Current Sensor Research and Future Needs in Agriculture, Natural Resources, and Food Systems

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The U.S. Dept. of Agriculture, initially established in 1862, has grown over time to include a diverse set of 17 agencies responsible for: conservation programs; farm subsidy programs; nutrition assistance programs; animal, plant and grain inspection; and agricultural research, education and extension (REE). These REE activities account for approximately 12% of USDA's discretionary budget and 2.5% of its total budget authority. The mission of USDA's National Institute of Food and Agriculture (NIFA) is to serve as the federal partner in agricultural REE at land-grant institutions. The latter include universities established in 1862, historically African-American colleges and universities, and Native American institutions. Despite NIFA's land-grant partnership role, the agency also works closely with other federal agencies (within and beyond USDA), non-profit associations, professional societies, commodity groups and grower associations, private industry, citizen groups, and foundations.

NIFA is also the principal extramural research agency in USDA, with programs aligned primarily within four sub-institutes. Annually, approximately one-half of the agency's $1.25B budget authority is used to support competitive grants and the other half, capacity-building programs at land-grant institutions. In recent years, total competitive grant funding has been approximately $680M, which also includes several mandatory competitive grant programs. Grant program eligibility varies by program, but it is often very broad and can sometimes include federal labs, businesses, individuals, and any academic institution. Unlike many other federal research agencies, NIFA has more than 100 different funding authorities, with about 60 of those having appropriated budget dollars at any point in time. Except for the Agriculture and Food Research Initiative, most funding authorities target very specific agricultural issues, e.g., integrated pest management, water quality, organics, specialty crops, biomass, etc. Some grant programs fund research-only projects, some extension only, some education only, and some programs fund projects that integrate various combinations of those functions. Because of issue-based budget authorities, R&D related to sensors is diffused throughout a number of agency competitive grant programs. Furthermore, because individual program priorities can, and often do, change from year to year, the suite of programs that support sensor R&D shifts frequently, as does the funding level.

Of the capacity funds allocated to land-grant institutions, some are used by faculty to support investigator-directed sensor research. Additionally, 25% of research capacity funds allocated to 1862 land-grant institutions must support multi-state projects. There is a formal structure for the portfolio of multi-state projects and most are renewed every five years. A number of these projects bring faculty together to work on sensor R&D for agricultural issues. NIFA capacity funds currently support sensor research within approximately 900 projects, either investigator directed or faculty participation in multi-state projects.

The largest component of NIFA's competitive grant portfolio is the $280M Agriculture and Food Research Initiative (AFRI). This Initiative includes a set of foundational programs (up to $500K per grant), a set of challenge area programs (much larger grants), and a fellowship grants program (up to $150K). Each of these program areas can support sensor research (depending on current program priorities), but often not in isolation from the biological or physical sciences or without clear application to agriculture.

Two programs supported by mandatory funds are worth noting. The $60M Specialty Crop Research Initiative supports research and extension in a number of focus areas that could, and often do, incorporate sensor engineering and technology. The $20M Organics Research and Extension Initiative places less emphasis on technology, but can also fund some sensor research. Neither of these programs supports research-only projects however; extension/outreach must be included.

A small number of other grant programs could fund projects that included a sensor component as part of a broader research effort. NIFA also operates the USDA Small Business Innovation Research program, in which at least five of the 13 topic areas could support sensor R&D.

The concept of "big data" has become a hot topic in many different settings in both public and private sectors. Agriculture is one of those sectors where data are collected, but then are often discarded or stored with limited accessibility, or underutilized. As more agriculture-related sensors come on line, we need to ensure that they collect data at the correct scale and frequency so that data analytics can be usefully applied. This could have application to understanding climate change impacts, food traceability, regional pest pressures, water resources, and many other important issues.

Unmanned vehicle systems (UVS)—ground, air, and aquatic—will have a growing influence on our lives. Driver-assist technologies in automobiles are rapidly moving this robotics agenda forward. For UVS to be useful in agriculture, however, will require greater sensor capability. Mobility of UVS, alone, will demand control-linked sensors and environment sensors. Payload sensors will provide vision capabilities, sensing of chemicals and biologics, and sensor-driven actuators.

Controlled-environment food production systems (e.g. green houses, vertical farms) can allow us to grow food using less land, water, chemicals, energy, etc. and do so closer to the consumer. However, such intense agriculture will require sophisticated sensors for monitoring and control of many plant, animal, and growth environment conditions, as well as overall facility management.

As noted in several places above, sensors without links to control systems or without backend data analysis or decision making will only be curiosities rather than useful technologies. Sensors systems must include tight coupling to, and well thought-out, companion hardware and software. In agriculture, it is often crucial that such "systems" are co-developed and designed with the uniqueness, nuances, and vagaries of the end application in mind.