Smart Systems For 21\textsuperscript{st} Century Food Systems

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Nutritional Security An Existential Threat
Food, Shelter, Fiber, Fuel > 9 billion
Path Forward

- Transformative discoveries
  - Smart Systems
  - Big Data
- 21st Century Extension
- Farming systems
  - 21st Century Farms
- Education
- Policies, regulation, marketing
- Human dimensions
- Communications
Smarter Agricultural Production?

**Goal** – Develop new or improved engineered devices, products, or systems that:

- Precisely **sense**, “**reason**,” and **respond**
- **Improve** the **profitability**, **productivity**, and/or **efficiency** of ag-related operations of all sizes
- **Benefit consumers** and society
Technology Challenges

Robust technologies that can be applied to a wide variety of crops and operations: e.g., varying fruit size, plant size and arrangement, and cultural practices

Scale-neutral technologies: viable for both large and small producers

Crisis-driven industries: weather, regulation, insects and diseases
Cyberphysical Systems, Robotics, Agriculture Technology

While producing safe, nutritious, and affordable food to serve a growing global population—as well as feed, fiber, and fuel—the agricultural enterprise consumes large amounts of land, water, and petro-chemicals.

Availability and cost of farm labor has created an economic disadvantage for many agricultural industries in the U.S. as they try to compete in the global marketplace.

Robotics can help agriculture be more productive and efficient, and reduce its footprint in consuming resources and generating waste.

Using robotics to eliminate unskilled, unsafe, and low-wage jobs will create new business opportunities, with higher-wage, technically demanding jobs, that can lead to more viable and resilient rural economies.
Smart Systems For Food Production Systems

1) Assist in the production process
2) Measure plant performance
3) Track environmental conditions
4) Inform real-time decision making

Combine **next-generation sequencing** & **new sensor technologies** to acquire genotype, phenotype, and environmental data to identify relationship between genotype and phenotype

**Long-term goal:** accelerate breeding via marker-assisted selection and genomic selection to aid rapid seedling screening

**DEVELOPING NEW TECHNOLOGIES**

**SCREENING GENOTYPES AND PHENOTYPES**

**DESIGNING SMART SYSTEMS FOR PRODUCTIVITY AND MANAGING BIOTIC & ABIOTIC STRESSORS**

Designing sensors, robots, and drones to measure environments and traits, production to post-harvest

Generating large quantities of environmental, trait, and genetic data

New technologies, statistical tools, and experimental design strategies are decreasing the costs of marker-assisted breeding
Genomes to Field Initiative
Smart Systems Generate Data

**Storing** collected **raw data**

Using **algorithms** to **generate results** from the raw data

**Modeling** to develop understanding of the data, inform breeding selections and field trials

**DEVELOPING NEW TECHNOLOGIES**

**SCREENING GENOTYPES AND PHENOTYPES**

**MANAGING BIG DATA**

**DESIGNING SMART SYSTEMS FOR MANAGING AND ANALYZING DATA**

- Designing sensors, robots, and drones to measure environments and traits, production to post-harvest
- Generating large quantities of environmental, trait, and genetic data
- Storing, processing, and analyzing the collected data to identify the genetic basis of desirable agronomic traits

#BigData
Big Data: Opportunities

Open Data is a powerful, evidence-based tool for long-term sustainable development by improving economic opportunities for farmers and the health of consumers.

Transparent, Collaborative, Participatory research, meta-analysis, and open publication of data are vital resources for nutritional security.

Iain Chalmers: Cochrane Collaboration
http://www.cochrane.org
Big Data: Challenges

- Ownership
  - Open Ag Technology Systems
- Decision Support Tools
  - Open Ag Toolkit – NIFA funded
  - FarmBot
- Cost
- Bandwidth
- Quality
- Curation
- Disambiguation
- Connectivity
- Cybersecurity
- Storage

Courtesy: Dennis Buckmaster; https://engineering.purdue.edu/oatsgroup/
Smart Systems From Farm to Table

**DEVELOPING NEW TECHNOLOGIES**
Designing sensors, robots, and drones to measure environments and traits, production to post-harvest

**SCREENING GENOTYPES AND PHENOTYPES**
Generating large quantities of environmental, trait, and genetic data

**MANAGING BIG DATA**
Storing, processing, and analyzing the collected data to identify the genetic basis of desirable agronomic traits

**BREEDING DESIRABLE CROP VARIETIES**
Selecting, genetically screening, field testing, and scaling desirable varieties for production

**HARVESTING & DISTRIBUTING TO CONSUMER**
Using new technologies to harvest and transfer high-quality berries from farm to table
Supply Chain

- On Farm Production
- Soil Health, Water, Nutrients
- Pests/Control
- Energy
- Traceability and Tracking
- Supply Chain Management
- Processing
- Inspection
- Transportation
- Storage

- Retailers
- Inventory
- Access
- Smart Refrigerators
- Food Safety
- Ripeness
- Shrink Wrap
- Waste
- Smart Services
- Etc.
Smart Systems Robotics

Application to Caneberries:

State-of-the-art machine harvesters in the Pacific Northwest optimize efficient harvest of high quality fruit for the Individually Quick Frozen market.

Color and size sorters ensure quality products in the fresh and processed packing industries.

Photos courtesy of Dr. Bernadine Strik, Oregon State University
Outcome of Big Data and Analytics

2014 National Corn Yield Average: 171 Bushels
Randy Dowdy, farmer from Georgia: 503 Bushels

Randy Dowdy used sensors, optimal varieties, irrigation and fertilizers, pest control, and Big Data analytics with the help of Monsanto and Climate Corp.
Real-time Ag Data Analytics and Control – Research Gaps

Increased production requires efficient production decisions

How can cyber-physical systems leverage “big data” real-time in a diversity of environments?

NSF/NIFA joint funding opportunity:

Cyber-Physical Systems (closes June 7, 2016)
Real-time Ag Data Analytics and Control – Drones & Sensors

Applications of drones:
- Fire fighting
- Scouting for insect pests
- Field monitoring

Advantages of drones:
- Cheap
- Lightweight
- Can carry a variety of sensors/cameras

*Funding opportunity: Small Business Innovation Research*
NIFA-Funded: Open Data, Open Access Tools, and Cyberinfrastructure

- MaizeGDB (corn)
- SoyBase (soybean)
- Legume Information System (legumes)
- T3: The Triticeae Toolbox
- GrainGenes (wheat, barley, oat)
- Gramene (rice, grape, other model plant systems)
- Genome Database for Rosaceae
Smart Systems to Accelerate Breeding: Funding Opportunities

• AFRI Foundational Plant Health and Production and Plant Products Program
  – Pre-breeding and germplasm enhancement, cultivar development, selection theory, applied quantitative genetics, and breeding
  – Conventional breeding for development of publicly available cultivars

• AFRI Foundational CARE and ERG program

• AFRI Food Security Challenge Area
  – Breeding and phenomics of crops to produce varieties with improved resilience to extreme weather and increased protection from pests
  – Enhanced nutritional composition for improved human health
  – Training next generation of plant breeders

• AFRI Education and Literacy Initiative
  – Undergraduate, predoctoral, and postdoctoral fellowships
Smart Systems to Accelerate Breeding: Funding Opportunities

• **NIFA International Wheat Yield Partnership**
  – Breakthrough breeding, genetics, and genomics

• **NIFA/DOE Joint Plant Feedstock Genomics for Bioenergy Program**
  – Breeding and genomics to develop new feedstocks

• **Early Concept Grants for Exploratory Research (EAGER) NSF/NIFA Joint Funding**
  – Breakthrough technologies for animal and plant phenomics and microbiomes

• **Plant Biotic Interactions Program NSF/NIFA Joint Funding**
  – Processes mediating beneficial and antagonistic interactions between plants, symbionts, and pests

• **NIFA/ARPA-E**
  – TERRA Genomes to Phenomes/Field program
NIFA SUPPORTS RESEARCH AND EDUCATION THAT SUSTAINABLY INCREASE PRODUCTIVITY BY:

**INCREASING**
photosynthetic, water use, and nutrient use efficiency in crops and animals

**DIVERSIFYING**
the product stream through novel crops, organisms, and processing technologies

**PROTECTING**
these products against predators, parasites, diseases, and pathogens to ensure food safety

**DEVELOPING & DEPLOYING**
the industrial, physical, and digital technologies to revolutionize planting, cultivation, harvest, storage, and transportation

**PREPARING** the next generation of agriculture professionals through education, training, and leadership development.
Humans Matter