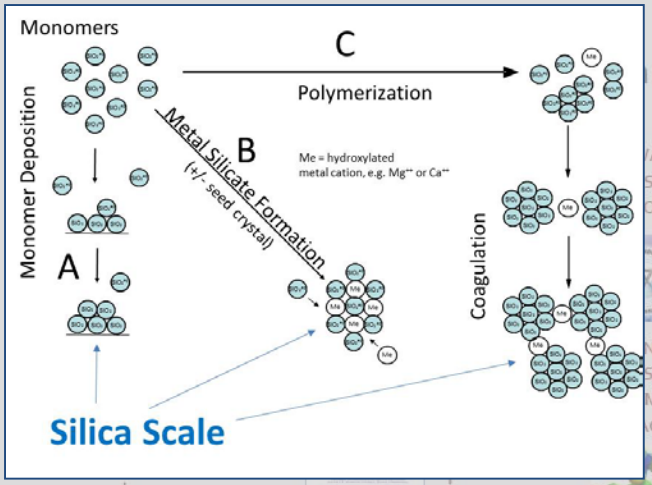
Target: Silica
Sorbent: Metal-Silicates, Catechol
Application: Industrial Water Treatment

2016

Target: Selenium
Sorbent: Ca-Phosphates
Application: Groundwater Clean-up



Silica Removal



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a broad … chnical challenges for over a decade

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

CAPABLE OF SORBING ANIONIC AND IONIC CONTAMINANTS FROM FLUID

DESALINATION RESEARCH FACILITY

SMALL COMMUNITIES

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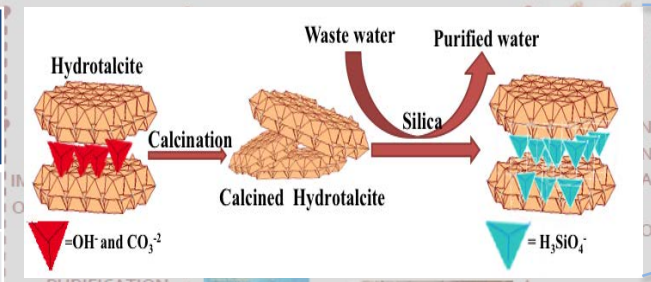
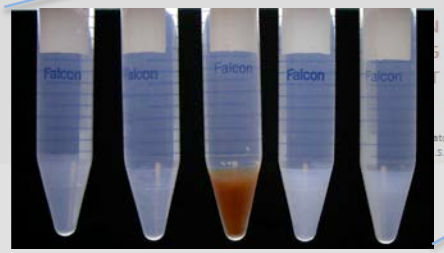
Silica: Chloride Ratio	% Silica Removed		Silica: Sulfate Ratio	% Silica Removed
1:1	99.0		1:1	99.0
1:5	98.8		1:5	97.0
1:10	98.5		1:10	95.8
1:15	97.9		1:15	95.2
1:20	97.6		1:20	94.8

ENVIRONMENTS AND MOBILE APPLICATIONS

THE REMOVAL OF BACTERIA AND VIRUSES



PURIFICATION TECHNOLOGY ROADMAP



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Mitigation of Biofouling

Sandia National Laboratories

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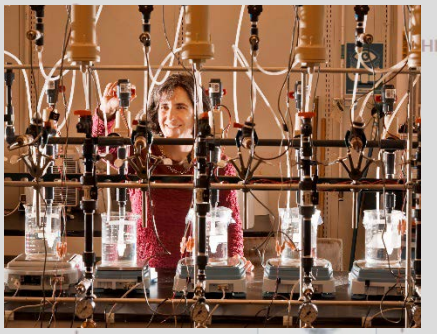

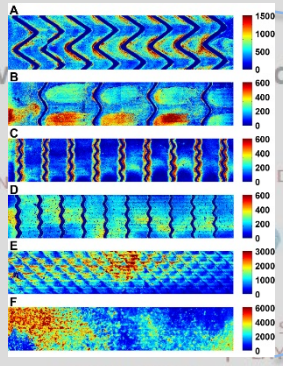

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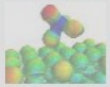
WATEREUSE

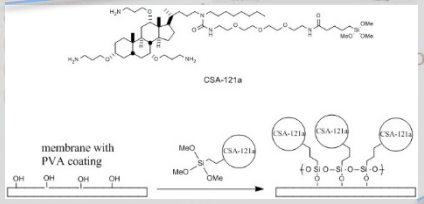
NOVEL ARSENIC TREATMENT APPROACHES



METHOD FOR SYNTHESIZING …VERED DOUBLE HYDROXIDE CAPABLE OF SORBING ANIONIC AND IONIC CONTAMINANTS FROM FLUID

COMMERCIALIZATION OF ZERO LIQUID DISCHARGE PROCESS FOR BRACKISH WATER DESALINATION

BRACKISH



MEMBRANES & SURFACES NANO-ENGINEERED FOR PATHOGEN CAPTURE & DESTRUCTION

MICRO-MIXERS FOR MITIGATING MEMBRANE FOULING

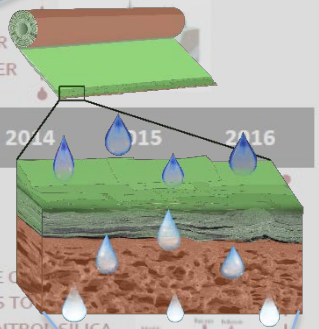
NOVEL SILICA REMOVAL STRATEGIES BY WARM LIME SOFTENING

BIOFOULING RESISTANT CERAGENIN-MODIFIED WATER TREATMENT MEMBRANES

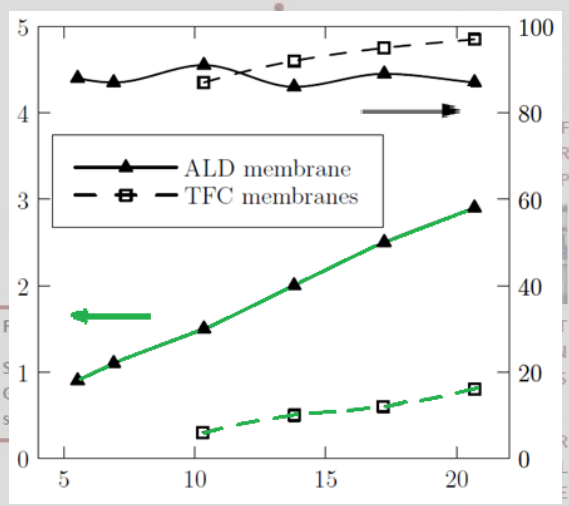
MEMBRANE TREATMENT OF SIDE-STREAM COOLING TOWER FOR REDUCTION OF WATER REUSAGE

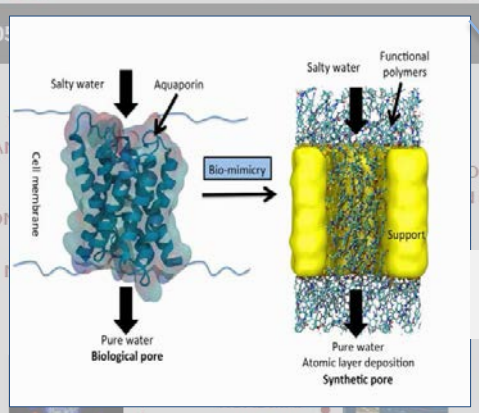
PATENT ON METHOD FOR RECOVERING ALKALI METALS

APATITE PERMEABLE REACTIVE BARRIERS FOR IN SITU REMEDIATION OF URANIUM IN SUBSURFACE OF UMTRA SITE

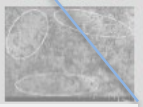


2000 2001 2002 2003 2004 2005 2010 2011 2012 2013 2014 2015 2016





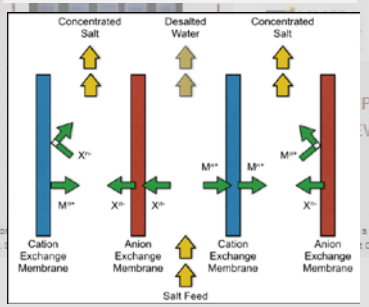
SELF-SEALING EVAPORATIVE POND LINER



CRYSTALLINE SILICOTITANATES FOR RADIOACTIVE

BIOMIMETIC MEMBRANE R&D 100 AWARD

Bio-inspired Ion-Selective ED Membranes



GRAPHENE OXIDE/POLYMER MEMBRANES

PROJECT …W MEXICO

PATENT FOR

R&D 100

MEMBRANE DISTILLATION WATER TREATMENT USING POWER PLANT WASTE HEAT

APPLICATIONS

U.S. DEPARTMENT OF ENERGY NNSA

Sandia National Laboratories is a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. … DE-AC04-94AL-8500 SAND2016-12525 M

Bio-Inspired Membranes

Pilot Testing

Sandia has been actively working in a broad range of w

Sandia National Laboratories

lenges for over a decade

LOW COST ARSENTIC TRATMENT FOR SMALL COMMUNITIES

MEMBRANE TREATMENT OF SIDE-STREAM COOLING TOWER WATER FOR REDUCTION OF WATER USAGE

ADVANCED CONCEPTS WATER-TREATMENT PROGRAM BEGINS

ARSENIC WATER TECHNOLOGY PARTNERSHIPS FORMS

JOINT WATER REUSE & DESALINATION TASK FORCE

WATEREUSE

METHOD FOR SYNTHESIZING AYERED DOUBLE HYDROXIDE CAPABLE OF ORBING ANIONIC AND IONIC CONTAMINANTS FROM FLUID

BRACKISH GROUNDWATER NATIONAL DESALINATION RESEARCH FACILITY

O-MIXERS FOR GATING BRANE FOULING

EL SILICA REMOVAL TEGIES BY WARM SOFTENING

FOULING RESISTANT CERAGENIN-MODIFIED WATER TREATMENT MEMBRANES

PATENT ON METHOD FOR RECOVERING ALKALI METALS

APATITE PERMEABLE REACTIVE BARRIERS FOR IN SITU REMEDIATION OF URANIUM IN SUBSURFACE OF UMTRA SITE

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

DEVELOPMENT OF SWEEPING GAS MEMBRANE DESALINATION USING COMMERCIAL HYDROPHOBIC HOLLOW FIBER MEMBRANES

FRONTIERS OF INTERFACIAL WATER RESEARCH WORKSHOP

ARSENIC PILOT DEMONSTRATION PROJECTS

V ULTRAVIOLET WATER N SYSTEMS FOR RURAL ONMENTS AND MOBILE APPLICATIONS

PRODUCED WATER PILOT SAN JUAN BASIN

CAPACITIVE IONIZATION FOR COAL-BED NATURAL GAS PRODUCED WATER

PAT N COAGUL THE REM BACTE

EXPLOITING

ROADMAP

SELF-SEALING EVAPORATIVE LINER

IMETIC NE R&D AWARD

CRYSTALLINE SILICOTITANATES FOR RADIOACTIVE CESIUM REMEDIATION

USE OF FLU GAS TO CONTROL SILICA AND CALCITE SCALE IN COOLING TOWERS

MEMBRANE

COAGULATION

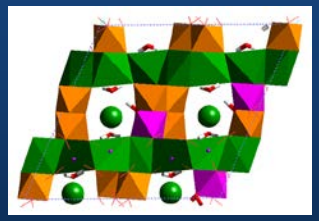
WASTE WATER FOR POWER GENERATION VIA ENERGY EFFICIENT SELECTIVE SILICA SEPARATIONS

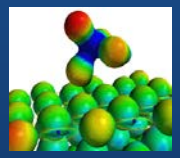
GRAPHENE OXIDE/POLYMER MEMBRANES

We Manage the Life-Cycle of our Technology

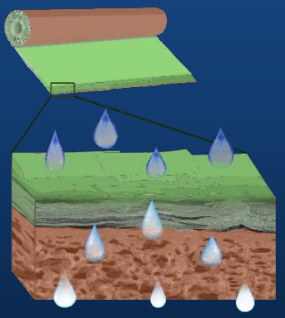
Sandia National Laboratories

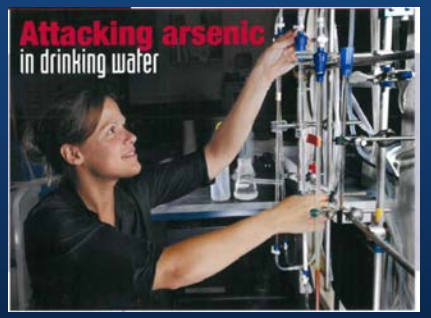
Research





Technology Development

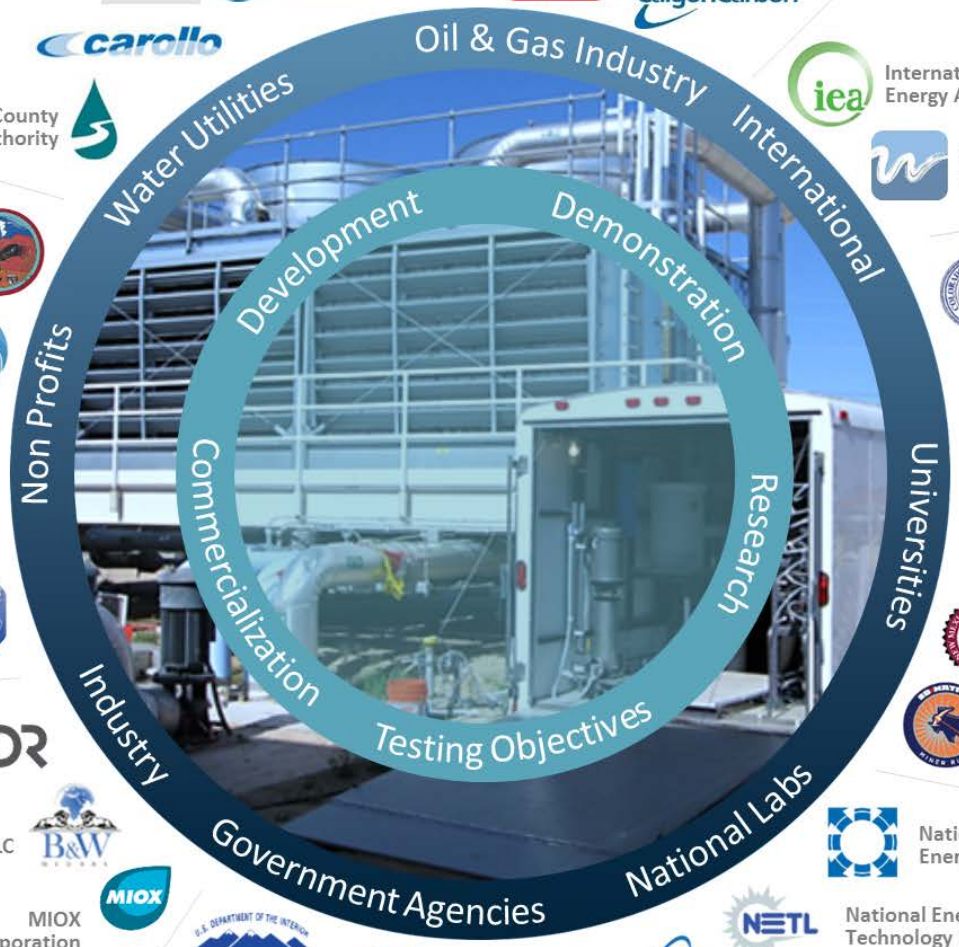




Commercialization

Pilot Programs

Sandia Water Treatment Partnerships: Past and Present



TROJAN technologies
el paso WATER
Imperial Oil
uop A Honeywell Company
conoco
CalgonCarbon
carollo
ABQ Bernalillo County Water Utility Authority
Jemez Pueblo
WateReuse Foundation
Water Research Foundation
Electric Power Research Institute EPRI
Brackish Groundwater National Desalination Research Facility
HDR Engineering
B&W Global Tech LLC
MIOX Corporation
Sandia National Laboratories
U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration
Bureau of Reclamation
Environmental Protection Agency
Los Alamos National Laboratory
NETL National Energy Technology Laboratory
National Renewable Energy Laboratory
UT El Paso
New Mexico State
University of New Mexico
New Mexico Tech
University of Illinois Affordable Desalination Coalition
Colorado School of Mines
Water Education Foundation
iea International Energy Agency

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Technology Management Optimization (TMO)

Sandia National Laboratories

Background

- Sandia has experience informing long-range investments for technologically sophisticated, complex systems
- Advanced modeling to establish more detailed decision support capabilities began in 2008 with a focus to:
  - cover large trade-spaces with complex interactions
  - address multiple performance considerations and metrics
- Applications include: system design, trade space analysis, investment planning, enterprise planning, and requirements analysis
- Customers include the U.S. Army, Department of Energy, Sandia weapons programs, and Sandia facilities
- Incrementally funded by Lockheed Martin, the U.S. Army, and Sandia

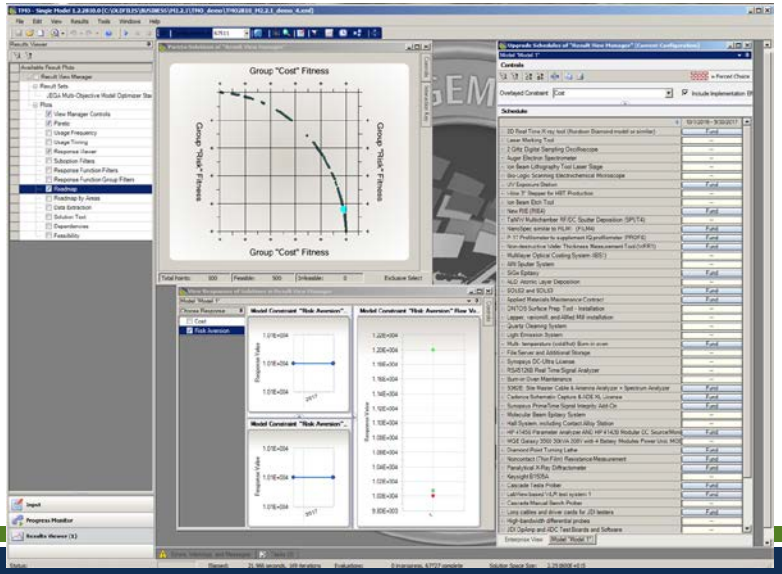
Approach

- TMO computes optimal future courses of action and investment planning roadmaps
- TMO help inform decision makers of the best tradeoffs in a decision space
  - What investments should be made (or what activities should be conducted) and when
- TMO is designed to address:
  - Large-scale or architecturally complex systems
  - Multiple competing objectives and constraints (budget, efficiency, effectiveness, reliability, …)
  - Parametric and time-dependent uncertainty/risk
  - Dependencies between alternative actions
  - Multiple option spaces (replacement, upgrade, redesign, inaction)

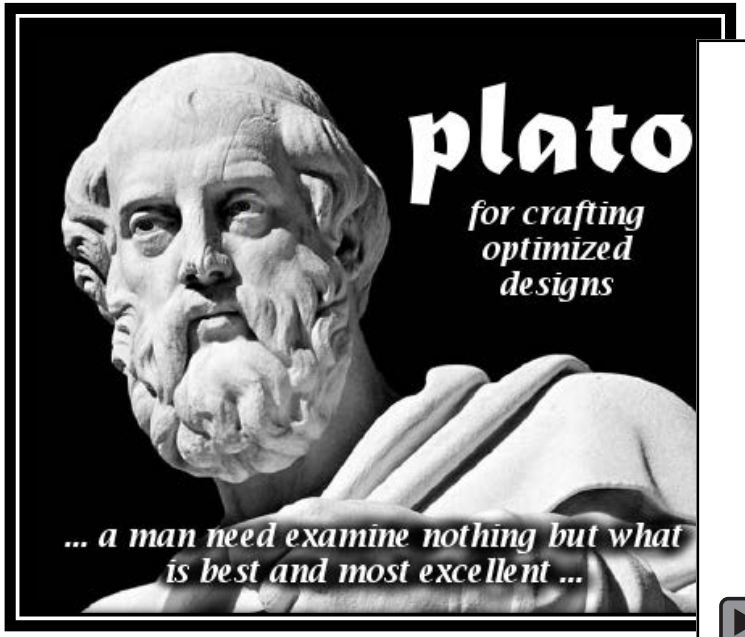
Examples

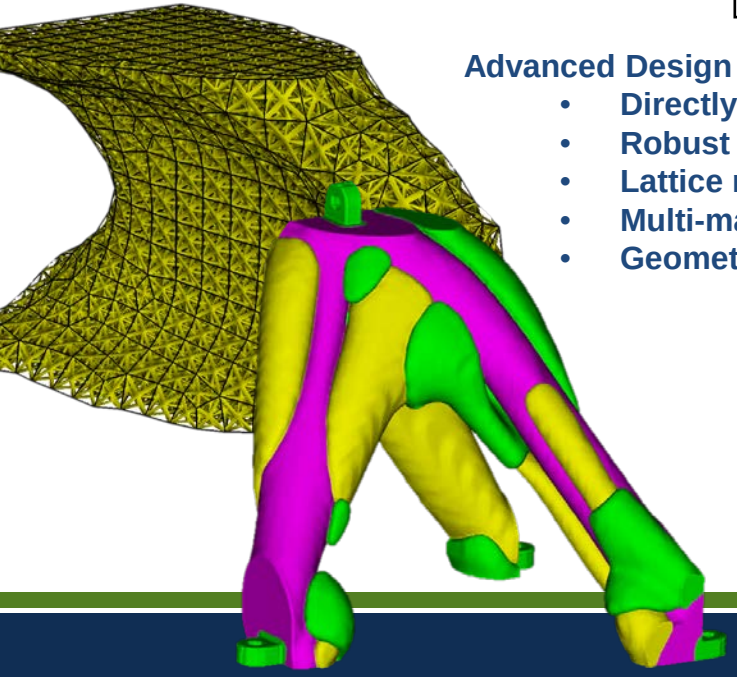
- Investment selections for Sandia's MESA fabrication facility with goal of achieving long range strategic performance objectives
- Requirements Assessments for US Army Ground Combat Systems (GCV)
- Demonstrated incompatible requirement set that suggested cancellation of programs and saved US gov't several billion dollars
- Currently being used to assess distributed energy resource investments in rural Alaskan villages, with goal of reducing diesel usage by 50%
- Investment selections for several weapons in the US arsenal. Informed decisions for R&D for components and timing of life extension programs (LEPs)

Optimal Technology Roadmaps



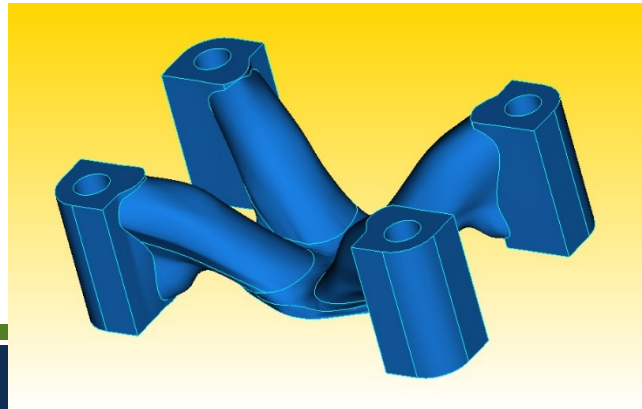
Generative Designs for Additive Manufacturing





Advanced Design with Topology Optimization

- Directly printable shapes
- Robust designs with uncertainty
- Lattice metamaterial incorporation
- Multi-material optimizations
- Geometric Conversion to CAD

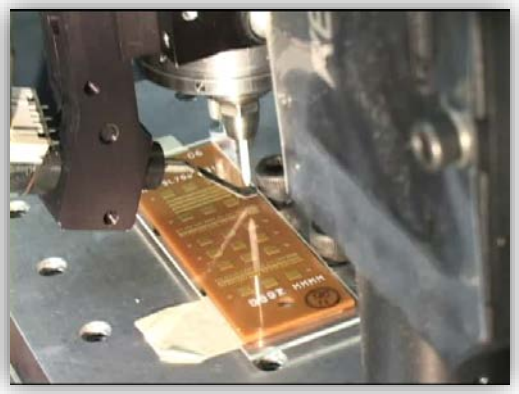


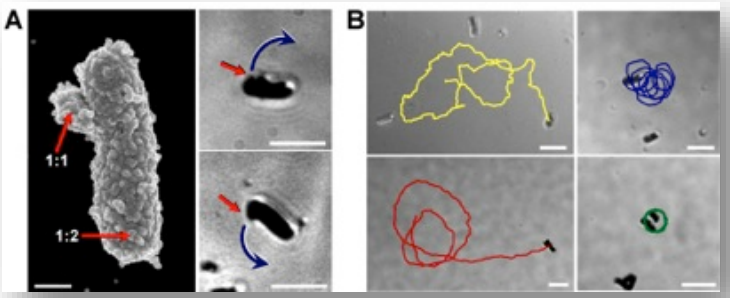
The AML has a wide range of capabilities important to Sandia's missions

Sandia National Laboratories

Synthetic Chemistry
- Novel inorganic precursors
- Catalysts
- Sol-gel
- Solvothermal
- Solution precipitation

Ceramic/glass processing
- science of sintering
- composite materials
- unique fabrication
- novel characterization





Nano-scale materials
- Nanoparticle synthesis (0D,1D,2D)
- Surface functionalization
- characterization

Bio-, Nano-materials capability
- BSL-2 Laboratory
- Surface functionalization

Characterization
- Diffractometry: SAXS, XRD, XPS
- Thermal (TGA, DSC)
- Spectroscopy (mass, FTIR, ICP)
- Multispectral ellipsometer

Materials processing
- Self- and directed-assembly
- Films (dip, spin coat)
- Fibers (electrospinning)
- Bulk materials (sintering)
- Multiphoton lithography
- Direct/aerosol write, inkjet
- Gravure/flexography