# Overview of the U.S. National Science Foundation's Investments in Precision Agriculture and Connectivity

Presentation to:
FCC/USDA Task Force on Precision Agriculture and Connectivity

Sudharman K. Jayaweera (TIP), Brandi Schottel (ENG), Ellen Zegura (CISE)

August 14, 2024

# NSF'S MISSION

To promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense.

## Director's Vision

- Advance the frontiers of research into the future
- Ensure accessibility and inclusivity
- Secure global leadership

We are in a **DEFINING MOMENT**

- Intensity of global competition
- Urgent need for domestic talent
- Broad support for science as path for solving global grand challenges

We can accomplish this vision with:

## SPEED AND SCALE

- PEOPLE
- PARTNERSHIPS
- TRANSLATION

NSF

## Use-Inspiration

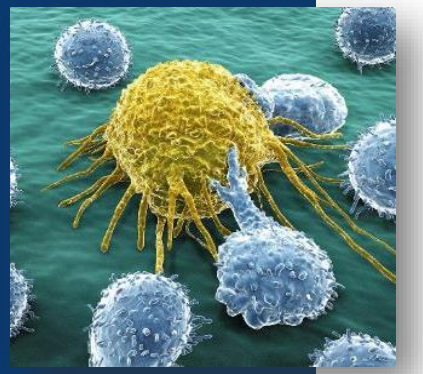
*"Scientific investigation … driven by the potential use to which the knowledge will be put."* (NOAA 2008, Stokes 1997)

Use-inspired exploration and discovery often involves *convergence research* and spans *both basic and translational activities*

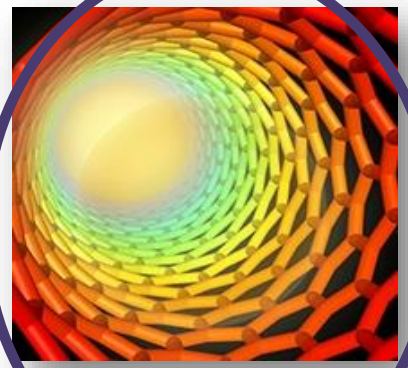
## Food and Nutrition Security

Food and nutrition security is an important source of use-inspiration across NSF programs and investments

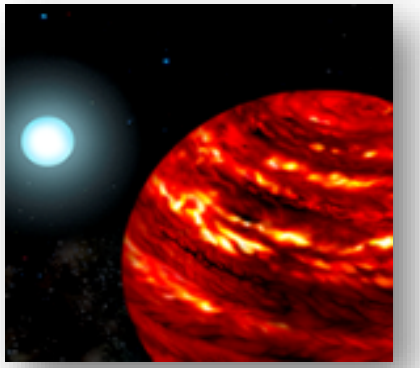
# NSF's Directorates and Offices



Biological Sciences



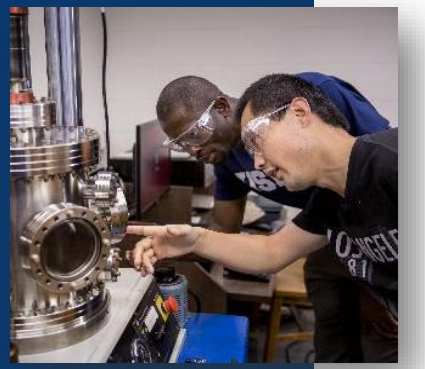
Engineering



Mathematical & Physical Sciences

Computer & Information Science and Engineering

Geosciences (and Polar Programs)



Integrative Activities

STEM Education

Social, Behavioral & Economic Sciences

Technology, Innovation, and Partnerships

International Science & Engineering

Dr. Brandi Schottel (ENG), Dr. Ellen Zegura (CISE), Dr. Sudharman K. Jayaweera (TIP)




# NSF's STRATEGIC THEMES

**Advancing Emerging Industries for Economic and National Security**

**Creating Opportunities Everywhere (e.g., EPSCoR)**

**Building a Resilient Planet**

**Strengthening Research Infrastructure**

# NSF funding supports…

## Research

Investing in research to **increase the knowledge base** surrounding broadening participation.

## Education

**Using Interventions and capacity building** to enhance access and opportunity to STEM education.

## Research Infrastructure

Developing the tools and infrastructure needed to **broaden the research community**.

## Outreach/Inreach/ Partnerships

Working with **external stakeholders**, the **research community**, and **NSF staff**.

# Example: Workshops May 2021 (left), July 2023 (right)

National Science Foundation (NSF)
Convergence Accelerator: Digital and Precision Agriculture
Workshop Report


## Sustainable Precision Agriculture in the Era of IoT and Artificial Intelligence

July 18-20, 2023

**BARD AG-AI Workshop**
Location: All Sessions will take place at the Ben Gurion University Campus in the W.A. Minkoff Senate Building (71A).

Website link:
https://www.agaiworkshop.co.il/

Book of Abstracts

Workshop Program

ICL BARD Helmsley Model Farm For Sustainable Agriculture

# Types of Funding Opportunities

| Program Solicitations | Dear Colleague Letters | Supplemental Funding | EAGER, RAPID |
|---|---|---|---|
| • Requests for proposals<br>• Contains program goals, instructions for proposal prep, award information<br>• Must also follow rules in the NSF rules doc PAPPG | • Notifications of *special opportunities*<br>• Elevate a specific topic area *for existing solicitations*<br>• Competitions for *supplements to existing NSF awards and/or conferences* | • *For existing awards*<br>• Up to 20% of original award amount to complete project activities<br>• Must contact a Program Officer (PO) before submitting | • High-risk, high-reward research proposal<br>• Not aligned with existing opportunity<br>• Can be solicited via DCLs, invited by a PO, or unsolicited<br>• Must contact a PO before submitting<br>• *Relatively rare* |

# Categories of Funded Efforts

| Institutes and Centers | Research Projects | Education | Research Infrastructure |
| --- | --- | --- | --- |
| • Large scale, complex problems<br>• Generally multi-institution<br>• Long standing (e.g., Engineering Research Centers)<br>• Newer (e.g., AI Institutes) | • Most common NSF funding type<br>• Single or few PI efforts in response to solicitations<br>• Standing, core solicitations with broad scope<br>• Specialized solicitations | • K-12, 2-year, 4-year<br>• Training<br>• Research Experiences for Undergrads (REUs)<br>• Research Experiences for Teachers (RETs)<br>• Graduate and postdoc fellowships (GRFP) | • From campus-level to national-scale to international<br>• From general purpose to highly specialized<br>• Any combination of facilities, equipment, instrumentation, hardware and software, and supporting human capital |

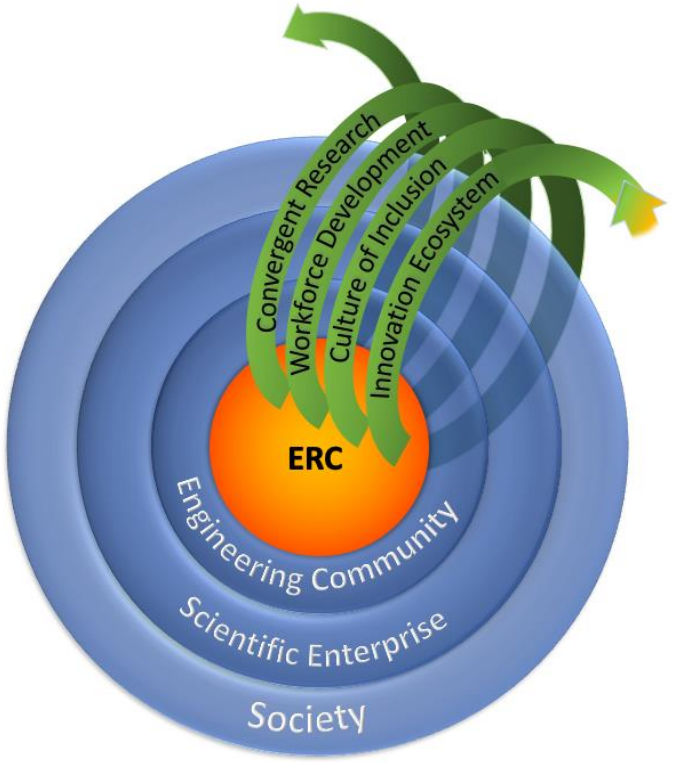

# Institutes and Centers

# Engineering Research Centers (ERC)

Support convergent research, education, and technology translation leading to strong societal impacts; support lasts for up to 10 years (~$52M)

**Highlights:**

- 75 ERCs supported since 1985
- 240 spinoff companies
- 900 patents
- 14,400 degrees to ERC students
- Numerous research outcomes enabling new technologies



# IoT4Ag

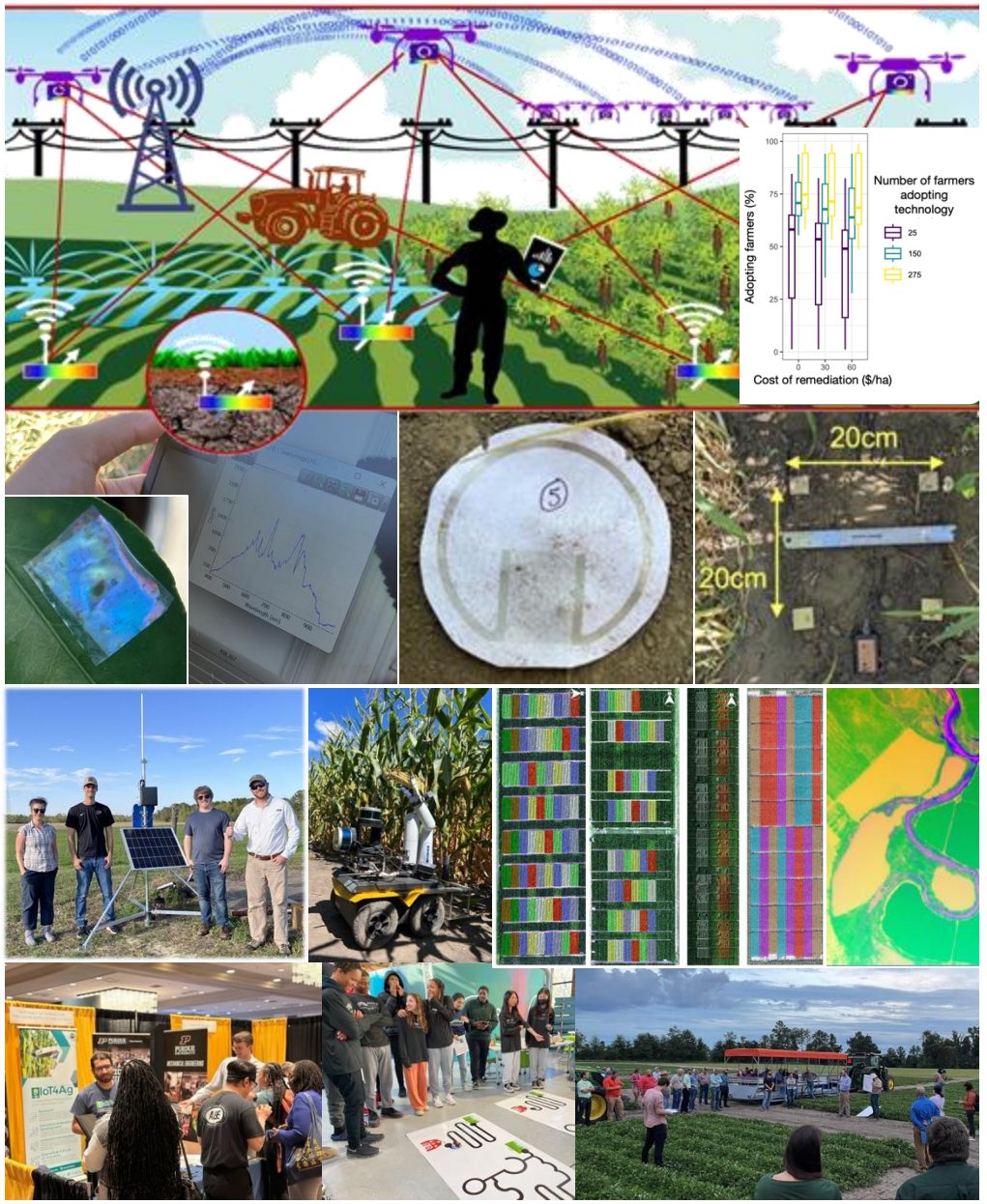
The Internet of Things for Precision Agriculture
*an NSF Engineering Research Center*

**Vision:** To ensure food, energy, and water security by advancing technology to increase crop production, while minimizing the use of energy and water resources and the impact of agricultural practices on the environment.

**Mission:** To create and translate to practice Internet of Things (IoT) technologies for precision agriculture and to train and educate a diverse workforce that will address the societal grand challenge of food, energy, and water security for decades to come.

## Highlights Across ERC Foundational Components:

- Biodegradable Leaf and Soil Sensors and Air Batteries for Sensing
- Unmanned Agricultural Robotics for Mapping and Sampling
- Edge Computing and Communication for Agricultural Sensors
- Multi-Resolution Raster Data Fusion for IoT-enabled Ag Systems
- Improving Efficiency of Crop Input Applications from Modeling to Smart Application Systems
- Teach & Excite – Tech Meets Ag: K12 Outreach
- Education an Inclusive World: Pathway to PhD Program
- Enabling Professional Advancement: MSI and Practitioner Partnerships




Penn University of Pennsylvania | Purdue University | University of California Merced | UF University of Florida | ASU Arizona State University | NSF

# NSF-led National AI Research Institutes Program

- $20M (~4M/year) over 5 years
- Foundational and use-inspired AI research
- Innovation in AI education and workforce development
- New partnership development

## AI Institutes and Funding Partners


NSF · USDA · DHS · NIST · DOE · IES · Simons Foundation

Google · amazon · intel · accenture · IBM · Capital One

## A network of networks

AIVO
AI Institutes Virtual Organization

**Facilitator and Resource Center**

- Directory of Institute contacts
- Advice on partnership inquiries

Learn more about AI Institutes at https://aiinstitutes.org

# National Artificial Intelligence (AI) Research Institutes

*Sustained investments in AI research in areas with the potential for long-term payoffs. Emphasis on convergent foundational and use-inspired research focused on societal challenges and enhancing national competitiveness in AI.*

- **Goals of each Institute:**
  - Significantly advance research in AI in a multi-disciplinary, multi-institutional collaborative setting
  - Accelerate the development of transformational, AI-powered innovation
  - Grow a workforce of future AI researchers and practitioners
  - Nexus points for Institute-level collaboration between universities, federal agencies, industries, and nonprofits

# 25 Active Institutes

- **2020: First cohort of Institutes (5 NSF, 2 NIFA)**
- **2021: Second cohort of Institutes (9 NSF, 2 NIFA)**
- **2023: Third cohort of Institutes (6 NSF, 1 NIFA)**

**AIVO**: https://aiinstitutes.org
Link to all awards: NSF Award Search

# USDA-NIFA AI Institutes

## *AI Institute for Next-Generation Food Systems (**AIFS**)*

USDA-NIFA Integrate a holistic view of the food system with AI and bioinformatics to understand biological data and processes, addressing issues of molecular breeding to optimize traits for yield, crop quality, and pest/disease resistance; agricultural production, food processing and distribution, and nutrition.

## *AI Institute for Resilient Agriculture (**AIIRA**)*

USDA-NIFA Transform agriculture through innovative AI-driven digital twins that model plants at an unprecedented scale.

## *AI Institute for Agricultural AI for Transforming Workforce and Decision Support (**AgAID**)*

USDA-NIFA - Integrate AI methods into agriculture operations for prediction, decision support, and robotics-enabled agriculture to address complex agricultural challenges.

## *AI Institute for Future Agricultural Resilience, Management, and Sustainability (**AIFARMS**)*

USDA-NIFA - Advance AI research in computer vision, machine learning, soft object manipulation and intuitive human-robot interaction to solve major agricultural challenges including labor shortages, efficiency and welfare in animal agriculture, environmental resilience of crops, and the need to safeguard soil health.

## *AI Institute for Climate-Land Interactions, Mitigation, Adaptation, Tradeoffs and Economy (**AI-CLIMATE**)*

USDA-NIFA- Advance foundational AI by incorporating knowledge from agriculture and forestry sciences and leveraging these unique, new AI methods to curb climate effects while lifting rural economies.

# IUCRC: Center for Soil Technologies

**Center Mission:** Support critical industries such as energy, climate, agriculture, telecomm, defense, & infrastructure through research in **remote sensing**, chemical, electrical, and hydrological **sensor development,** and integration of multi-scale knowledge of soil dynamics into **predictions and decision-making**.

*Phase I NSF Support: $600k/yr (operations)*
*Industry support: $400k in Year 1 (research)*

## University Partners

USC University of Southern California

Iowa State University

University of Washington

UConn University of Connecticut

## Industry Advisory Board

Bayer

Raytheon

NASA

Mitsubishi Electric

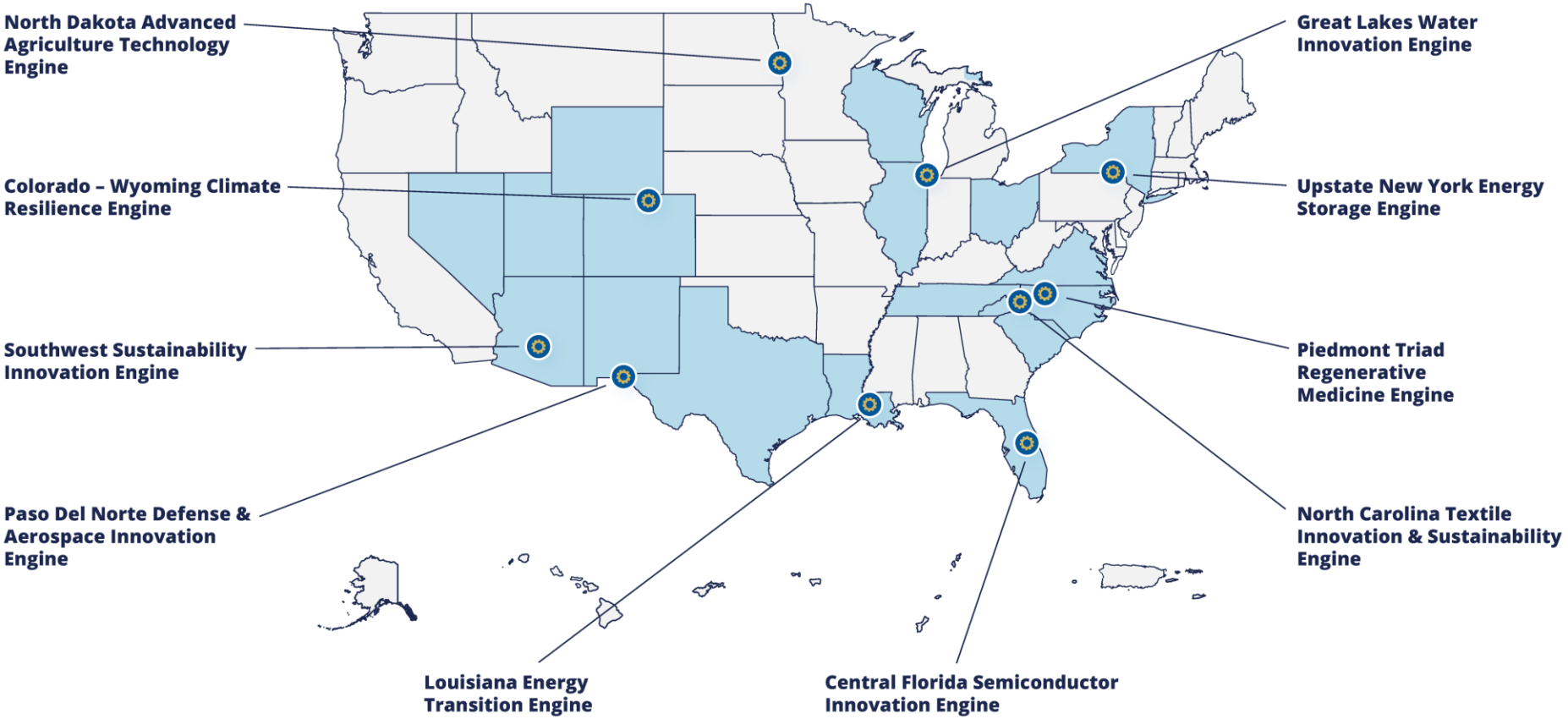
John Deere

Onset

Foundation for Food & Agriculture Research

syngenta

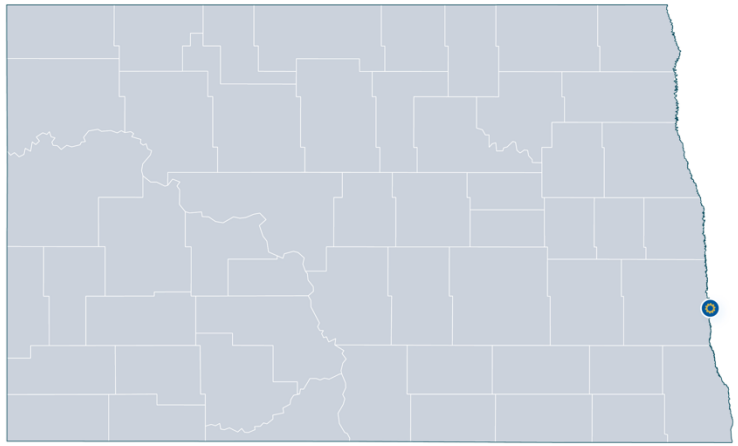
# NSF Regional Innovation Engines (10 initial)



# North Dakota Advanced Agriculture Technology Engine

**Lead organization:**
North Dakota State University

**Region of service:**
North Dakota (entire state)



**Aims:**
Create resilient and secure food systems in North Dakota by combining advanced genomics, climate modeling, nanoscale sensors and computer networks to monitor and improve the growth of crops via strong networks of stakeholders across the state — including bringing tribal, rural and farming communities intentionally and meaningfully into the process of co-creating a blueprint for the future of agriculture and workforce development.

**65 partners, $160M over 10 years**

**Key Technology Areas:**
Biotechnology, advanced computing and semiconductors, advanced materials, advanced communications, artificial intelligence, data and cybersecurity, disaster prevention and mitigation, robotics and advanced manufacturing..

**Learn More:**
**www.FARMSfeedstheworld.com**

# Categories of Funded Efforts

| Institutes and Centers | Research Projects | Education | Research Infrastructure |
| --- | --- | --- | --- |
| • Large scale, complex problems<br>• Generally multi-institution<br>• Long standing (e.g., Engineering Research Centers)<br>• Newer (e.g., AI Institutes) | • Most common NSF funding type<br>• Single or few PI efforts in response to solicitations<br>• Standing, core solicitations with broad scope<br>• Specialized solicitations | • K-12, 2-year, 4-year<br>• Training<br>• Research Experiences for Undergrads (REUs)<br>• Research Experiences for Teachers (RETs)<br>• Graduate and postdoc fellowships (GRFP) | • From campus-level to national-scale to international<br>• From general purpose to highly specialized<br>• Any combination of facilities, equipment, instrumentation, hardware and software, and supporting human capital |


# Research Projects in Core Areas

# Cyber-Physical Systems (CPS)

*Deeply integrating computation, communication, and control into physical systems everywhere*

## Characteristics of CPS

- Pervasive computing, sensing and control
- Networked at multi-&-extreme scales
- High degrees of automation
- Scalable, interoperable, safe, usable
- Autonomy & human-in/on-the-loop

## Application Domains

**Critical Infrastructures**

**Energy & Industrial Automation**

**Healthcare and Biomedical**

**Transportation Systems**

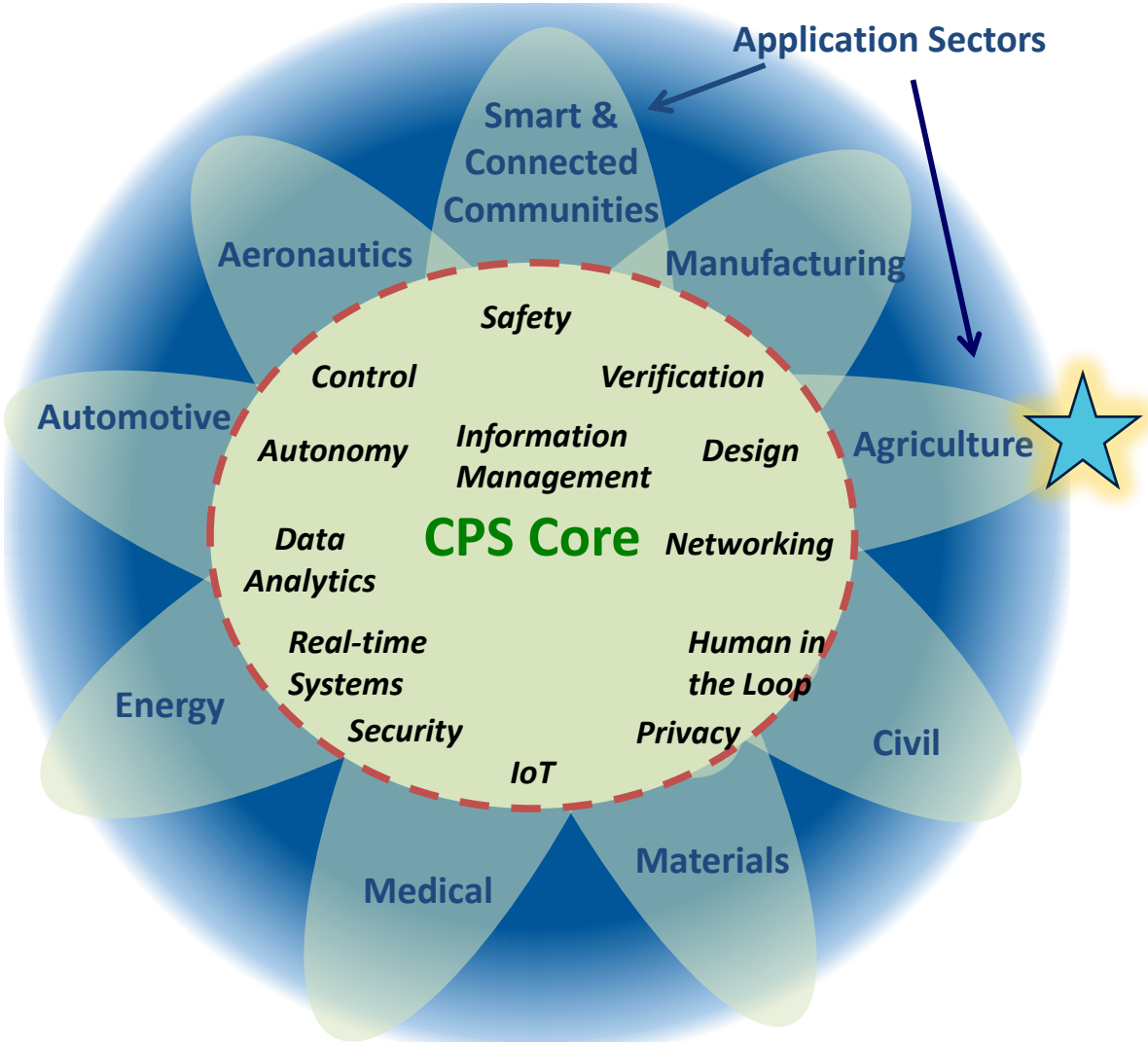
**Agriculture**

# Overview of the CPS Program

The **goal** of the CPS program is to develop the core system science needed to engineer complex cyber-physical systems upon which people can depend with high confidence

Multi- agency: NIFA, DOT, NIH (past), DHS

More than $400M, over 200 active projects since program start



# FY 2023 Partnerships with Other Agencies

- **U.S. Department of Agriculture**
  - National Institute of Food and Agriculture
- **U.S. Department of Transportation**
  - Federal Highway Administration
- **Department of Homeland Security**
  - Science & Technology Directorate
- **National Institutes of Health (past)**
  - National Institute of Biomedical Imaging and Bioengineering
  - National Cancer Institute
  - National Center for Advancing Translational Sciences
  - Office of Behavior and Social Sciences Research

# Selected Funded / Active Projects

- **CNS-1954556, Soumik Sarkar, Iowa State University**
  - *COALESCE: Context Aware Learning for Sustainable CybEr-Agricultural Systems*
  - Aims to transform CPS capabilities in agriculture to enable farmers to respond to crop stressors with lower cost, greater agility, and significantly lower environmental impact than current practices.
- **CNS-1932300, Ayan Dutta, University of North Florida**
  - *Towards Efficient and Secure Agricultural Information Collection Using a Multi-Robot System*
  - Aims to develop novel information collection techniques for autonomous mobile robots that collect, store, and share data in an efficient yet secure manner using blockchain.
- **CNS-2038853, Josiah Hester, Georgia Tech**
  - *Batteryless Sensors Enabling Smart Green Infrastructure*
  - This project builds Smart Green Infrastructure; augmenting GI with battery-free smart devices, powered by energy harvested directly from soil, which gather data, infer, actuate, and collaborate with each other.

# Networking Technology and Systems (NeTS)

NeTS seeks to advance fundamental scientific and technological advances leading to the development of future generation networks

- Both 'wired' and 'wireless', from on-chip to Internet-scale, IoT, and other network systems
- Research that advances secure-by-design, high performance, robust and manageable networks

# Selected Funded / Active Projects

- **CNS-2212050, Mehmet Vuran, University of Nebraska**
  - *Field-to-Edge Connectivity for Joint Communication and Sensing in Next-Generation Intelligent Agricultural Networks*
  - Experts in millimeter-wave communications, metamaterial and metasurface-inspired antenna array design, dynamic spectrum access, radio access networks, agricultural robotics, and sensor-based plant phenotyping aim to provide connectivity to rural farm fields and increase national competence.
- **CNS-2212575, John Byers, Boston University**
  - *Real-Time Liquid Wireless Networking for Data-Intensive Rural Applications*
  - Aims to address the essential building blocks of rural broadband – subject to environmental factors such as weather, terrain, foliage, crop types, and densities, operating over larger areas with less density than urban networks.
- **CNS-210701, Chandra Krintz, University of California – Santa Barbara**
  - *Detroit: A New End-to-end System for Practical and Accessible IoT*
  - Aims to develop a portable, multi-tier (sensors, edge, cloud) platform that supports "write-once-run-anywhere" programming for IoT devices, enabling secure IoT innovation to become broadly practiced,  rather than solely the domain of distributed and embedded systems experts.

# NSF TIP Convergence Accelerator

## Track J – Food & Nutrition Security

**Goal**: Transform food systems across the nation to ensure access to healthy, safe and affordable food, as well as create sustainable agricultural forestry and food practices that consider the climate, regeneration and waste reduction. The track's focus also aligns with one of USDA's core priorities to ensure everyone in the country has consistent and equitable access to safe, healthy, affordable food essential to optimal health and well-being.
https://new.nsf.gov/funding/initiatives/convergence-accelerator/updates/nsf-leads-federal-investment-agricultural-technologies

- **$35 million NSF investment**
- **Seven Phase 2 teams**
- **$5 million per team, 36 months**

# Track J: Food & Nutrition Security – Phase 2 Teams

AquaSteady

Led by Pratt Institute

CropSmart

Led by George Mason University

CULTIVATE IQ
EMPOWERING REGIONAL FOOD SYSTEMS

Led by University of Arkansas

Dairy NutriSols
Dairy Done Right

Led by Boise State University

nourish
Fresh food where it's needed

Led by University of California, San Fransisco

NourishNet
A FOOD RECOVERY TOOLBOX

Led by University of Maryland, College Park

SENSD
Safe, Equitable Food Systems

Led by University of Missouri, Columbia


# Education

# Education: Research Experiences for Undergrads

BTI BOYCE THOMPSON INSTITUTE

## Plant Genome REU

The USDA and NSF-funded **Plant Genome** Research Experiences for Undergraduates encompasses a wide variety of plant science research, including bioinformatics. This program involves labs and faculty members at both the Boyce Thompson Institute and Cornell University

***Click here for more information on the Plant Genome and Bioinformatics REU programs.***

cropps Center for Research on Programmable Plant Systems

## Programmable Plant Systems REU

The NSF-funded **Programmable Plant Systems** Research Experiences for Undergraduates is funded through CROPPS, the Center for Research on Programmable Plant Systems, and involves trans-disciplinary research that connects engineering and plant science. This **program involves labs and faculty members at both the Boyce Thompson Institute and Cornell University, as well as at the University of Illinois, Urbana-Champain, IL**

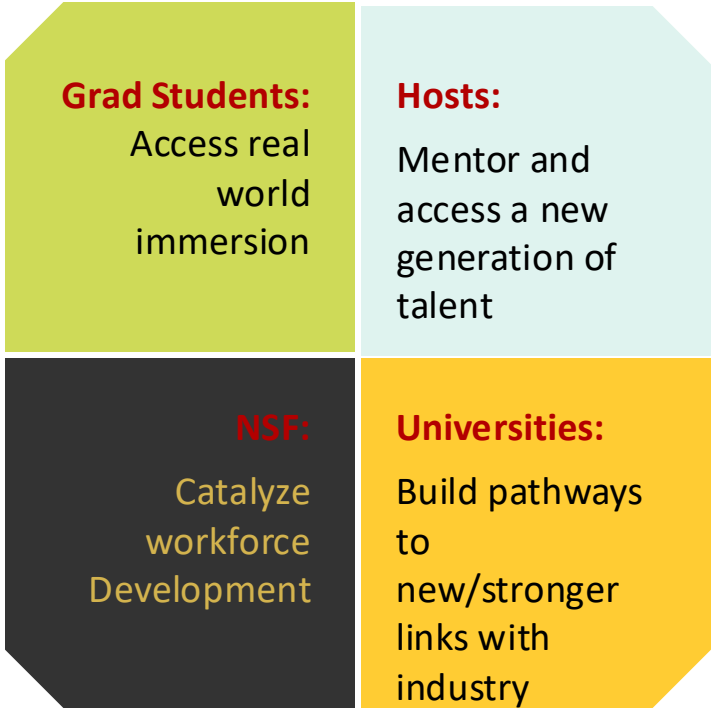
# Education: INTERN Model and Benefits

## Host organizations types:

- Industry laboratories or research and development groups
- Start-ups or small businesses
- Government agencies and National Laboratories
- Policy think-tanks
- Non-profit organizations

## Other details:

- Supplemental to award
- Up to $55K for up to 6 months
- Funds for faculty co-mentoring
- Open to international students
- NSF waives IP rights



# 1650+ INTERNs supported NSF-wide since FY17

## A random sampling of Host Organizations

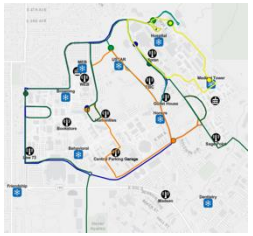

# Research Infrastructure

# Example: Platforms for Advanced Wireless Research (PAWR) NextG Research and Testing

Salt Lake City, UT

POWDER
RENEW

Software defined networks and massive MIMO



West Harlem, NY

COSMOS

Millimeter wave and backhaul research

Raleigh, NC

AERPAW
Aerial Experimentation and Research Platform for Advanced Wireless

Unmanned aerial vehicles and mobility

Ames, Iowa

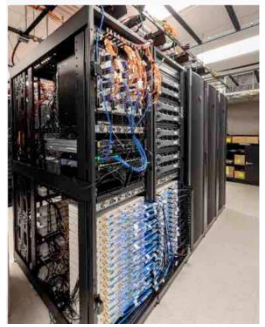
ARA

*Rural broadband and precision agriculture*

Boston, Massachusetts

COLOSSEUM
at Northeastern University

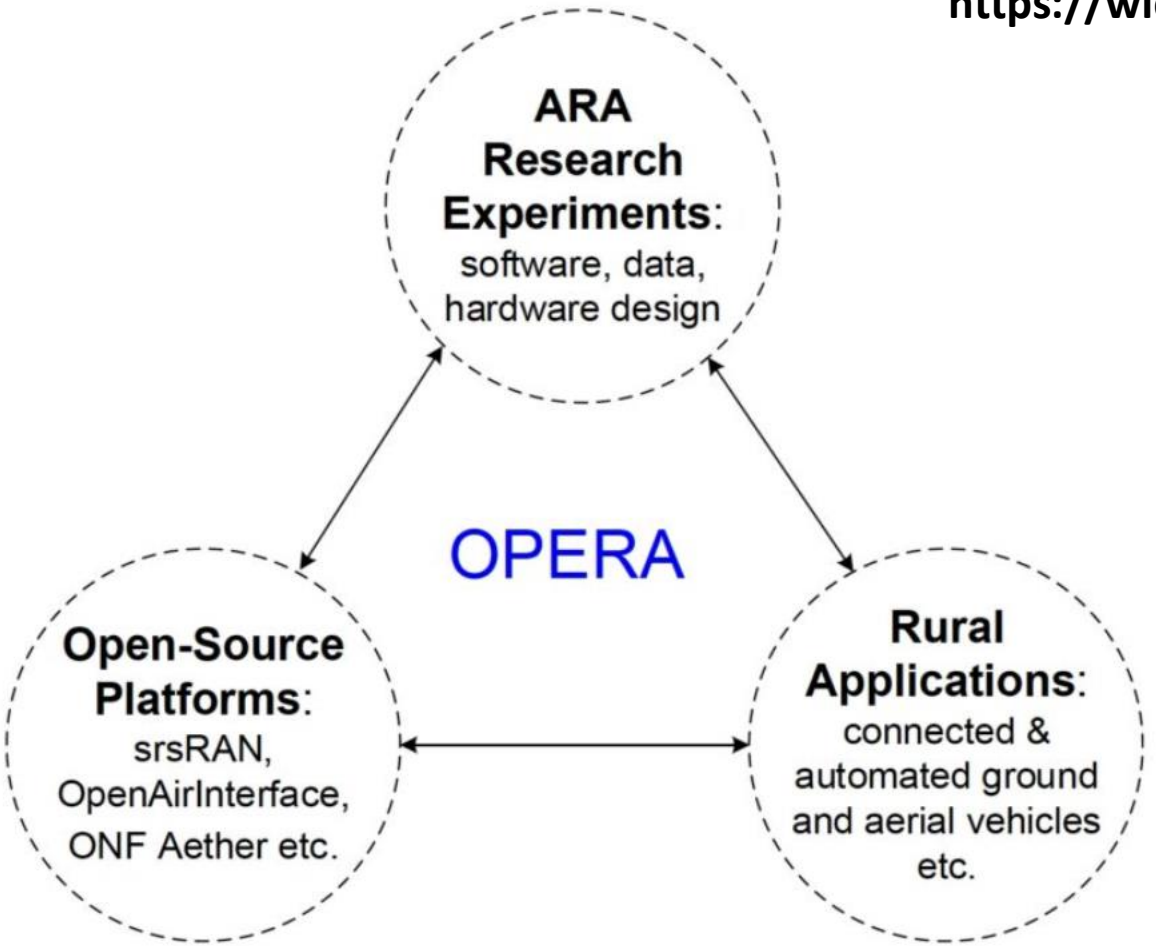
The World's Largest NextG Wireless Emulator



ARAFest: August 25-27, 2024 in Ames, Iowa with Farm Progress Show

# OPERA: Open-Source Ecosystem for Broadband Prairie (in conjunction with ARA Platform)

**https://wici.iastate.edu/opera/**



# NSF Advanced Technological Education (ATE)

- **Creating a Sustainable Educational Pipeline for the Controlled Environment Agriculture Workforce through a Remote Dual-Credit High School to College Model**
  2301183; Richard Shultz; Santa Fe Community College
- **Creating an Agriculture Workforce Pipeline of STEM Technicians Trained in Water Analysis**
  2300420; Peter Fandel; Illinois Central College
- **Mobile Controlled Environment Agriculture Technician Education**
  2055223; Lew Nakamura; University of Hawaii
- **Advancing Precision Agriculture in the Urban Environment**
  2202151; Trentee Bush; Northeast Community College
- **Expanding Precision Agriculture Education and Certification to Secondary Students**
  2055728; Derrick Baker; Parkland College
- **Modernizing Agriculture Technician Education in Appalachian Northeast Georgia**
  2000444; Russell Logan; North Georgia Technical College
- **Grow with Rhodes: Expanding Awareness of Agriculture Technology Careers and Pathways**
  2300008; James Uphaus; Rhodes State College
  **Agricultural Robotics and Automation Technologies**
  2348815; Keith Olander, Central Lakes College
- **Cross-Pollination Skillsets: Growing Mechatronics and Agricultural Collaborations for Producing Skilled Agricultural Technicians**
  Award Number:2350254; David Berry; Virginia Western Community College;
- **Creating a Workforce Pipeline of Agriculture Drone Operators and Remote Sensing Technicians**
  2300513; Zachery Harber; University of Arkansas System


# Discussion