IUCRC

SOUTH DAKOTA MINES
An engineering, science and technology university

Syracuse University

Northeastern University

NSF Industry-University Collaborative Research Center (IUCRC)

Center for Solid-State Electric Power Storage (CEPS)

CEPS
IUCRC

NSF Model and CEPS Structure

- The IUCRC model was developed by NSF
- Centers have federal and international status
- Universities find investors to perform pre-competitive research jointly
- CEPS centers become self-sustainable in 10-15 years
- Memberships are defined by the NSF

THREE UNIVERSITIES
(CURRENT STATUS)

Syracuse

SD Mines

Northeastern

CEPS MEMBERS
INDUSTRY, NATIONAL LABS, & the GOVERNMENT

Matching funds: "Governor's Research Center for Electrochemical Energy Storage (2021-2026)

SD Mines

South Dakota State University

$3.9 M for 5 years w/o overhead

CEPS Management Team: Responsibilities and Expertise

Director Alla White Smirnova, SD Mines
- Overall management and technical supervision
- **Expertise:** Materials engineering, electrochemistry, energy storage

CEPS Managing Director
Dr. Serge Pann, NU
- Technology development and management, students' assistance
- Recruitment of industry partners

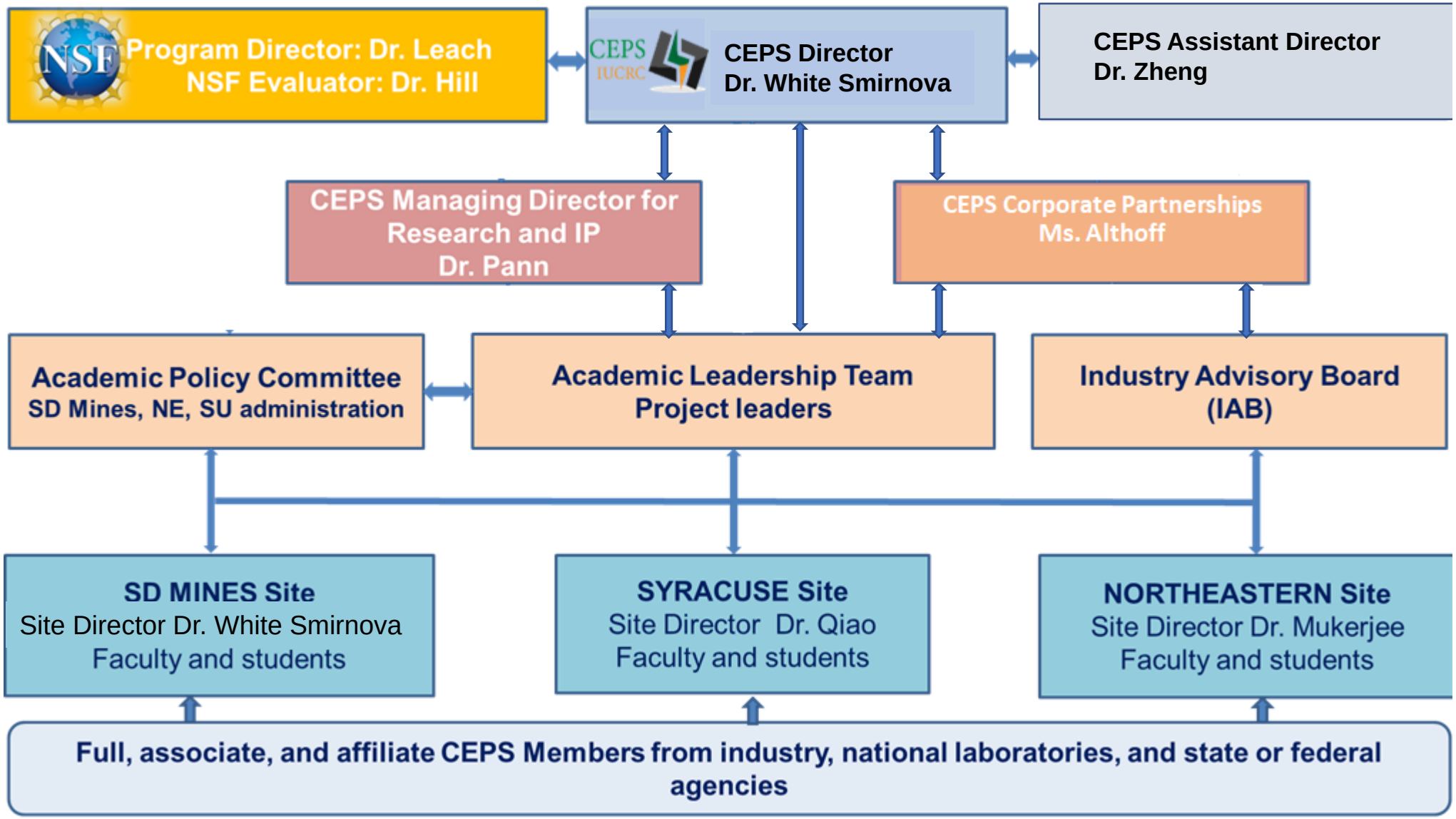
Site Director Sanjeev Mukerjee, NU
- Overall management and technical supervision at Northeastern Site
- **Expertise:** Catalysis, electrochemistry, fuel cells, and batteries

Assistant Director: Dr. Fan Zheng
- Technical assistance for GR and UG students at SD Mines
- **Expertise:** Electrospinning, sensors, photovoltaics, and batteries

Site Director Quinn Qiao, SU
- Overall management and technical supervision at Syracuse Site
- **Expertise:** Electrical and materials engineering, and battery system design

Website manager and IAB organizer
Pascal Britton
- Website and AirTable design
- Moderator for the IAB meetings

IUCRC CEPS Management

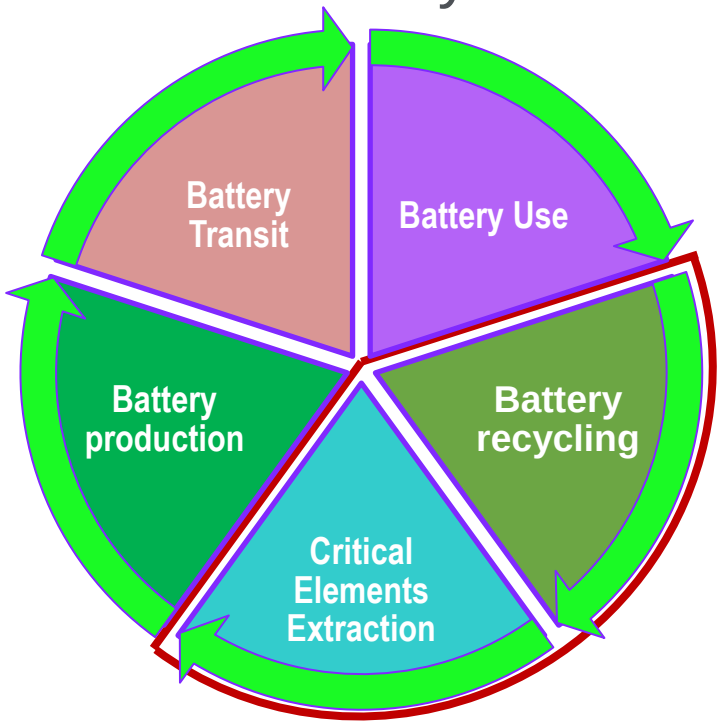


U.S. Energy Security Policy and Commitments

- Energy security is our goal
- We have oil and gas resources, but they are not sustainable in long term
- Climate change is another challenge
- Our goals:
  - Net-zero emissions by 2050
  - Net-zero power sector by 2035
- They require new energy storage technologies

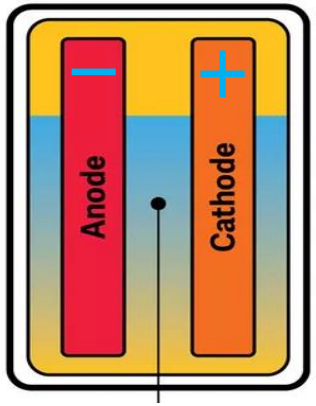
- Main challenge:
  - Supply chain for battery materials
- Major milestones in energy storage:
  - Critical elements
  - New materials engineering
  - Innovative additive manufacturing technologies
  - Workforce development

The concept of circular economy



DOE: "Energy Storage Grand Challenge"
https://www.energy.gov/energy-storage-grand-challenge/energy-storage-grand-challenge

CEPS focus: Next-generation solid-state energy storage

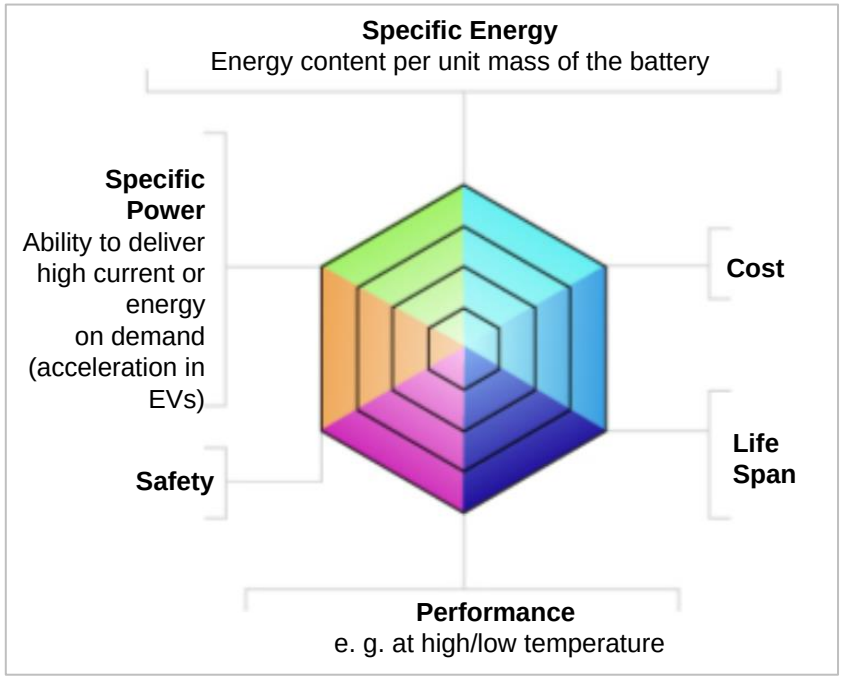


Liquid Electrolyte

- Conventional lithium-ion batteries reached the limit of their technological capabilities

- Solid-state lithium-ion battery is promising
- Comprise thin solid or polymer electrolytes
- Benefits:
  - Ultra-fast charge
  - Long-range
  - Long lifetime
  - Safe
  - Small and light
  - Highly efficient
  - Eco-friendly
  - Lithium metal anode
- They are close to commercialization

- There are still many problems to be solved
- Battery characteristics are different for different types of batteries

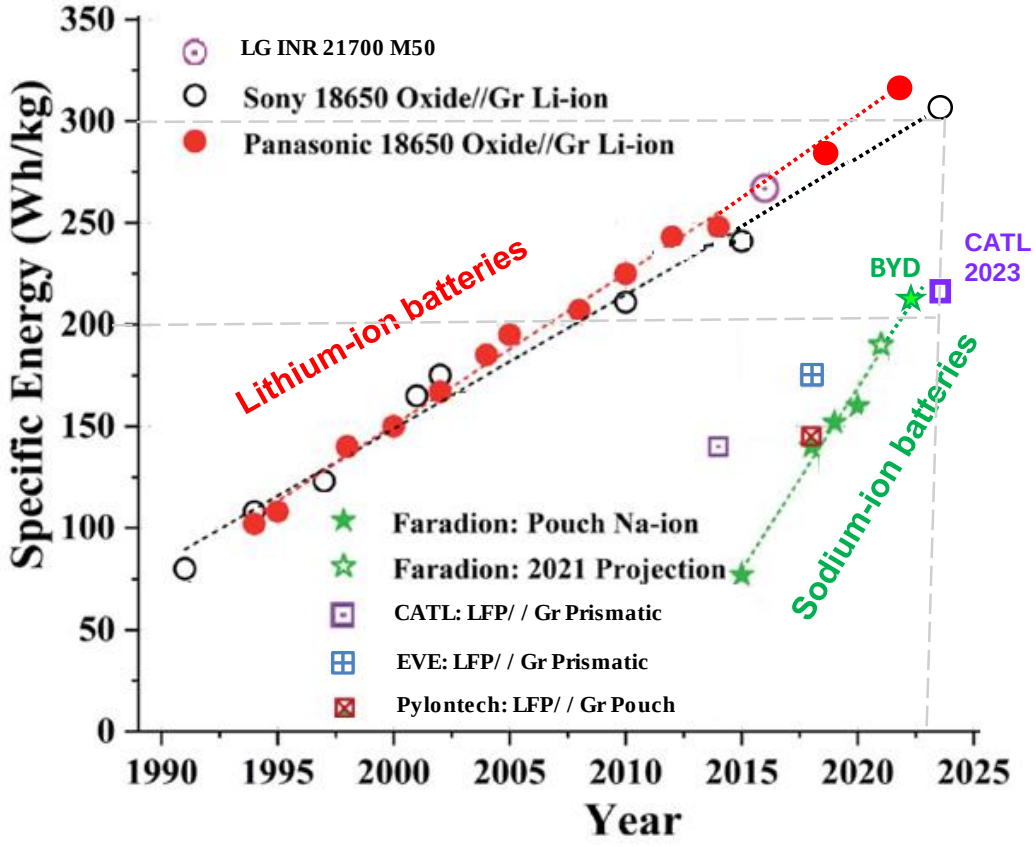


https://dragonflyenergy.com/why-does-energy-density-matter-in-batteries/

CEPS beyond lithium
Sodium-ion battery – a game-changing technology

- Advantages of Sodium-Ion Batteries (SIBs) vs. LIBs
  - Eco-friendly & cost-effective
    - 1T Na = $150
    - 1T Li = $20,000
  - Perform at lower temperatures
  - Charge faster than LIBs
  - 75% energy density compared to LIBs

Progress in Sodium- vs. Lithium-Ion Battery R&D



FARADION Advanced Energy Storage Solutions
HiNa BATTERY
NGK INSULATORS, LTD.
TIAMAT
CATL

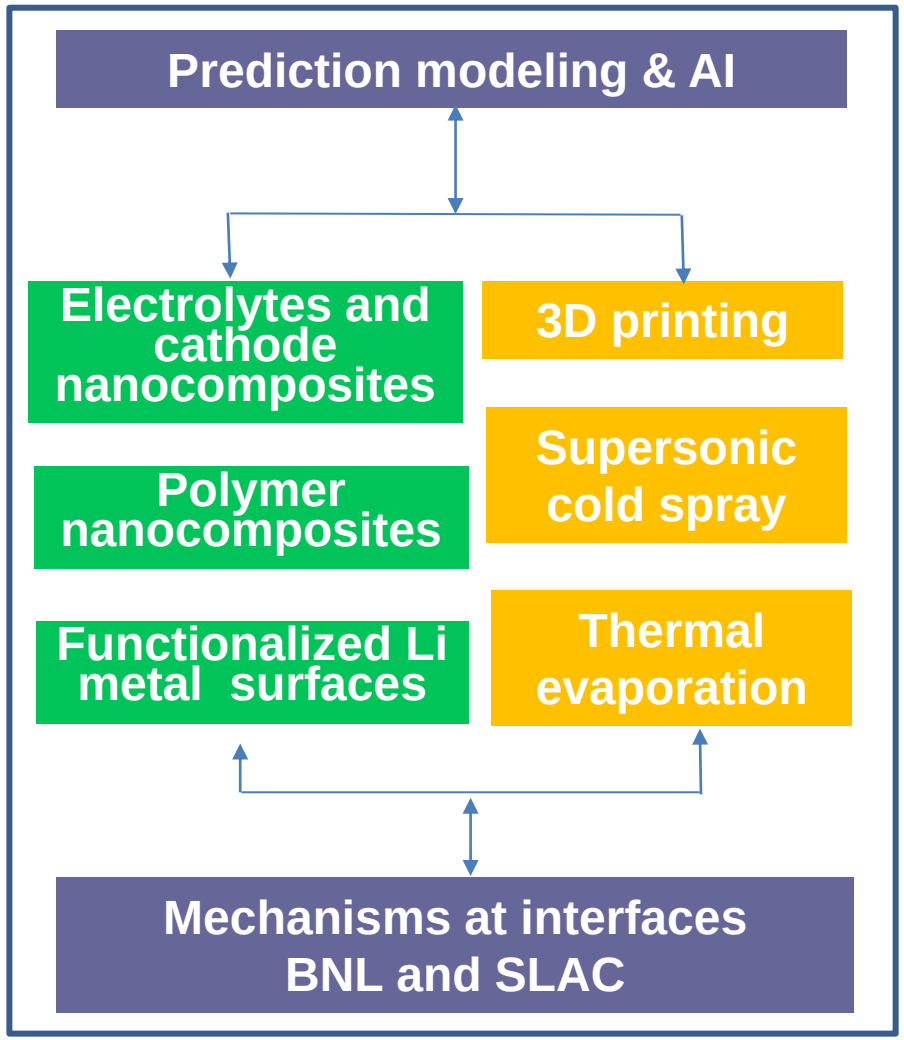
CEPS roadmap for pre-competitive & industry-inspired R&D

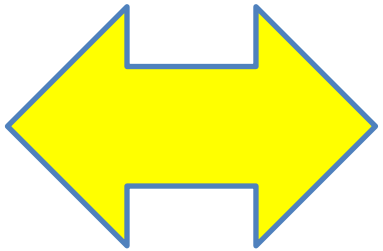
Materials Engineering

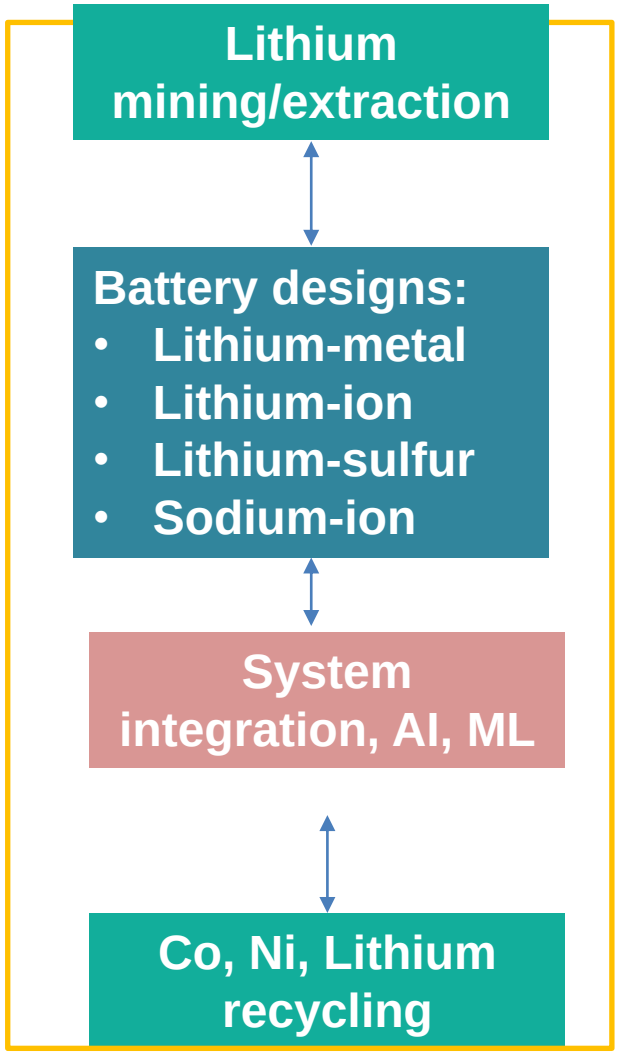
Characterization and analysis

Manufacturing technology

Supply chain & Commercial integration



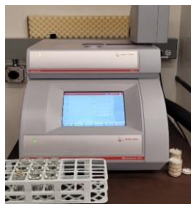




CEPS unique technical capabilities in each trust area

Materials Engineering

- Sol-gel/wet
- Mechanical
- Hydrothermal
- Electrospinning
- High planetary ball-milling

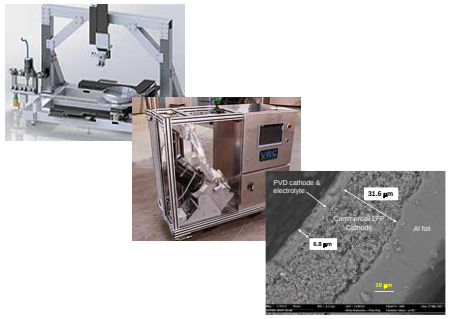


Gloveboxes (N_2 & Ar) with:

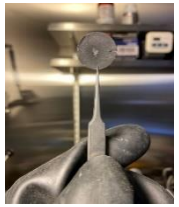
- Thermal evaporator
- Microwave oven
- Automatic press
- Vacuum heating system
- Hot-plates
- Coin-cell crimpers
- Spin-coater
- Microwave reactor
- Wet materials processing
- Automatic samplers

Manufacturing technology

- Thermal
- PVD
- Spin-coating
- Lazer
- Cold spray (CS)



Lazer and CS deposition



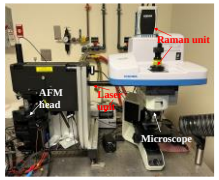
Spin-coating in nitrogen

PVD 2300-Pulsed Laser Deposition System, Arcast 200

Characterization and analysis

- Synchrotron (XAS & TEM)
- FIB SEM/EDX
- TEM/EDX
- In-situ/operando: XRD and Raman
- AC iimpedance
- TGA/DTA

Malvern Empyrean in-situ/operando XRD



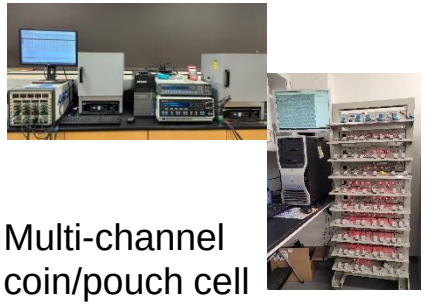
Confocal Raman and Tip-Enhanced Raman Spectroscopy

AFMs

System design & integration, AI, ML

- Big data analysis
- High-end machine learning

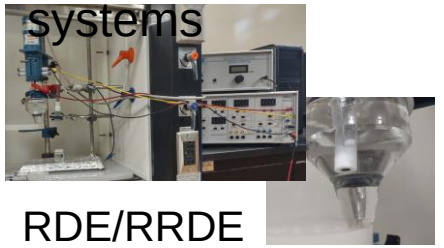
FIB-SEM/EDS



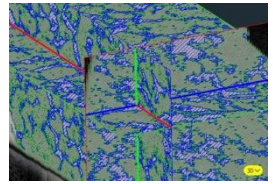
Multi-channel coin/pouch cell test stations with environmental chambers and AC impedance

Critical metals & battery recycling

- ICP-MS for trace elemental analysis
- Electrochemical systems



RDE/RRDE system with bipotentiostat



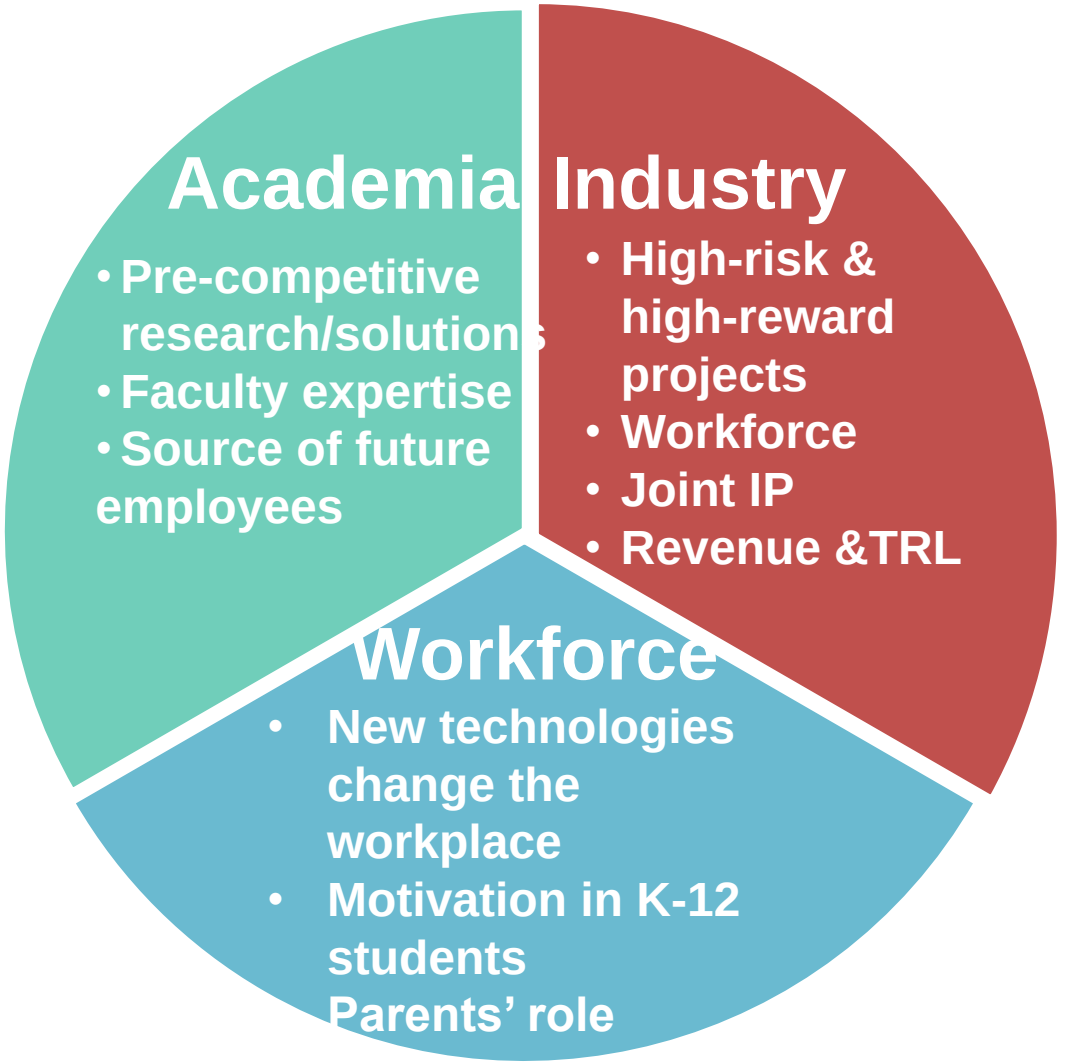
3D-structure of NMC cathode after treatment at ~5 nm resolution

Short- and long-term benefits for CEPS participants
Value proposition for industry members

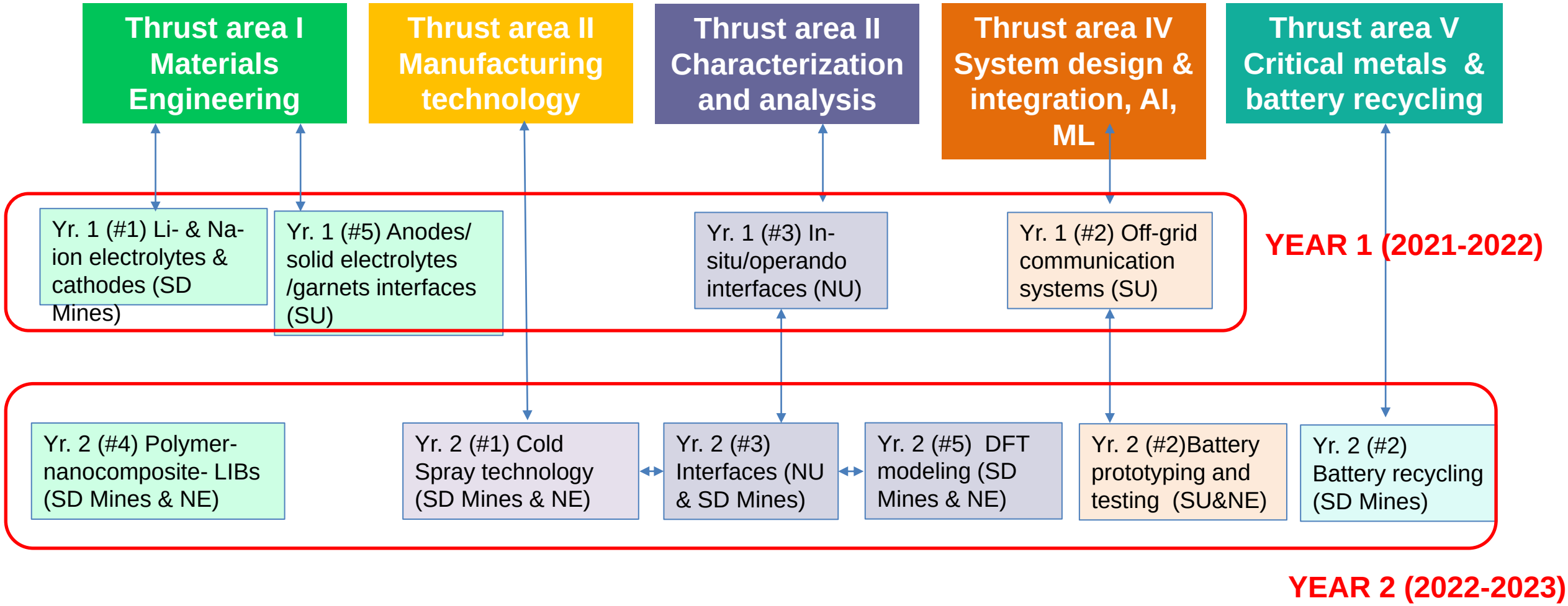
- Our goal is to accelerate transition of new technologies to the market

- Faculty solve specific industry problems
- Propose new ideas
- Minimize technology risks

- CEPS model is flexible through IP sharing or exclusive licensing
- Exclusive licensing is available through the supplemental INTERN NSF IUCRC program
- NSF pays $55K/year to INTERN working at the company



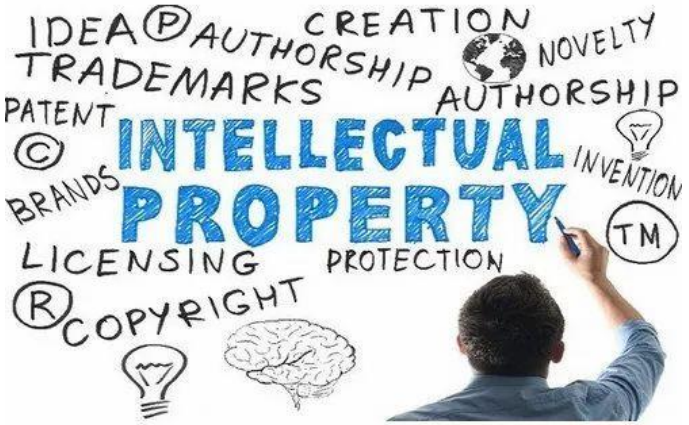
NSF CEPS research project approved by IAB



SD Mines – South Dakota School of Mines and Technology
SU – Syracuse University Site
NU – Northeastern University Site

NSF highlights: Value proposition for industry partners

- Access to Talent
- Mentorship and training
- Desired skills to work with industry partner



- Leveraged funding
- Higher return on investment when funded jointly

- Access to research data and IP
- Royalty-free, non-exclusive licensing on produced IP

https://iucrc.nsf.gov/
https://iucrc.nsf.gov/industry/

Supplemental funding for CEPS members

- Workforce development: supplemental funding for talented students: https://iucrc.nsf.gov/universities/solicitation/#funding-for-existing-centers
  - INTERN
  - NSF AFRL INTERN
  - RET
  - REU
  - REM
  - VRS
  - Senior design
  - Diversity, Equity, Inclusion and Accessibility (DEIA)
- Access to SBIR/STTR and “Partnerships for Innovation” projects https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504790

- Skills Training in Advanced Research & Technology (START) – ATE 2yr-4yr

https://www.nsf.gov/pubs/2021/nsf21076/nsf21076.jsp?WT.mc_id=USNSF_27&WT.mc_ev=click

Contribution of Government agencies to CEPS

- Direct access to governmental programs (non-competitive funding) https://iucrc.nsf.gov/universities/solicitation/iucrc-interagency-agreement-requests/

- Federal government agencies, Federally Funded Research and Development Centers (FFRDC) and National Laboratories may become IUCRC Members with the same rights and responsibilities as industry members.
- To ensure that IUCRC research remains pre-competitive, federal entities may not use the IUCRC to conduct contractual research.
- NSF provides government agencies the option to use either Inter-Agency Agreements (IAAs) or Military Interdepartmental Purchase Requests (MIPRs) to provide funds to support research at CEPS

NSF workforce development through IUCRC supplements

Veterans Research Supplement (2022-2023; $10K)

- Four UG students (Airforce and Navy)
- In 2022-2023 (R. Barrett, EE, and S. McQueen MME)
- https://www.sdsmt.edu/Campus-Life/Veterans-Resource-Center/

Research Experience for Teachers (2022-2023K; 10K)

- Two science teachers from two SD schools
- Newell (rural) and Stevens (urban) high schools

Research Experience and Mentoring (REM) ($109K, 2023-2024) "Broadening participation in critical STEM research and innovation through sustainability"

- Three schools (3 science teachers and 8 HS students)
- Newell, Stevens, Central HSs
- https://etap.nsf.gov/
-

Proposals pending or planned for submission

Non-Academic Research Internships for Graduate Students (INTERN)

Medtronic -SD Mines ($55K)
"First Principles-based Modeling of CF_x for Battery Applications", B. Lama, PI T. Paudel)

Research Internships for Graduate Students at the Force Research Laboratory (NSF-AFRL-INTERN)

"Additive manufacturing of solid-state batteries using Cold Spray at Ellsworth AFB"

Partnerships for innovations

"Additive LIB manufacturing by cold-spray technology"

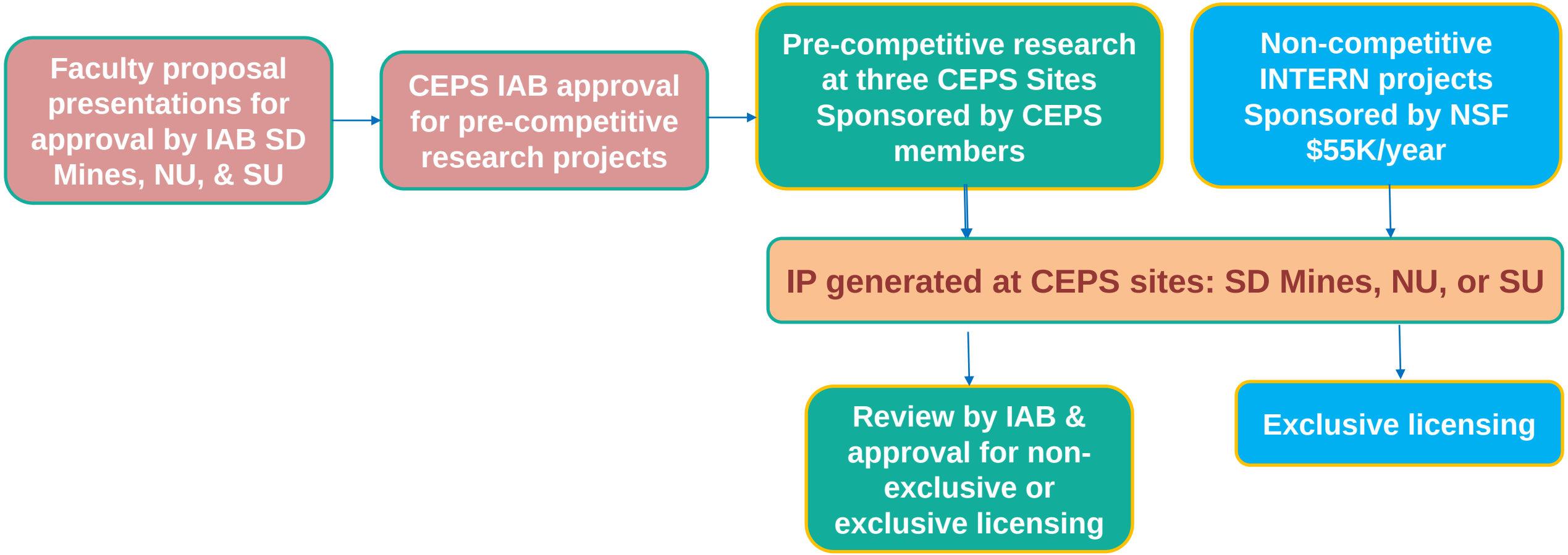
- SD Mines, NU, SU, and VRC Metal Systems

Skills Training in Advanced Research & Technology (START)

"Energy Storage Training Center for 2-year South Dakota colleges"

- Mitchell, Southeast, Lake, and Western Dakota Technical colleges

IP development and approval process for CEPS members



Acknowledgments

- Industry-University Cooperative Research Centers (IUCRC) program
- South Dakota Board of Regents
- CEPS management team
- CEPS industry members
- Faculty at SD Mines, SU, and NU
- All graduate and undergraduate students
- Ceramics Expo conference management team
- American Ceramic Society

Thank you for your interest in CEPS