Engineering Solutions for Agriculture

Daniel L. Schmoldt
National Program Leader
National Institute of Food & Agriculture
U.S. Agriculture

- 2.2 million “farms”
- 55% of farms less than 100 acres, and 55% of farms are operated by retirees or persons with primary occupations elsewhere
- ~90-10 rule
- Net exporter
- Accounts for 1% of GDP (12% for food & fiber system)

Figure 3: As the number of farms declined, their average size increased

Food System

focused science and application studies

PRODUCTION
- plant development: genetics, physiology
- harvest
- crop management
- reduce environmental footprint
- food security

TOTAL SYSTEM

DISTRIBUTION & PROCESSING
- efficiency
- reduce environmental footprint
- post-harvest
- food safety
- nutrition

CONSUMER & MARKETS
- preferences
- nutrition
- health
- vitality of rural communities
- impacts on urban systems
Funding
USDA Agencies

Under Secretary for Research, Education, and Economics

- Forest Service
- Natural Resources Conservation Service

- Farm Service Agency
- Foreign Agricultural Service
- Risk Management Agency

- Rural Utilities Service
- Rural Housing Service
- Rural Business Cooperative Service

- Food and Nutrition Service
- Center for Nutrition Policy and Promotion

- Food Safety and Inspection Service

- Agricultural Research Service
- National Institute of Food and Agriculture
- Economic Research Service
- National Agricultural Library
- National Agricultural Statistics Service

Library
- National Agricultural Statistics Service
2013 Outlays

*Includes Rural Development, Research, Food Safety, and Marketing and Regulatory functions
Research, Education & Econ

2013 REE Budget Authority
Total = $2.6 Billion

- NIFA 48%
- ARS 42%
- ERS 3%
- NASS 7%
National Institute of Food & Agriculture

Mission: To advance knowledge for agriculture, the environment, human health and well being, and communities

Program leadership to identify, develop, and manage programs to support university-based and other institutional research, education, and extension activities.

Fair, effective, and efficient administration of Federal assistance implementing research, education, and extension awards and agreements.
NIFA Budget

Budget Authority

<table>
<thead>
<tr>
<th></th>
<th>2011 Enacted</th>
<th>2012 Enacted</th>
<th>2013 Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory</td>
<td>1219</td>
<td>1207</td>
<td>1244</td>
</tr>
<tr>
<td>Discretionary</td>
<td>137</td>
<td>146</td>
<td>27</td>
</tr>
</tbody>
</table>

[$ Millions

$0 $200 $400 $600 $800 $1000 $1200 $1400 $1600

0 2011 Enacted 2012 Enacted 2013 Budget

Mandatory

Discretionary
NIFA Budget

Budget Authority

<table>
<thead>
<tr>
<th></th>
<th>2011 Enacted</th>
<th>2012 Enacted</th>
<th>2013 Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
<td>660 (Mil)</td>
<td>661 (Mil)</td>
<td>654 (Mil)</td>
</tr>
<tr>
<td>Competitive</td>
<td>679 (Mil)</td>
<td>675 (Mil)</td>
<td>590 (Mil)</td>
</tr>
</tbody>
</table>
NIFA Outlays: Fields of Science

Total Expenditures (2000-2006)

- Biological: 76%
- Engineering: 5%
- Other Physical: 8%
- Social & Behavioral: 11%

Other

Total Expenditures (2000-2006)
Agriculture & Food Research Initiative

$264M appropriation in FY 2012

Funds basic and applied research, education, and extension

In 2012, ~$70M will support Foundational Programs

- Plant health and production and plant products
- Animal health and production and animal products
- Food safety, nutrition, and health
- Renewable energy, natural resources, and environment
  - Agriculture systems and technology
- Agriculture economics and rural communities

In 2012, ~$200M expended in five USDA Challenge Areas

- Keep American agriculture competitive while ending world hunger
- Improve nutrition and end child obesity
- Improve food safety for all Americans
- Secure America’s energy future through renewable biofuels
- Mitigate and adapt agriculture to variations in climate
Ag Systems & Technology

Legislative description

- New uses and products from traditional and nontraditional crops, animals, byproducts, and natural resources
- Robotics, automation, precision and geospatial technologies, energy efficiency, computing, and expert systems
- New hazard and risk assessment and mitigation measures
- Water quality and management and irrigation

Two individual programs

- Engineering, Products, and Processes
- Nanotechnology for Agricultural and Food Systems

Grant awards up to $500K, and up to five years duration
Ag Systems & Technology

**Engineering, Products, and Processes**

- Enable computing and information systems to collect, manage, interpret and apply geospatial information about factors such as crops, soils, pests, invasives, animal and plant diseases, and climate to assess and mitigate risks, protect water quality, and manage water use
- Contribute to improved animal welfare through enhanced or alternative housing, transport, or harvest systems
- Refine agricultural and forestry systems that balance economic, environmental, and social outcomes

**Nanotechnology for Agricultural and Food Systems**

- Novel uses and high value-added products from nano-biomaterials of agricultural origins for food and non-food applications
- Nanoscale-based sensing mechanisms and devices for reliable early detection of diseases and monitoring physiological biomarkers for optimal production
- Precision agriculture technologies including applications of agricultural chemicals and water resources, and water quality improvements
### Biomass Research & Development Initiative

<table>
<thead>
<tr>
<th>Joint USDA/DOE Program focused on advanced biofuels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Funding</strong></td>
</tr>
<tr>
<td>• Range: $3M - $7M</td>
</tr>
<tr>
<td>• USDA contribution - FY 2011 $30M, FY 2012 $40M</td>
</tr>
<tr>
<td>• DOE contribution - FY 2011 $5M, FY 2012 $??</td>
</tr>
<tr>
<td><strong>Interest in:</strong></td>
</tr>
<tr>
<td>• Small-scale processing</td>
</tr>
<tr>
<td>• Rural-based processing and manufacturing</td>
</tr>
<tr>
<td>• Biobased industrial products</td>
</tr>
<tr>
<td><strong>Required integration of:</strong></td>
</tr>
<tr>
<td>• Feedstock development/production, feedstock logistics</td>
</tr>
<tr>
<td>• Feedstock conversion, product development</td>
</tr>
<tr>
<td>• System analysis, e.g. life cycle analysis, impacts on food/feed supply</td>
</tr>
<tr>
<td><strong>Emphasis on:</strong></td>
</tr>
<tr>
<td>• Demonstration projects</td>
</tr>
<tr>
<td>• Consortia of institutions, disciplines, and technologies</td>
</tr>
</tbody>
</table>
Biomass Research & Development Initiative

DOE Office of Biomass and Golden Field Office administer pre-application process

Approximately 248 pre-applications reviewed for 2011

51 pre-applications invited

USDA-NIFA administers the invited full application process

Awards anticipated in February/March 2012
FY 2012 solicitation announced March 2012
Small Business Innovation Research

Research for the development of a profit-making technology, product, or service

- Two-phase program - feasibility and development
- $100,000 (Phase I); $400,000 (Phase II)
- Small businesses of 500 employees or less
- 2.5% set-aside of USDA extramural funding for research

Topic areas

- Forests and Related Resources
- Plant Production and Protection - Biology
- Animal Production and Protection
- Soil and Water Resources
- Food Science and Nutrition
- Rural Development
- Aquaculture
- Biofuels and Biobased Products
- Small Mid Size Farms
- Plant Production and Protection - Engineering
National Robotics Initiative

The realization of co-robots acting in direct support of individuals and groups

- Manufacturing; exploration; discovery; agriculture; security; ...
- NSF, NIH, NASA, USDA, DoD, ...
- Five-year initiative
- No new money

Multi-agency RFP: Co-X Robots
- 680 LOIs for small projects / 445 proposals
- 67 LOIs for large projects / 261 proposals
NRI Details

Eligibility
- NSF: Restricted
- USDA/NIFA: (1) State agricultural experiment stations; (2) colleges and universities (including junior colleges offering associate degrees or higher); (3) university research foundations; (4) other research institutions and organizations; (5) Federal agencies, (6) national laboratories; (7) private organizations or corporations; (8) individuals who are U.S. citizens, nationals, or permanent residents; and (9) any group consisting of 2 or more entities identified in (1) through (8). Eligible institutions do not include foreign and international organizations.

Project classes
- Small: $100-$250K/yr in direct costs for 1-5 years
- Large: $250K-$1M/yr in direct costs for 1-5 years

Indirect costs
- USDA: Restricted (30% of request)
- NSF, NIH, NASA: Full negotiated rate
NRI Technology Space

- Cognition: Learning, Knowledge representation, Planning, Navigation
- Networked Multi-Agent
- HW/SW Architecture platforms – Mechanisms, Control, Modeling
- Mobility: legged, wheeled, aquatic, aerial
- Intelligent Co-Robot
- Sensors & perception
- Human-robot interaction: physical & social, language & communication
- Manipulation: Haptics, Tactile
- Exo-skeleton augmentation
- Soft structures

- Smart structures and environments
- Cognitive prosthetics
NRI Application Space

Co-Defender
- Monitoring Inspection
- Intelligent Transportation
- Unmanned Vehicles
- Medical Surgery

Robust Intelligent Robot

HR Interface
- Logistics
- Manufacture & Automation Macro
- Manufacture & Automation Micro/Nano

Services
- Security

Co-Inhabitant
- Co-Explorer
- Co-Worker

Co-Explorer
- Rehab Orthotics Prosthetics
NRI Review

What is the intellectual merit of the proposed activity?

- How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of the prior work.) To what extent does the proposed activity suggest and explore creative, original, or potentially transformative concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

What are the broader impacts of the proposed activity?

- How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?
Robotics Priorities for Ag

High-Throughput Robotic Technologies. Examples include the following areas:

- Automated systems for inspection, sorting, processing, or handling of animal or plant products (including forest products) in post-harvest, processing, or product distribution environments.
- Improved robotics for inspection, sorting, and handling of plants and flowers in greenhouses and nurseries, or for handling (e.g., sorting, vaccinating, deworming) large numbers of live animals.
- Multi-modal and rapid sensing systems for detecting defects, ripeness, physical damage, microbial contamination, size, shape, and other quality attributes of plant or animal products (including forest products), or for monitoring air or water quality.

Multi-Agent Command, Coordination, and Communication. Examples include the following areas:

- High-level task planning, execution, and control systems for spatially distributed autonomous or semi-autonomous robots that operate in concert with human co-workers.
- Communication protocols and standards for inter-agent coordination and unattended collaboration.
- Distributed intelligence and fault tolerance that will allow high-level task completion despite failure of one or more agents.
Robotics Priorities for Ag

**Dexterous Manipulators with Tactile Feedback.** Examples include the following areas:

- Vision-directed robotic arms that can distinguish targets within complex natural crop environments, e.g., tree canopies, vines, beds.
- Dexterous end-effectors that can harvest/handle fruits, vegetables, plants, or animals with appropriate force and motion for proper extraction and to minimize damage.
- Programmable and versatile end-effectors that can perform a variety of vision-based, fine motor-skill tasks, e.g., pruning, thinning, spraying, in different crop environments.

**Robotic Co-Worker Assistive Technologies.** Examples include the following areas:

- Full or partial worker exoskeletons that will improve worker strength, reach, or speed, or will help reduce worker fatigue or injury risk.
- Assistive robotic structures or platforms that increase worker productivity and/or improve safety.
- Universal design of assistive technologies for use in off-road, uneven, or obstacle-laden environments by workers with mobility limitations.
Specialty Crop Research Initiative

- $230 million in mandatory funding 2008-2012
- Research and extension
- Priority given to multi-state and multi-institutional projects
- 100% non-federal match requirement
- Address the critical needs of the specialty crop industries by developing and disseminating science-based tools to address needs of specific crops and their regions
Specialty crops are defined in law as fruits and vegetables, tree nuts, dried fruits, and horticulture and nursery crops, including floriculture.
SCRI Legislation

Five focus areas (10% of funds in each area)

- Research in plant breeding, genetics, and genomics to improve crop characteristics
- Efforts to identify and address threats from pests and diseases, including threats to specialty crop pollinators
- Efforts to improve production efficiency, productivity, and profitability over the long term (including specialty crop policy and marketing)
- New innovations and technology, including improved mechanization and technologies that delay or inhibit ripening
- Methods to prevent, detect, monitor, control, and respond to potential food safety hazards in the production and processing of specialty crops, including fresh produce
The Problem-Solving Enterprise: Systems Approach

A systems approach is any process of estimating or inferring how local policies, actions, or changes influence the state of the neighboring universe. It is a framework that is based on the belief that the component parts of a system can best be understood in the context of relationships with each other and with other systems, rather than in isolation. The only way to fully understand why a problem or element occurs and persists is to understand the part in relation to the whole.
The Problem-Solving Enterprise: Transdisciplinary Teams
## SCRI 2008-2011 Results

<table>
<thead>
<tr>
<th>Year</th>
<th>Avail $$</th>
<th>PB</th>
<th>PM</th>
<th>PP&amp;PE</th>
<th>Tech</th>
<th>FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>28.4M</td>
<td>3.8 (13%)</td>
<td>4.8 (17)</td>
<td>10.4 (37)</td>
<td>6.1 (22)</td>
<td>3.2 (11)</td>
</tr>
<tr>
<td>2009</td>
<td>46.7</td>
<td>8.5 (18)</td>
<td>12 (26)</td>
<td>14 (30)</td>
<td>7.2 (15)</td>
<td>5 (11)</td>
</tr>
<tr>
<td>2010</td>
<td>46.7</td>
<td>9.2 (20)</td>
<td>11.3 (25)</td>
<td>14.2 (30)</td>
<td>6.5 (15)</td>
<td>4.8 (10)</td>
</tr>
<tr>
<td>2011</td>
<td>46.5</td>
<td>10.9 (23)</td>
<td>10.8 (23)</td>
<td>13.2 (28)</td>
<td>5.2 (11)</td>
<td>6.4 (14)</td>
</tr>
<tr>
<td>Total $$</td>
<td>170.0</td>
<td>34.0 (20)</td>
<td>39.1 (23)</td>
<td>52.6 (31)</td>
<td>25.0 (15)</td>
<td>19.2 (11)</td>
</tr>
</tbody>
</table>
Finally…

R&D is a very small portion of overall USDA expenditures

Within NIFA R&D, engineering has traditionally received the smallest piece of the pie

More grant programs include engineering components

A number of NIFA grant programs are supporting large, collaborative projects

Upcoming Farm Bill (research title) and annual budgets will have a large impact on engineering R&D