IoT4Ag™

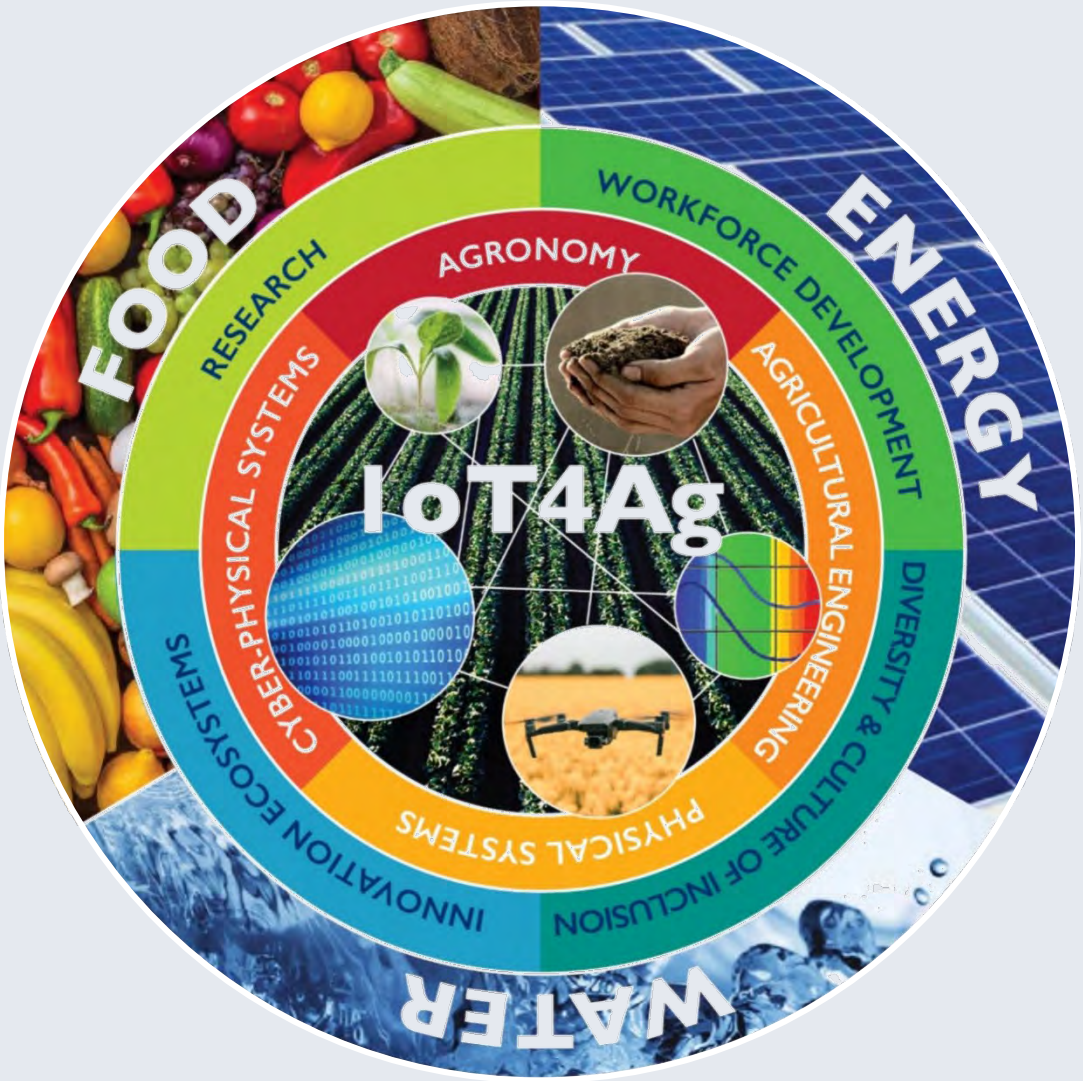
NSF ENGINEERING RESEARCH CENTER
FOR THE INTERNET OF THINGS
FOR PRECISION AGRICULTURE

NSF

Established 2020

Strategic Plan and 90-day Deliverables

Create and translate to practice precision agriculture technologies to ensure food, energy, and water security



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VISION: SUSTAINABLE, HIGH-OUTPUT PRECISION AGRICULTURE

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.

NEED: FOOD, ENERGY, AND WATER SECURITY

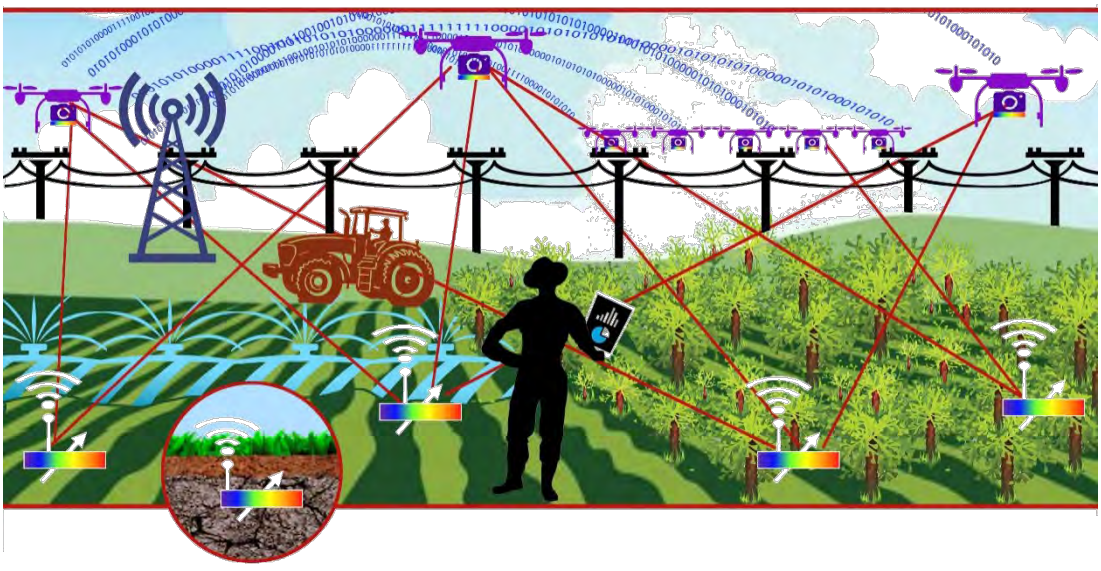
By 2050, the US population is estimated to grow to 400 million and the world population to 9.7 billion. Current agricultural practices account for 70% of global water use, energy use is one of the largest costs on a farm, and inefficient use of agrochemicals is altering Earth's ecosystems. With finite arable land, water, and energy resources, ensuring food, energy, and water security will require new technologies to improve the efficiency of food production, create sustainable approaches to supply energy, and prevent water scarcity.

MISSION: TRANSFORM THE FUTURE OF AGRICULTURE

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.

SOLUTIONS: BREAKTHROUGH IoT TECHNOLOGY AND PRACTITIONERS

IoT4Ag will create novel, integrated systems that capture the microclimate and spatially, temporally, and compositionally map heterogeneous stresses for early detection and intervention to better outcomes in agricultural crop production. The Center will create internet of things (IoT) technologies to optimize practices for every plant; from sensors, robotics, and energy and communication devices to data-driven models constrained by plant physiology, soil, weather, management practices, and socio-economics.



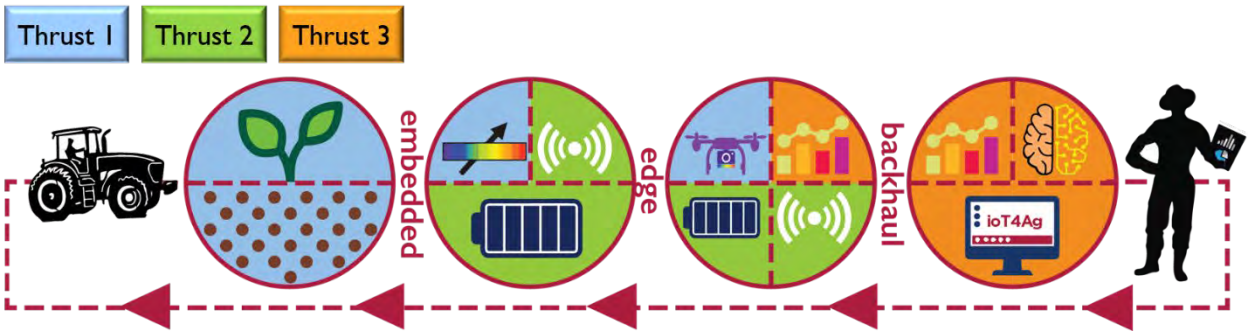
Diverse participant groups will be well-prepared through IoT4Ag educational and inclusion programs to have strong science and engineering knowledge and to establish a workforce able to discover, innovate, translate, and practice precision agriculture solutions. The Center will form an innovation ecosystem and network with academic, industry, investment, and government partners to collaboratively build the future of precision agriculture.

IOT4AG WILL DELIVER MORE CROP FOR EVERY DROP OF WATER AND JOULE OF ENERGY TO ENSURE A FOOD, ENERGY, AND WATER SECURE FUTURE!

CONVERGENT RESEARCH

Monitoring of agricultural crops is still accomplished primarily through the expensive, labor-intensive, and time-consuming process of crop scouting, by manual sampling and documenting the state of the field. Precision agriculture involves the use of technology to acquire and analyze data from the field. However currently technologies such as sensors are limited or non-existent to spatially, temporally, and compositionally monitor the state of the field, data is coarse-grained and siloed in equipment, communications infrastructure is limited or non-existent on the farm, and interventions are reactive and over-provisioned, increasing economic and environmental costs. While the concept of precision agriculture has existed for 30 years, *the exponential growth in information technology and data science and the reduction in their cost is setting the stage for the next revolution in agricultural practices.*

The IoT4Ag team unites a convergence of expertise in agronomy, agricultural engineering and economics, and environmental science and in the science and engineering of physical and cyber-physical systems. The Center is structured into three thrusts that vertically integrate fundamental knowledge and technology from different disciplines and that are horizontally integrated to achieve next-generation engineered systems for agriculture.



Thrust 1: Agricultural sensor systems will design and manufacture resilient, networked, intelligent sensor-robotic systems that monitor the state of plant and soil health over extended areas. Thrust 1 will address fundamental scientific questions to uncover how the complex system of abiotic and biotic variables affect crop yield and resilience, and with this knowledge design technologies and systems that will be deployed with the spatial, temporal, and compositional resolution needed to capture the state of the field.

Thrust 2: Communication and energy Systems will enable advanced approaches for powering IoT devices and robots in the field and for data communication from heterogeneous platforms of sensors, robots, and farming equipment. Thrust 2 will establish the knowledge and technologies specifically needed in agriculture, from powering devices and communicating from below the soil surface to deploying technologies at field scales.

Thrust 3: Agricultural response systems will create and deploy smart response systems that are driven by machine learning and decision-based models for precision agriculture. Thrust 3 will create techniques to manage uncertainty and fuse the spatially, temporally, and compositionally heterogeneous data from the field to collect not just more, but better data. The Thrust will build models, constrained by the biophysics of plants in agricultural fields, to establish a decision-Ag interface for growers to intelligently manage their fields in a cost-effective manner.

IoT4Ag Breakthrough Technologies

- Multi-mode, low-cost, distributable, environmental and soil sensor technologies
- Autonomous aerial and ground-based robots
- Energy storage and delivery technologies for field-scale operation
- Ag-specific communications
- Biophysically-constrained data analytics to produce decision Ag interventions and improve outcomes in agricultural fields

IoT4Ag Testbeds

IoT4Ag 'sense-communication-response' technologies will be evaluated in two Testbeds: Integrated Systems for Precision Farming of 1) Tree Crops and 2) Row Crops. These testbeds will be used to assess and demonstrate IoT4Ag solutions in the different agricultural environments of orchards and row crops, many of which are mainstays of the food supply chain. IoT4Ag technologies will be deployed in fields in phases from control facilities to plot and field scale university testbeds and then to our industry and agricultural partners.

LOGIC MODEL – CONVERGENT RESEARCH

INPUTS & RESOURCES	ACTIVITIES	OUTPUTS	OUTCOMES		
			SHORT-TERM	MEDIUM-TERM	LONG-TERM
•NSF funding and ERC program resources •Excellent faculty; undergraduate, graduate, and postdoctoral Fellows; and staff •State-of-the-art PI research laboratories and shared experimental and cloud and edge computing facilities •Existing and innovative science and technologies; data; and tools, and methods from different disciplines •Agricultural extension campuses with row and tree crop control, plots, and field and orchard-scale instrumented testing facilities, representing the diversity of crops and agricultural environments in the US •Scientific advisory board members •Existing and new relationships with industry members, government and innovation partners, and the end-user community of growers joining our industry practitioner and Ag-systems advisory boards	•Use current and create new IoT sensors for high-resolution, multi-mode sensing of plant and environmental targets •Construct an autonomous robotic fleet to map targets in unstructured fields at scale •Design, fab and test bio-degradable IoT battery, antenna •Optimize waveforms for rural and agricultural communication networks •Investigate rapid recharging of and high-power density batteries •Generate robust, interpretable, interoperable analysis for data with different spatial and temporal resolutions •Implement active learning for uncertainty reduction in agricultural situational awareness •Use biophysical models to constrain and train machine learning models •Integrate all thrust technologies in a system •Evaluate technologies in control, plot, and field testbeds and with industry and grower groups	•Reliable, accurate, multi-mode sensor systems distributable at field scales for early detection of biotic/abiotic targets affecting crop yield and resiliency •Hardware-software tools for mapping and fusing chemical and physical data on targets above and below the soil surface •Ag-specific edge and backhaul communication technologies •Powers sources for field-scale deployment of IoT sensors and robot fleets •Data sets and software for use in research and adaptable to production for model development, training, calibration, or decision making •Data-driven decision and control systems for agricultural response •Control, plot, and field testbed protocols for system evaluation •Cost-effective, integrated Ag sense-communication-response systems •Studies of the socio-economic benefit of precision Ag	•Knowledge of technology requirements through guidance from our stakeholders composed of industry members, government and innovation partners, and growers •Disciplinarily diverse experts create new research and development opportunities •Advances in knowledge of plant, environmental, device, and data science and engineering •Creates innovative sensor, robotic, power, and communication technologies and new biophysically-constrained models, controls, and software interfaces to advance Ag practices •Produces publications, patent applications, copyrights, and new industry collaborations •Recognized as a global leader in sense-communication-response systems for agriculture, and commercial innovation through technology transfer	•Academia – government – industry partnership shortens the cycle to define-develop-deploy IoT4Ag systems •Increased number and types of measurable and interpretable plant and environmental targets, and increased areas and resolution in mapping •Higher data rate and longer-range communications with more coordinated robotic and farm machinery platforms; Ag-use case included in future communication standards •Better quality data for precision and scalable analytics and risk-aware interventions •Increased crop yield and quality from deployment of IoT4Ag systems, benchmarked against current industry methods •IoT4Ag builds on knowledge and technologies to receive additional funding from federal, state, philanthropic, or industry sources •Research yields new educational resources and tools	•Multidisciplinary Ag–Tech research is sustainable and growing, and broadens the impact of IoT in other sectors •Known best practice example of convergent research driving new knowledge and innovative technologies and systems for the benefit of society •Help realize the "NSF 10 Big Ideas" in Understanding the Rules of Life, Harnessing the Data Revolution, Mid-scale Research Infrastructure, and Growing Convergence Research •Deployed automated, integrated systems for early detection and intervention that transform agricultural practices •Increased efficiency of energy, water, and agrochemical use in farming establishing sustainable agricultural processes •Increased production of high-quality crops for greater US and global food security and higher profitability of farms •US is the global leader in precision agriculture

WORKFORCE DEVELOPMENT

IoT4Ag will prepare diverse groups of pre-college, community college, and university students and agricultural professionals through national and international partnerships with educational institutions, museums, and organizations and *via* our industrial practitioner and Ag-systems advisory boards.

Pre-College Education: Faculty, students, and staff at all university partners sites will co-develop audience-specific lesson plans, hands-on labs and kits, and exhibits to increase K-12 STEM interest and competency.

Community College Education: The Center will engage students pursuing certificates and two-year degrees in fields related to precision agriculture at Community College partner institutions through guest lectures and technology demonstrations, hands-on laboratory activities, field demonstrations, and research experiences. IoT4Ag aims to increase the knowledge and pipeline of Ag and engineering students *via* education and training in innovative Ag technologies.

University Education: IoT4Ag will educate undergraduate and graduate students and postdoctoral fellows to prepare Ag – Tech leaders through collaborative co-education and co-training in and across our classrooms, labs, and agricultural research and education extension facilities, and with international partners. The Center will create and deliver multi-disciplinary educational activities, mirroring our disciplinary diversity and convergent research, through virtual and in-person bootcamps, coursework, professional development, international exchange, intra-ERC research exchange, and research experiences.

Professional Education: The Center will increase precision agriculture technology competency of the end-user community of growers and support certification of Ag professionals through our Ag-systems advisory board and in cooperation with university and state Extension Facilities located near Merced, Purdue, and UF. IoT4Ag will contribute to end-user development by creating educational materials for Certified Crop Advisor (CCA) training, for tech service industry and extension agent training, and for transferring IoT4Ag technologies to growers.

LOGIC MODEL – WORKFORCE DEVELOPMENT

INPUTS & RESOURCES	ACTIVITIES	OUTPUTS	OUTCOMES		
			SHORT-TERM	MEDIUM-TERM	LONG-TERM
•NSF funding and ERC program resources •Talented and dedicated university faculty and staff •Excellent research and teaching facilities •K-12 teachers and museum coordinators committed to STEM education •Existing relationships with under-represented K-12 and university organizations •Partnerships with Ag-focused community college programs •High quality undergraduate and graduate programs •Agricultural extension agents focused on bringing new technologies to growers •Growers seeking to improve crop production •Existing international exchanges and training programs focused on agriculture •WFD advisory board members	•Exhibits, kits, and outreach modules for schools, organizations, and museums •High school student and teacher research internships and programs •Community college course modules and mentoring partnerships •Cross-institutional university courses and training •New research opportunities for graduate students and postdocs •Professional development workshops for graduate and undergraduate students •Professional education for growers through Ag-extension programs •Test location field days •International exchanges	•50,000+ pre-college and community college students participating in IoT4Ag lessons, exhibits, and labs •100+ high school students and teachers and community college and undergraduate student research experiences •500+ undergraduate IoT4Ag research/design projects •500+ cross-institutional, IoT4Ag course units taken by students •75+ PhD and postdoctoral Fellows trained to tackle the interdisciplinary challenge of food, energy, and water security •50+ Fellows participating in intra-Center and international exchanges •40+ professional development workshops for undergraduate and graduate students and postdoctoral fellows	•New programs to engage pre-college, community college, undergraduate and graduate students, and agricultural professionals •Development of strong partnerships for education and exchange between K-12 institutions, community colleges, universities, and agricultural industries and growers •Convergence of disciplinarily and demographically diverse students begin to collaborate through technical and professional co-educational programs and to acquire current and future workforce needs	•Mature programs deepen and broaden the interests of students at all levels •Incorporation of IoT4Ag research into community college and university courses •Increased numbers of students entering and graduating from community colleges prepared for careers in precision agriculture •Farmers trained and beginning to incorporate IoT4Ag technologies in agricultural crop production •Partnerships among stakeholders expand and strengthen to address current and future workforce needs •Increasing numbers of URM students participating in IoT4Ag outreach and research activities	•Sustainable programs continue to increase student interest and competency in STEM •Modules, lessons, and labs, and other new pedagogical tools adopted by organizations outside of IoT4Ag •Increased flow of diverse students entering and graduating from community colleges and universities prepared for careers in precision agriculture and in sectors benefitting from IoT technologies •IoT4Ag training increases the competency of Ag-professionals and their adoption of technologies •Sustainable academia-industry-government partnerships ensure continued efforts to address future workforce needs •Help realize the "NSF 10 Big Ideas" in the Future of Work

DIVERSITY AND CULTURE OF INCLUSION

IoT4Ag is committed to creating, sustaining, and promoting a diverse community of students, scientists, and staff. As such, IoT4Ag recognizes value in creating its own Diversity and Culture of Inclusion (DCI) activities, while also leveraging resources and initiatives at all partner universities. DCI is a pipeline, which involves recruiting as a first step, followed by developing a climate that seeks to retain IoT4Ag members (from students to advisory board members), and creates an environment where all can thrive. DCI requires partnership with local programs to meet the needs of different student populations and center-wide programs to foster a sense of belonging to the IoT4Ag program and Center identity. Through continuous improvement, IoT4Ag successes will strengthen DCI for affiliated organizations and partners, and ultimately, the scientific community.

Recruiting: IoT4Ag will build on and establish partnerships with national scholars' programs and minority serving institutions and engage students by sharing IoT4Ag research, education, inclusion, and innovation at meetings of national, minority serving societies and organizations. The Center will create a new signature Pathway to PhD (PPP) program. PPP is a 2-day workshop and network building program designed to address the often-observed lack of awareness by under-represented minority (URM) and first-generation low-income (FGLI) students about graduate school. PPP will prepare students to apply to graduate programs and fellowships, and to connect students to faculty and peer mentors in support of their future.

Climate: The Center will initiate, organize, and monitor activities that aim to create and sustain a positive climate and an inclusive environment where all can thrive. To this end, the Center will create educational and training sessions/modules on topics related to implicit bias, sexual harassment, and conflict resolution (in workplace), and other topics. Hierarchical peer-to-peer (between graduate and undergraduate students) and faculty-student mentoring programs will be developed and assessed *via* triannual teleconference check-ins. The check-ins are intended to build a sense of belonging to the Center, and to facilitate a positive climate and inclusion. IoT4Ag will explore diversity and inclusion topics at its meetings and workshops, build and value diversity through social and professional gatherings, and feature IoT4Ag students, faculty, staff, and professionals on our webpage and through our newsletters and social media. In early CY2021, the DCI team will host implicit bias training for Center members, which will kick off the DCI training presentations that will be held quarterly.

LOGIC MODEL – DIVERSITY AND CULTURE OF INCLUSION

INPUTS & RESOURCES	ACTIVITIES	OUTPUTS	OUTCOMES		
			SHORT-TERM	MEDIUM-TERM	LONG-TERM
•NSF funding and ERC program resources •Students, teachers, faculty, and staff and partner K-12 institutions, community colleges, and universities •Existing relationships with minority serving institutions (MSIs) and national organizations •Existing and new relationships with industry members, government and innovation partners, and the end-user community of growers joining our industry practitioner and Ag-systems advisory boards •Student Leadership Council •DCI advisory board members •NSF ERC Gen 4 Cohort and DCI focus group	•Develop and implement DCI baseline measurements •Execute triannual check-ins with all participants and hierarchical peer and faculty mentoring •Develop DCI recruitment plans, materials, and activities •Recruit at minority serving institutions (MSIs), through national meetings & programs •Establish the Pathway to PhD Program (PPP) to bring undergraduates to IoT4Ag sites for a workshop supporting and encouraging their application to PhD programs and fellowships •Engage and feature members of the Student Leadership Council and DCI advisory board •Create DCI educational programs for all students, faculty, and staff participants •DCI annual assessment surveys •Provide academic and professional support •Develop a diversity, equity, and inclusion communication strategy *via* newsletters, our website, and social media	•50+ visits to MSI and national meetings •200+ URMs and women undergraduate, graduate, and postdoc participants in the IoT4Ag research program •20,000+ URM and women undergraduate participants in IoT4Ag outreach activities •1000+ student participants in the PPP program •50+ educational programs on diversity, equity, and inclusion •20+ IoT4Ag climate surveys •100+ DCI features of people, programs, and successes showcased on the DCI page of the IoT4Ag website and in the quarterly newsletters •20+ contributions to the NSF ERC DCI focus group •5+ proposals submitted to support DCI programming •5+ publications in academic and non-academic journals to disseminate findings/results from DCI practices and organizational behavior	•Good practices and strategies for equitable recruiting and effective mentoring at university partner sites •New programs to engage diverse pre-college, community college, undergraduate and graduate students in STEM •Diverse perspectives from traditionally underrepresented groups enhance IoT4Ag research, education, and innovation •Center contributions to monthly NSF ERC DCI focus group meetings and initiatives •Awareness of exemplary practices	•Increasing numbers of URM students participating in IoT4Ag outreach and research activities •Predictable, productive relationships with MSIs •Institutionalization of IoT4Ag best practices leading to increased (against baseline) awareness and practice of diversity, equity, and inclusion amongst university and partner organizations •IoT4Ag center-wide, embedded culture of inclusion and measurable sense of belonging from traditionally underrepresented groups •IoT4Ag Center reputation for advancing diversity, equity, and inclusion in engineering research •Expanded DCI programs and cohesion into research, WFD, Innovation, and other initiatives	•Transformative changes to equity in science and engineering, especially at the graduate level •Sustained increase in the number of URMs and women applying, recruited, and retained •Parity in student satisfaction with educational experience, retention, and graduation •Increased flow of diverse students entering and graduating from community colleges and universities prepared for careers in precision agriculture and in sectors benefitting from IoT technologies •Sustainable partnerships to ensure continued efforts to address the future of diversity, equity, and inclusion •DCI practices sustained post-ERC funding •Publications (peer reviewed, trade, and outreach) cited •Contribution to realizing the "NSF 10 Big Ideas" in NSF INCLUDES

INNOVATION ECOSYSTEM

IoT4Ag will develop a vibrant innovation ecosystem that will engage our industrial, government, non-profits, innovation partners, and the end-use grower community in guiding the direction of Center research, workforce development, and diversity and inclusion activities. We will establish two bodies for outside stakeholders: the normal ERC industrial/practitioner advisory board (IPAB), but also an Ag systems advisory board (ASAB) that will help balance "tech push" vs. "industry pull". This ecosystem will also ensure transfer of knowledge and technology from IoT4Ag university labs to application through entrepreneurship and commercialization by industry partners and adoption by growers. Engagement with our IPAB and ASAB partners throughout the life cycle of IoT4Ag research, from problem definition to evaluation and deployment of our systems to technology transfer, is essential to maximize impact of the Center. Early and frequent engagement of IPAB and ASAB partners in research, education, inclusion, and innovation will ensure IoT4Ag pursues research that has a clear value proposition for industry and that is well-suited for commercialization and adoption by the farming community, and that IoT4Ag educates a diverse workforce to create, translate, and put to practice the Center's technologies.

Industrial/Practitioner Advisory Board: We have recruited and will continue to pursue industrial, government, and innovation partners with interests that align with each of the three thrusts, spanning agro-science, technology, and protection; sensor, communication, and energy devices; robotics; and data science and decision-making in food, energy, and water security.

Ag Systems Advisory Board: The Board will include representatives from farming associations, commodity producer boards (row, vegetable, fruit and nut crops), crop consultant associations, farm cooperatives with precision Ag advisors, and Ag and horticulture extension agents.

LOGIC MODEL – INNOVATION ECOSYSTEM

INPUTS & RESOURCES	ACTIVITIES	OUTPUTS	OUTCOMES		
			SHORT-TERM	MEDIUM-TERM	LONG-TERM
•NSF funding and ERC program resources •Excellent faculty; undergraduate, graduate, and postdoctoral Fellows; and staff •State-of-the-art PI research laboratories and shared experimental and cloud and edge computing facilities •Existing and innovative science and technologies •Agricultural extension campuses with row and tree crop control, plot, and field and orchard-scale instrumented testing facilities, representing the diversity of crops and agricultural environments in the US •Existing and new relationships with industry members, government and innovation partners, and the end-user community of growers joining our industry practitioner and Ag-systems advisory boards •I-Corps/IUCRC sites •University tech-transfer offices and incubators •Background IP	•Disseminate IoT4Ag programming *via* webpage and social media •Marketing IoT4Ag and lead generation •Execute core research program and sponsored research projects •Create of IP •Research exchange and student – faculty – industry/government professional networking *via* IoT4Ag meetings, newsletters, workshops, short courses, and webinars •Industry and Ag-systems guided research project definition and field-scale deployments •Technology demonstrations at university testbeds and field days •Host industry members as visiting scientists at university partner sites •Student business plan development and senior design projects •Market research and competitive analysis	•10+ of marketing pieces and campaigns •1000's of impressions, new leads, and conversions •20 meetings with 60+ attendees, 35+ newsletters, and 30+ workshops-short courses-webinars •80+ research projects with 500+ students and 20 teachers supported •>$3M memberships fees received •20+ industry members, 10+ government and innovation partners in the industry practitioner advisory board •20+ end-user growers in the Ag-systems advisory board •50+ industry visiting scientists •5+ market reports •Patented and copyrighted technologies •A technology outlook and roadmap for precision agriculture	•Knowledge of technology requirements through guidance from our stakeholders composed of industry members, government and innovation partners, and growers •Collaborative exchange on technology outlook, to benchmark current trajectories and new technologies in the lab and marketplace for precision agriculture •Initiate IoT4Ag Technology Roadmap on Precision Agriculture •IoT4Ag is recognized as a global leader in sense-communication-response systems for agriculture, and our technologies spur commercial innovation	•Academia – government – industry partnership shortens the cycle to define-develop-deploy IoT4Ag systems •Benchmarking of IoT4Ag systems to current industry methods •Intellectual property disclosures, patent filings, and copyrights •Technology transfer to industry *via* licensing of IoT4Ag IP to industry •SBIR and investor backed start-up companies based on IoT4Ag technologies •IoT4Ag student fellows participate in internships and are hired upon graduation by industry members •Industry-driven sponsored projects •IoT4Ag builds on collaborations to receive externally funded joint university/industry awards (e.g., USDA, DARPA) •Refinement of IoT4Ag Technology Roadmap on Precision Agriculture	•IoT4Ag technologies are licensed by industry and its integrated systems are adopted by end users, transforming agricultural practices •Early IoT4Ag startup companies mature, and new ones are created •IoT4Ag partners in defining new standards for precision agriculture technologies and government policies and regulations •Increased profitability of industry members and growers •US is the global leader in precision agriculture •IoT4Ag technologies impact other business sectors

EVALUATION AND ASSESSMENT PLAN

The evaluation plan below updates the specific components of the evaluation that would be aligned with the program activities. The plan outlines the formative assessment, summative assessment, outputs, outcomes, and long-term impacts for each of the four pillars of IoT4Ag.

Pillars	Formative Assessment	Summative Assessment	Outputs	Outcomes	Long-term Impacts
Convergent Research	Monitoring development of Scientific Advisory Board and working with them to find their evaluative data needs	SWOT analyses by Scientific Advisory Board Documentation of research publications, presentations and technical Documentation of convergent research	Multi-mode sensor systems Hardware-software tools Ag-specific communication technologies Control, plot, and field testbed protocols # of publications/ presentations by IoT4Ag researchers	SWOT analysis report by Scientific Advisory Board Documenting technologies and knowledge developed for precision agriculture Increased crop yield and quality New educational resources and tools	Multidisciplinary Ag-Tech research Best practice in convergent research Automated, integrated systems for early detection and intervention that transform agricultural practices IoT4Ag technologies for precision agriculture
Workforce Development	Systematic tracking in database of all participants in IoT4Ag Working with workforce development committee on data collection designs and instrumentation	Annual student survey[1] Grad student Mentor survey Mentor interviews Longitudinal tracking of students' career progression in the field	# of K-12 students participating in IoT4Ag # of community college students participating in IoT4Ag # of undergraduate students participating in IoT4Ag # of graduate students participating in IoT4Ag # of students participating in cross-institutional IoT4Ag course units # of students graduating with PhD	Gains in knowledge and skills Increased awareness of careers in STEM Satisfaction with the quality of mentorship received Overall satisfaction with program experiences Retention and graduation rates Career placement SWOT analyses of Workforce Development Board	Partnerships expand and strengthen to address workforce needs Persistence year to year in the IoT4Ag program Graduation from an IoT4Ag university Job obtainment in industry Job obtainment in academia Ability to apply skills learned in IoT4Ag into career New courses and programs Pathway to PhD program

[1] Undergraduate students, graduate students, and post-docs complete the survey.

			# of fellows participating intra-Center and international exchanges # of students who obtain careers in industry # of students who obtain careers in academia # of lectures and technology demonstrations and demonstrations		
Diversity and Culture of Inclusion	Systematic tracking in database of all participants in IoT4Ag Working with diversity and culture of inclusion committee on data collection designs and instrumentation	Data reported for Workforce Development (outputs and outcomes) reported by underrepresented students Annual student survey on culture of inclusion [2]	# of URM and female students in programs # of URM and female students who progress in their IoT4Ag programs across years # of URM and female students who obtain careers in industry # of URM and female students who obtain careers in academia	Strong culture of inclusion (annual survey and focus groups) Gains in knowledge and skills for URM and Female students Increased awareness of careers in STEM for URM and Female students Increased motivation to pursue a career in STEM for URM and Female students Demonstration of a diverse and inclusive culture in STEM for URM and Female students Satisfaction with the quality of mentorship received for URM and Female students Satisfaction with program experiences for URM and Female students	Persistence year to year in the IoT4Ag program for URM and Female students Graduation from a IoT4Ag university for URM and Female students Job obtainment in industry for URM and Female students Job obtainment in academia for URM and Female students Ability to apply skills learned in IoT4Ag into career for URM and Female students

[2] Faculty, undergraduate students, graduate students, and post-docs complete the survey.

				SWOT analyses of Diversity and Culture of Inclusion Board	
Innovation Ecosystem	Monitoring development of Industry Advisory Board, innovation partners and government partners -- working with them to find their evaluative data needs Monitoring development of Agriculture Advisory Board and agriculture partners -- working with them to find their evaluative data needs	SWOT analyses of Industry Advisory Board SWOT analyses of Agriculture Advisory Board Documentation of collaborations with industry and agriculture	# of Industry collaborations – research and internships # of Government and innovation collaborations – research and internships # of agriculture collaborations # of patented and copyrighted technologies	SWOT analyses of Industry Advisory Board SWOT analyses of Agriculture Advisory Board Innovation awards and prizes Intellectual property and licensing Documentation of industry, innovation and government partners	Dissemination of intellectual property Collaborative community of industry partners Collaborative community of government and innovation partners Collaborative community of agriculture partners

CENTER GOVERNANCE MODEL AND ORGANIZATIONAL CHART

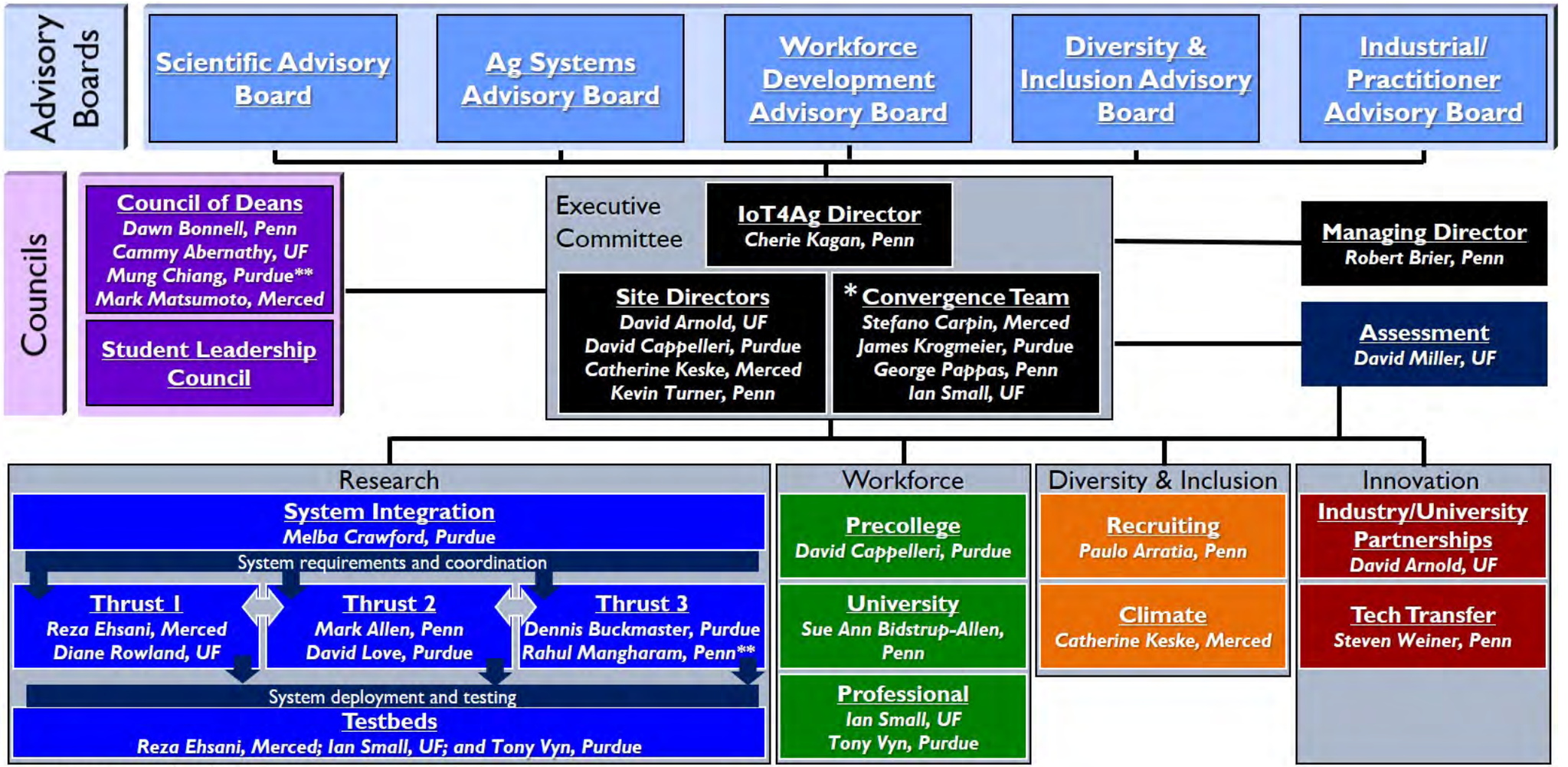
The Internet of Things for Precision Agriculture (IoT4Ag) Center is a partnership of four universities, including University of Pennsylvania (PENN) (primary), Purdue University, University of Florida (UFL) and University of California-Merced (UCM). The leadership team is led by the Executive Committee who will oversee and be ultimately accountable for the success of the IoT4Ag collaborative research program, university and pre-college education, diversity and inclusion activities that broaden participation, and innovation and industrial engagement activities across the four campuses. Research Systems Integration, Thrust, and Testbed leaders and the Workforce Development, Diversity and Culture of Inclusion, and Innovation Ecosystem Directors will be responsible for leading the Research, Education, Diversity and Inclusion, and Innovation Ecosystem enterprises. They will work with participating faculty, students, pre-college and community college partners, international partners, government and industry partners, and agricultural professionals and growers to meet IoT4Ag goals and milestones. These leaders and Directors will report to and be supported by Center Director and Site Directors. The Executive Committee will expand the leadership to include a Convergence team to represent the disciplinary and institutional diversity of the Center. The Convergence team will be rotated to broaden technical, institutional, and gender/racial participation of current and future IoT4Ag team members in the executive committee. The leadership team will be led from headquarters at PENN by Director Cherie Kagan and Administrative Director Robert (Bob) Brier, who will work collaboratively with the Site Directors.

The IoT4Ag leadership will work in partnership with its Councils and Advisory Boards selected to support the IoT4Ag mission, which are the following:

- Council of Deans
- Student Leadership Council
- Scientific Advisory Board
- Workforce Development Advisory Board
- Diversity & Inclusion Advisory Board
- Industrial/Practitioner Advisory Board
- Ag Systems Advisory Board

The detailed structures of the Councils and Boards are described in their Charters below. The Councils and Boards will advise, support, and two-way report to/from the IoT4Ag Executive Committee.

ORGANIZATIONAL CHART



- rotating membership
- ** George Pappas, Penn to serve as Thrust 3 co-leader while Rahul Mangharam on leave

INNOVATION ECOSYSTEM MEMBERSHIP AGREEMENT

IoT4Ag Engineering Research Center Industry Member Agreement

This IoT4Ag Engineering Research Center Industry Member Agreement ("Agreement") is made as of xxx ("Effective Date") between The University of Pennsylvania, a non-profit, tax-exempt educational institution organized and existing under the laws of the Commonwealth of Pennsylvania, with an address at Penn Center for Innovation, 3600 Civic Center Blvd, 9th Floor, Philadelphia, PA 19104-4310 ("PENN"), on behalf of the Center for the Internet of Things for Agriculture ("the Center"), and [NAME] a [TYPE OF ORGANIZATION] organized and existing under the laws of [INSERT], with an address at [INSERT] (referred to herein as an "[NAME]").

WHEREAS, PENN has received funding from the National Science Foundation ("NSF") to act as the "Lead Institution" under the Engineering Research Center ("ERC") program and has joined together with the University of Florida, University of California – MERCED, and Purdue University (each of which may be referred to herein individually an "Institution Member" or in any combination as "Institution Members", PENN and the Institution Members collectively being the "Core Institution Members") to establish the Center, headquartered at PENN for the purpose of stimulating industrial innovation in the area of precision agriculture; and

WHEREAS, the Center has also sought industry members such as [NAME] to support the Center (each of which may be referred to herein as an "Industry Member" or collectively as the "Industry Members"). The Industry Members and the Core Institution Members may each be referred to herein as a "Center Member" or collectively as the "Center Members"

NOW, THEREFORE, PENN and [NAME] ("Party" or "Parties") hereby agree to the following terms and conditions.

This Agreement shall be valid for an annual term beginning on the Effective Date and may be renewed on an annual basis by continued payment of the annual membership fee (the first such annual term following the Effective Date set forth above is referred to herein as the "Initial Term").

1. CENTER ORGANIZATION

1.1 Definitions

a. "Affiliate(s)" as used herein means companies, controlled by, controlling or under common control as a party to the Agreement, with control being defined as direct or indirect ownership of over fifty percent (50% of the outstanding voting securities of an entity).
b. "Center Director" as used herein means Professor Cherie Kagan ("Center Director"), a faculty member at PENN.
c. "Life of the Center" as used herein means from the Effective Date until the expiration or termination of the NSF award for the Center.
d. "Core Research" as used herein means research that the Executive Committee (as defined below) determines shall be: (a) conducted through the Center by faculty, students and staff from Core Institution Members, and (b) financially supported by funds from NSF ERC program, Core Institution Members *via* cost sharing, and from Membership Fees.

e. "Executive Committee" as used herein refers to the leadership of the Center, led by the Center Director (as defined below) and compromised of representatives from each of the Core Institution Members. The Executive Committee is responsible for management and administration of the Center under the direction of the Center Director, including addressing issues concerning the effectiveness of the Center and selecting, overseeing, and managing the Core Research to be conducted by the Center.

f. "IPAB" as used herein means the Industry and Practitioners Advisory Board. Every Industry Member can select a representative to serve on the IPAB. The IPAB is responsible for advising the Executive Committee on the direction of Core Research and the operational policies of the Center. The IPAB shall communicate with the Executive Committee via an Industrial and Practitioner Executive Committee ("IPEC") consisting of 10 members elected by the IPAB. The Executive Committee and the IPEC shall meet at least biannually. A quorum of the IPAB shall consist of a simple majority of the Industry Members. In all matters before the IPAB, each Industry Member shall be entitled to the number of votes indicated in the table of section 1.4 below and a simple majority is needed for any vote to pass. The meeting logistics and other operating procedures of the IPAB and IPEC are outside of this Agreement and will be determined separately by the IPAB.

g. "Research Results" as used herein means all data and information which are generated by or on behalf of a Core Institution Member in the performance of the Core Research during the term of this Agreement. Research Results expressly excludes Intellectual Property.

h. "Intellectual Property" as used herein means all inventions, whether patentable or not, conceived and first reduced to practice (as determined by United States patent law) by or on behalf of a Core Institution Member in the conduct of the Core Research, including all United States and foreign patent applications claiming said patentable inventions, including any divisional, continuation, continuation-in-part (to the extent that the claims are directed to said patentable inventions), and foreign equivalents thereof, as well as any patents issued thereon or reissues or reexaminations thereof. Intellectual Property also includes all significant copyrights and copyrightable software authored (as determined by United States copyright law) by a Core Institution Member in the conduct of the Core Research.

1.2 Center activities were funded by the NSF ERC program on September 1, 2020. The Center is managed and administered under the direction of the Center Director and supported jointly by Institution Members, Industry Members, and by PENN personnel selected by the Center Director from PENN faculty and staff. At the discretion of the Center Director, additional personnel from Institution Members and Industry Members may be added at any time to assist in management and administration of the Center; provided that any such personnel who will be temporarily in residence at PENN as researchers for the Center will be considered Visiting Scholars and may be asked to sign a separate Visiting Scholars Agreement before such residency shall begin.

1.3 Core Research supported by Membership Fees (as defined below) is not subject to facilities and administrative costs. Membership in the Center does not preclude any

Industry Member from entering into separate research agreements with Core Industry Members who participate in the Center.

1.4 Each Industry Member (excluding Non-Commercial Entities, as defined below) that comprises a company, corporation, partnership, sole proprietorship, or any other legally recognized business entity (each a "Commercial Entity") will provide payment of its annual membership fee ("Membership Fee") and shall be entitled to a corresponding number of votes on the IPAB in accordance with the following Membership Fee schedule:

Type of Entity	No. of Employees	Annual Contribution	IPAB Votes
Large Entities	≥500	$30,000	3
Medium Entities	100-499	$15,000	2
Small Entities	11-99	$2,500	1
Very Small Entities	≤10	$1,000	1

Governmental agencies, government offices, government organizations duly authorized by the United States Government or government of any State or Nation, and legally recognized non-profit organizations other than the Core Institution Members who are not representatives or affiliates of any for-profit entities (each a "Non-Commercial Entity") may also become an Industry Member, but such Non-Commercial Entities will not be required to pay a Membership Fee, shall not be entitled to any votes on the IPAB, and shall not receive the Intellectual Property license rights or Option set forth in Article 3 below.

[NAME's] entity type (Commercial/size or Non-Commercial) is indicated here:

_____

1.5 An organization that qualifies as a Non-Commercial Entity but voluntarily wishes to join as a dues-paying Commercial Entity may do so with the Center Director's prior written consent and will be deemed a Commercial Entity for purposes of this Agreement.

1.6 A Commercial Entity who voluntarily wishes to join and pay dues at a higher tier than required for its size, in order to obtain the larger number of IPAB votes corresponding to that tier in the table of 1.4, may do so with the Center Director's prior written consent.

1.7 The Center Director shall have discretion to make exceptions to Section 1.4 whereby a Commercial Entity may provide a portion of its payment of its annual Membership Fee to IoT4Ag in the form of in-kind contributions; provided that such contributions shall be limited to tangible contributions (i.e. material, capital equipment, etc.).

1.8 Payment of the Membership Fee shall be made within thirty (30) days after the execution of this Agreement and receipt of an invoice from PENN. Payments shall be made in United States dollars and sent to the address noted on the invoice. Industry Members cannot direct use of the Membership Fees.

1.9 Following expiration of the Initial Term, and for the remaining Life of the Center, a Commercial Entity may elect to renew its participation as an Industry Member under this Agreement, on a yearly basis, by making payment(s) of subsequent annual Membership Fee(s) within thirty (30) days of receipt of an invoice from PENN showing the annual Membership Fee applicable for the following annual term. A Commercial Entity's status as an Industry Member shall expire at the conclusion of the Initial Term (or of a renewal term) if renewal payment is not made in accordance with this Section 1.9.

1.10 Industry Member may terminate the Agreement by giving ninety (90) days written notice of such termination. The Center Director may terminate this Agreement, and the Industry Member's status as a Center Member, if the Industry Member materially breaches any of the terms or conditions of this Agreement and fails to cure such breach within thirty (30) days after receiving written notice thereof. In the event of an incurable material breach, the Center Director may terminate this Agreement, and the Industry Member's status as a Center Member, effective immediately upon written notice to the Industry Member. Membership Fees paid prior to the effective date of early termination of this Agreement by either Party will not be refunded.

2. RESEARCH RESULTS; REPORTS

2.1 Core Institution Members engaged in Core Research shall provide the Executive Committee and the IPAB with interim reports detailing preliminary Research Results and the status and progress of the Core Research as requested by the Executive Committee. Core Institution Members engaged in Core Research shall also provide the Executive Committee and the IPAB a final report detailing the complete Research Results at the conclusion of a Core Research project. The interim reports and final reports shall together be referred to herein as "Reports".

2.2 Center Members shall have the right to use Research Results disclosed to them in Reports for any lawful purpose, and are hereby granted a royalty-free, nontransferable, non-exclusive right to copy, reproduce and distribute said Reports, provided that: (a) a Center Member shall need to obtain a license to use Research Results from the Center Member(s) who generated such Research Results if such use would infringe any copyright or any claim of a patent application or issued patent owned by the Center Member(s) that authored the Report; (b) Center Members shall maintain the Research Results confidentially pending publication in accordance with Section 4.6; (c) Center Members may not charge fees for said research reports, use said research reports for advertising or promotional activities, or alter or modify said research reports without the prior written permission of the Center Member(s) who authored the Report.

3. INTELLECTUAL PROPERTY

3.1 Ownership of Intellectual Property shall follow inventorship in accordance with United States patent law or authorship in accordance with United States copyright law, as applicable.

3.2 The owner(s) of Intellectual Property in accordance with Section 3.1 hereby grant the other Center Members (excluding Non-Commercial Entities) a non-exclusive, royalty-free, non-transferable, non-sublicensable license to practice such Intellectual Property for only non-commercial, internal research

use for the Life of the Center (hereinafter an "Internal Use License"), provided that (a) such Intellectual Property was conceived and first reduced to practice, or first authored, during the Center Member's membership in the Center; (b) with respect to Industry Members, the Industry Member has paid its annual Membership Fee; and (c) Center Member acknowledges the Center and the NSF Engineering Research Center (ERC) program in any publication based on use of this license.

3.3 Core Institution Members shall provide the IPAB with prompt written notice of any Intellectual Property reasonably considered patentable or, in the case of Intellectual Property consisting of software or data collections, is reasonably considered to be technologically valuable ("IP Disclosure").

a. The IPAB will have thirty (30) days following receipt of an IP Disclosure ("Review Period") to make a recommendation with respect to the filing and prosecution of a patent application claiming such Intellectual Property.
b. If the IPAB makes a recommendation during the Review Period in support of filing and prosecution of a patent application claiming the disclosed Intellectual Property, the owner of the Intellectual Property shall control the preparation and prosecution of such patent application and the costs associated with preparation and filing fees (initial U.S. application only) will be reimbursed by the Center from Industry Membership Fees, provided sufficient funds are available. In the event sufficient funds are not available the costs associated with such preparation and filing fees will be borne equally by the Industry Members voting in favor of filing and prosecution of a patent application.
c. If the IPAB does not respond within the Review Period or makes a recommendation during the Review Period against filing and prosecution of a patent application claiming the disclosed Intellectual Property, the owner of the Intellectual Property may decide independently to proceed with patent filing and prosecution at its own expense and may offer an option to Industry Members according to the terms outlined below.

3.4 Industry Members (excluding Non-Commercial Entities) shall have sixty (60) days from receipt of an IP Disclosure ("Option Period") to elect to exercise an option to negotiate a royalty-bearing non-exclusive license to practice the Intellectual Property for commercial purposes ("Option"). The Option is non-transferable and is personal to the Commercial Entity that is an Industry Member.

3.5 Any Industry Members (excluding Non-Commercial Entities) who exercise their Option during the Option Period will negotiate with the owner of the Intellectual Property in good faith to determine the terms of a license agreement. If a license agreement is not executed within six (6) months after the Industry Member's election of the Option, the owner of the Intellectual Property shall be free to license Intellectual Property to any Center Member, or to any non-member small business or start-up, upon such terms as it deems appropriate, without any further obligation to the Industry Member(s).

3.6 Center Members' respective rights under this Article 3 shall be subject to the Center's and the Core Institution Members' obligations to and the rights of the United States Government, if any, as subject to the provisions of 35 U.S.C. 200, et seq., 37 C.F.R. Part 401, and other applicable laws and regulations.

4. CONFIDENTIALITY AND PUBLICATION

4.1 From time to time Center Members may have the need to exchange Confidential Information in connection with the performance of Core Research. The Core

Institution Members shall be a "Disclosing Party" and/or a "Receiving Party" of Confidential Information as context dictates. The Industry Members shall be a "Receiving Party" only. "Confidential Information" means any of a Core Institution Member's confidential or proprietary information that is necessary to be disclosed to another Center Member in connection with performance of the Core Research and is marked "confidential" or "proprietary" or, if disclosed orally, is summarized in writing sufficiently for identification and is designated in writing as confidential within thirty (30) days following disclosure. Failure to mark any Confidential Information as confidential or proprietary will not affect its status as Confidential Information under this Agreement if it is information that a reasonable person with expertise in the field would consider the Disclosing Party's Confidential Information hereunder based upon the nature of the information and the circumstances of the disclosure. Confidential Information shall not include information:

a. that is or becomes generally known or available to the public without breach of this Agreement;
b. that is known to the Receiving Party at the time of disclosure, as evidenced by written records of the Receiving Party;
c. that is independently developed by the Receiving Party, as evidenced by written records of the Receiving Party; or
d. that is disclosed to the Receiving Party by a third party without an obligation of confidentiality owed by Receiving Party to such third party; or
e. that is required to be disclosed by law, in which case Receiving Party shall promptly inform the Disclosing Party and shall cooperate with the Disclosing Party to minimize the extent of the disclosure.

4.2 Receiving Party will be permitted to make all disclosures of Disclosing Party's Confidential Information required by law or regulation. Receiving Party shall use reasonable efforts to provide prompt written notice to Disclosing Party to allow Disclosing Party to offer its objections to the production of Confidential Information. The Confidential Information that is disclosed pursuant to this paragraph shall remain confidential for all other purposes in accordance with the terms and conditions of this Agreement.

4.3 Receiving Party will take all reasonable measures to protect the secrecy of, and avoid the unauthorized disclosure or use of, Confidential Information. Such measures will include the highest degree of care that Receiving Party utilizes to protect Receiving Party's own confidential information of a similar nature, but no less than a reasonable degree of care. Receiving Party will not use Confidential Information for any purpose, other than as necessary to carry out the Core Research. Specifically, Receiving Party will not use Confidential Information to file patent applications or for experimental activity. No licenses or other rights are granted. Receiving Party may disclose Confidential Information to Affiliates, employees, agents or consultants on a need to know basis only if such persons are bound to obligations of non-use or non-disclosure at least as restrictive as those set forth in this Agreement. Recipient will not disclose any Confidential Information to any other Affiliates, employees, agents, consultants,

or to any third parties. Receiving Party will promptly notify Disclosing Party in writing of any misuse or misappropriation of any Confidential Information that may come to Receiving Party's attention. Receiving Party will be responsible for any breach of this Agreement by its Affiliates, employees, agents, or consultants.

4.4 Disclosing Party represents that it has the right to make the disclosures of Confidential Information made hereunder. Except as expressly set forth in this Section 4.4, Disclosing Party is providing Confidential Information on an "*As Is*" basis for use by Receiving Party at its own risk without express or implied warranties of any kind.

4.5 Receiving Party's obligations as to any item of Confidential Information will survive during the term of this Agreement and shall continue for five (5) years following the expiration or termination of this Agreement. Upon the written request of Disclosing Party, Receiving Party will destroy or return to Disclosing Party all Confidential Information received from Disclosing Party, except that Receiving Party may maintain a single copy of any written Confidential Information for Receiving Party's records. Notwithstanding the foregoing, the obligation to return or destroy Confidential Information does not include Confidential Information that has been backed up as part of the Receiving Party's normal business procedures, and the Receiving Party may reproduce Confidential Information in the process of backing up computer systems in the normal course of business.

4.6 The Core Institution Members shall have the first right to publish, present or otherwise publicly disclose the Research Results developed under this Agreement ("Publish"). Any Core Institution Member wishing to Publish shall furnish the Executive Committee and IPAB with a copy of the proposed publication, presentation, or other public disclosure (each a "Publication") at least thirty (30) days in advance of the date of such presentation or disclosure, or the submission of said proposed publication, in order for the Executive Committee and IPAB to review and comment on said proposed Publication to (a) determine whether such Publication contains any Confidential Information of any of the other Core Institution Members; and (b) enable the Industry Members to identify any Intellectual Property for which it wishes to seek intellectual property protection. If within the thirty (30) day review period (i) a Core Institution Member requests deletion of Confidential Information from the proposed Publication, the Core Institution Members at issue will cooperate to modify the disclosure to ensure Confidential Information is not disclosed; or (ii) an Industry Member requests that the Proposed publication be delayed to allow for intellectual property protection on certain items of Intellectual Property in the proposed Publication, the publishing Core Institution Member shall delay the proposed Publication for up to sixty (60) days to allow for intellectual property protection to be sought.

5. DISCLAIMER OF WARRANTIES; INDEMNIFICATION

5.1 NO CORE INSTITUTION MEMBER MAKES ANY WARRANTIES, EXPRESS OR IMPLIED, AS TO ANY MATTER WHATSOEVER, INCLUDING, WITHOUT LIMITATION, WARRANTIES WITH RESPECT TO THE CONDUCT, COMPLETION, SUCCESS OR PARTICULAR RESULTS OF THE CORE RESEARCH, OR THE

CONDITION, OWNERSHIP, MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE OF THE CORE RESEARCH OR ANY INTELLECTUAL PROPERTY OR RESEARCH RESULTS, OR THAT USE OF INTELLECTUAL PROPERTY OR RESEARCH RESULTS WILL NOT INFRINGE ANY PATENT, COPYRIGHT, TRADEMARK OR OTHER INTELLECTUAL PROPERTY RIGHT OF A THIRD PARTY. EXCEPT AS SET FORTH IN SECTION 5.2, NO CORE INSTITUTION MEMBER SHALL BE LIABLE FOR ANY DIRECT, INDIRECT, CONSEQUENTIAL, PUNITIVE OR OTHER DAMAGES SUFFERED BY ANOTHER CORE INSTITUTION MEMBER RESULTING FROM THE CORE RESEARCH OR THE USE OF ANY INTELLECTUAL PROPERTY, ANY RESEARCH RESULTS OR ANY PRODUCTS RESULTING THEREFROM.

5.2 The Industry Member agrees to indemnify, defend, and hold harmless the Core Institution Members and their respective officers, directors, trustees, employees and agents ("Institution Indemnitees") against any and all claims, demands, actions, liability and expenses, related to or arising out of the Industry Member's breach of this Agreement; provided that the Industry Member's obligations pursuant to this Section 7.2 shall not apply to the extent such claims or suits result from the gross negligence or willful misconduct of any of Institution Indemnitees as determined by a court of law.

6. MISCELLANEOUS

6.1 All taxes and other contributions, fees, fiscal or para-fiscal contributions, imposts, duties, levies, fines, or charges, by whatever other name ("taxes") imposed by any government entity or a functional equivalent of a government entity and entailed by laws, in connection or as a result of an Industry Member's payment of the Membership Fee, are the exclusive responsibility of the Industry Member and will be paid by the Industry Member.

6.2 No Center Member shall use the name, logo, seal, trademark, or service mark (including any adaptation of them) of any other Center Member, including any school, organization, employee, student or representative thereof, without the prior written consent of that Center Member. No Center Member except PENN shall use the name of the Center without the prior written consent of PENN.

6.3 For purposes of this Agreement and membership in the Center, the Center Members shall be independent contractors and none shall at any time be considered an agent or an employee of the other. No joint venture, partnership or like relationship is created between any of the Center Members by their membership in the Center or this Agreement.

6.4 The terms and provisions hereof shall inure to the benefit of, and be binding upon, the Center Members and their respective successors and permitted assigns. No Center Member may assign or transfer this Agreement or any of its rights or obligations created hereunder, by operation of law or otherwise, without the prior written consent of the other Parties. Any assignment not in accordance with this Section 6.3 shall be void.

6.5 A waiver by a Center Member of any of the terms and conditions of this Agreement in any instance shall not be deemed or construed to be a waiver of such term or condition for the future, or of any other term or condition hereof. All rights, remedies, undertakings, obligations and agreements contained in this Agreement shall be cumulative and none of them shall be in limitation of any other remedy, right, undertaking, obligation or agreement of a Center Member.

6.6 When possible, each provision of this Agreement will be interpreted in such manner as to be effective and valid under law, but if any provision of this Agreement is held to be prohibited by or invalid under law, such provision will be ineffective only to the extent of such prohibition or invalidity, without invalidating the remainder of this Agreement. The Center Members shall make a good faith effort to replace the invalid or unenforceable provision with a valid one which in its economic effect is most consistent with the invalid or unenforceable provision.

6.7 This Agreement constitutes the entire agreement between the Parties with respect to its subject matter, and supersedes all previous communications and agreements, whether oral or written, between the Parties with respect to the subject matter hereof. This Agreement may be waived, modified, or amended only by an instrument in writing and signed by duly authorized representatives of both Parties.

6.8 This Agreement may be executed in counterparts, each of which will be deemed an original, and all of which together will be deemed to be one and the same instrument. A portable document format (PDF) or electronic copy of this Agreement, including the signature pages, will be deemed an original.

[SIGNATURE PAGE FOLLOWS]

IN WITNESS WHEREOF, the duly authorized representatives of the Parties hereby execute this Agreement as of the date first written above.

THE TRUSTEES OF THE UNIVERSITY OF PENNSYLVANIA	[INDUSTRY MEMBER]
By: _____	By: _____
Name: _____	Name: _____
Title:_____	Title:_____

ACKNOWLEDGED AS READ AND UNDERSTOOD BY CENTER DIRECTOR:

By: _____

Name: _____

Title:_____

INTELLECTUAL PROPERTY POLICY

Ownership

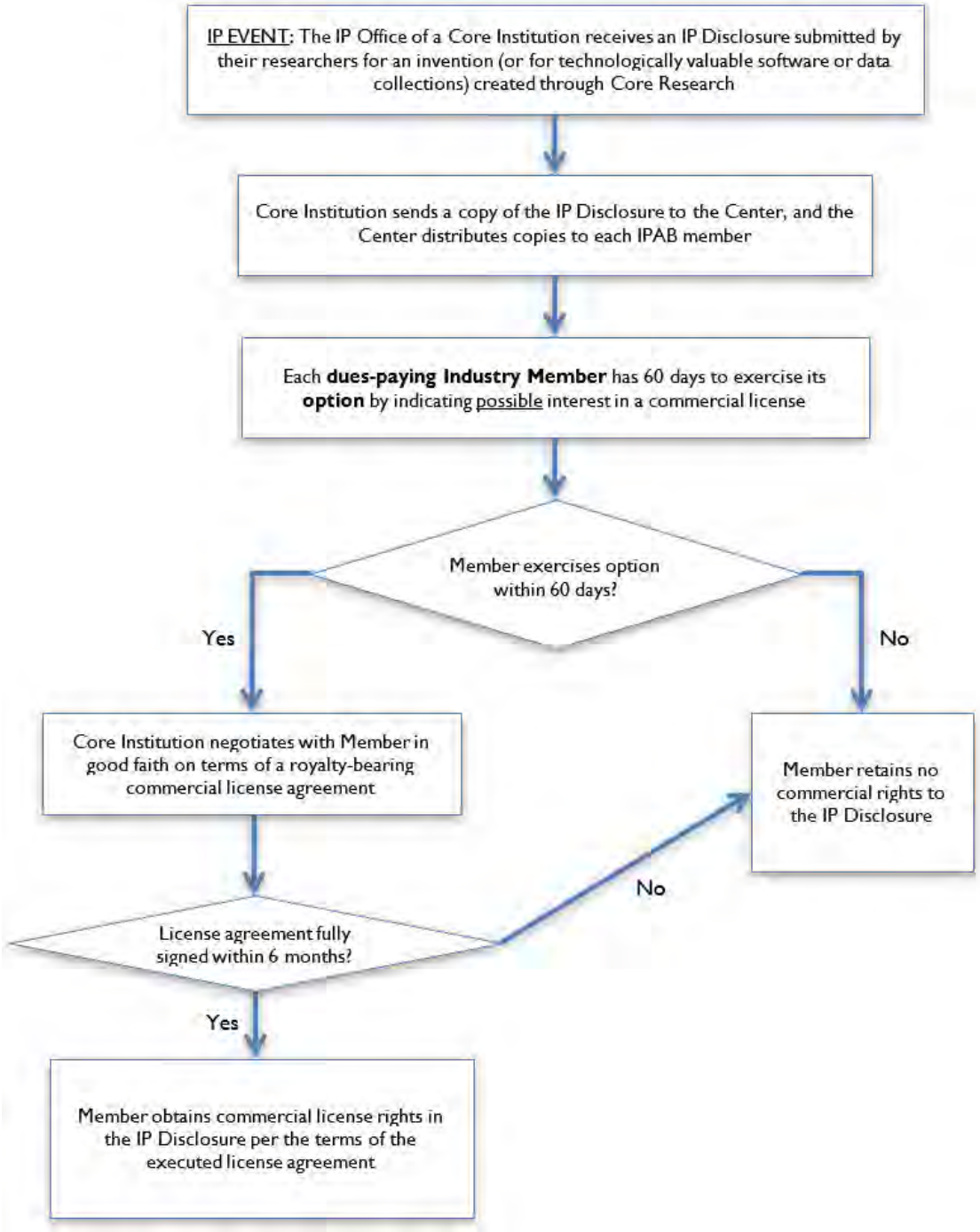
- Ownership follows invention/authorship for new IP that is created through Core Research
- Ownership of IP that is not created through Core Research, such as background IP, is unaffected by participation in the Center

License Rights for IP that is Created through Core Research

- Internal Use License: Each Industry Member (excluding Non-Commercial Entities) is granted a non-exclusive, royalty-free, non-transferable license for non-commercial, internal research only
- Commercial License: Each Industry Member (excluding Non-Commercial Entities) is entitled to a non-transferable 60-day option to negotiate a royalty-bearing, non-exclusive license for commercial purposes
    - See flowchart on the following page for more details
- US Government License: The US Government has certain rights set forth under the Bayh-Doyle Act and per NSF's implementing rules at 45 CFR §650.

COMMERCIAL OPTION/LICENSE NEGOTIATION PROCESS

Industry Member Agreement, Sections 3.4 – 3.5



CHARTERS FOR BOARDS, COUNCILS, AND COMMITTEES

IoT4Ag has two councils and five boards, as follows:

1. Council of Deans
2. Student Leadership Council
3. Scientific Advisory Board
4. Workforce Development Advisory Board
5. Diversity and Culture of Inclusion Advisory Board
6. Industrial Practitioner Advisory Board
7. Ag Systems Advisory Board

COUNCIL OF DEANS

COUNCIL COMPOSITION:

The Council of Deans will comprise four (4) members and will be the Dean from each partner institution, except if the Dean is a member of the Center, then the Vice Provost of Research will replace that Dean.

CHARGE:

The purpose of the Council of Deans is as follows:

- To advise the Center's leadership team on its efforts, including research, education, diversity and inclusion, and innovation ecosystem
- To ensure compliance with university, school, and departmental policies
- To support the Center in its efforts as noted above
- To promote the Center's activities

RESPONSIBILITY OF DEAN'S COUNCIL:

The Council of Deans will meet once a year at the NSF site visit typically held in the Fall in Philadelphia, PA (or virtually) and through quarterly virtual meetings. The Council's members may be asked to meet additionally in video conference calls to provide specific guidance and advice.

The Council will advise the Center's leadership team on research, education, diversity and inclusion, and innovation activities. The Council will ensure that the Center's activities are in compliance with each partner institution's university, school, and departmental policies. The Council will support the Center's efforts in each of the four pillars noted above and will promote the Center's activities within each institution.

IoT4Ag OBLIGATIONS:

The Center for the Internet of Things for Precision Agriculture (IoT4Ag) will provide as much advance notice as possible about meetings and video conferences.

IoT4Ag will provide to the Council members, in a timely fashion:

- Relevant sections of the NSF Annual Report in advance of the annual site visit.
- Both the slides to be presented during the NSF Site Team Visit in advance of the visit and slides that are presented in response to the NSF Site Team questions that arise at the annual meeting.
- Online access to research project briefs and research results, workforce development and diversity and culture of inclusion activities, and intellectual property and industry and entrepreneurial engagement to help keep the Council informed and facilitate comments as appropriate.

STUDENT LEADERSHIP COUNCIL

COUNCIL COMPOSITION:

The Student Leadership Council (SLC) for the Center of the Internet of Things for Precision Agriculture (IoT4Ag) is comprised of twelve (12) members from the four partner institutions, with two (2) graduate and one (1) undergraduate student(s) from each institution.

CHARGE:

The purpose of the Student Leadership Council (SLC) is as follows:

- To serve as a liaison between the student community and the Center's leadership team
- To encourage students to network, collaborate, and build friendships
- To educate and mentor students

- To promote connections and opportunities between students and industry
- To conduct an annual SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of research, education, diversity and culture of inclusion, and industry and entrepreneurial activities

RESPONSIBILITY OF STUDENT LEADERSHIP COUNCIL (SLC):

The SLC will meet six times a year, including at the annual NSF site visit typically held in the Fall in Philadelphia, PA (or virtually) and at the IoT4Ag Center meeting, to be held annually and to rotate amongst partner sites. The SLC members, or a subset, may be asked to meet additionally in video conference calls to provide specific guidance and advice.

The SLC will serve as a liaison between the student community and the Center's leadership team to provide guidance and advice to enhance the student's experiences in the following areas: research, education, diversity and inclusion, and industry and entrepreneurial activities. In that regard, the SLC will conduct a SWOT analysis and submit a report to the Center, as part of the feedback cycle of program evaluation and improvement, and for the annual NSF site visit, to document the Center's efforts in the listed areas as noted above.

The SLC will encourage and facilitate a student network to collaborate and build friendships across the Center, and will promote hierarchical, peer-to-peer student mentorship and faculty-student mentorship. The SLC will work with the Innovation Ecosystem to promote connections and opportunities between students and industry, government, and innovation partners.

The SLC may also reach out to SLC's at other Engineering Research Centers (ERC's) to share charges, activities, and experiences to enhance or improve the IoT4Ag ERC and to create connections and student relationships across the ERC network.

ROLES:

- President
- Vice President
- WFD Liaison Officer
- DCI Liaison Officer
- Innovation Ecosystem Liaison Officer

The SLC may determine if other roles are needed. The Administrative Director will assist the SLC to collect information from the other ERC SLC's to review their structures and roles as needed.

ELECTIONS:

The Site Directors from each partner institution will put forth the names of students from their institutions (two graduates and one undergraduate) to join the SLC each year. The presidential line will rotate yearly amongst partner institutions, and the Vice President will be from a different institution from and succeed the President in the following year. The SLC will hold internal elections to name the other officers noted above. The term for each office starts after the NSF annual site visit. Offices will be identified/elected annually by September 1 to allow the officers to work with the incumbents through the annual review process.

IoT4Ag OBLIGATIONS:

The Center for the Internet of Things for Precision Agriculture (IoT4Ag) will provide as much advance notice as possible of meetings and video conferences if requested by leadership team.

IoT4Ag will pay all travel expenses as it relates to the NSF annual site visit and to IoT4Ag Center meetings. All other meetings will be virtual. The Administrative Director may assist with scheduling zoom calls as needed and/or set up a Microsoft Teams channel for file sharing, communications, and virtual meetings.

SCIENTIFIC ADVISORY BOARD

BOARD COMPOSITION:

The Scientific Advisory Board (SAB) will be comprised of six (6) members, including experts in IoT4Ag-relevant fields such as industry, government, and academic members that represent the science, engineering, and socio-economics needed for a convergent understanding of the impacts and opportunities of physical and cyber-physical system enabled precision agriculture. All members will be external to the IoT4Ag center.

CHARGE:

The role of the Scientific Advisory Board (SAB) is:

- To provide the IoT4Ag Executive Committee and Research Systems Integration, Thrust, and Testbed Directors advice on IoT4Ag's fundamental science, technology, and integrated systems that comprise the Convergent Research pillar, including technical barriers to advancement of IoT4Ag projects
- To provide researchers input on the science and technology aspects of their IoT4Ag projects.

  To perform yearly SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the IoT4Ag value proposition

RESPONSIBILITY OF SCIENTIFIC ADVISORY BOARD:

The SAB will meet two times a year, including at the NSF site visit typically held in the Fall in Philadelphia, PA (or virtually). The SAB members, or a subset, may be asked to meet additionally in video conference calls one to two times per year to provide specific guidance and advice.

In addition to the general meetings described above, each SAB member will serve as liaison to core research projects, i.e., projects supported with NSF funding. Project assignment will be subject to mutual agreement of the faculty, the SAB member, and the IoT4Ag team. The faculty on a project will be responsible for contacting and briefing their SAB liaisons on a quarterly basis on their research progress. The form of the briefing (e.g., telephone call, PowerPoint presentation, technical memorandum, face-to-face discussion at IoT4Ag meetings) will be determined by mutual agreement of the SAB member and the IoT4Ag faculty. SAB briefings may also include the IPAB liaison if mutually agreed upon by all involved parties.

The SAB will provide a SWOT analysis of these efforts, as described above, at the NSF site visit.

IoT4Ag OBLIGATIONS:

The Center for the Internet of Things for Precision Agriculture (IoT4Ag) will provide as much advance notice as possible of meetings and video conferences.

IoT4Ag will pay all travel expenses and provide board members with an honorarium of $500 for attendance and participation in the annual meeting, expected to be held in the fall.

IoT4Ag will provide to the board members, in a timely fashion:

- Relevant sections of the NSF Annual Report in advance of the annual site visit.
- Both the slides to be presented during the NSF Site Team Visit, in advance of the visit, and slides that are presented in response to the NSF Site Team questions, that arise at the annual meeting.
- Online access to research project briefs and research results to help keep the board members informed and facilitate comments as appropriate.
- Periodic updates listing new publications and presentations emanating from the different research projects.

WORKFORCE DEVELOPMENT ADVISORY BOARD

BOARD COMPOSITION:

The Workforce Development Advisory Board (WFDAB) will be comprised of six (6) members, including four (4) non-IoT4Ag experts in education, extension, and outreach from each partner institution, one (1) K-12 representative, and one (1) community college representative.

CHARGE:

The role of the Workforce Development Advisory Board (WFDAB) is:

- To advise the Workforce Development Directors and the IoT4Ag Executive Committee on IoT4Ag's technical and professional educational programming.
- To contribute to Center and NSF WFD presentations, as time permits.
- To perform yearly SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the IoT4Ag Workforce Development program.

RESPONSIBILITY OF WORKFORCE DEVELOPMENT ADVISORY BOARD (WFDAB):

The WFDAB will meet two times a year, including at the NSF site visit typically held in the Fall in Philadelphia, PA (or virtually). The WFDAB members, or a subset, may be asked to meet additionally in video conference calls one to two times per year to provide specific guidance and advice.

The WFDAB will provide guidance and advice to the WFD Directors on the IoT4Ag Center activities as it relates to the workforce development activities in its efforts to reach its goals. The WFDAB will provide a SWOT analysis of these efforts at the NSF site visit.

IoT4Ag OBLIGATIONS:

The Center for the Internet of Things for Precision Agriculture (IoT4Ag) will provide as much advance notice as possible of meetings and video conferences.

IoT4Ag will pay all travel expenses and provide board members with an honorarium of $500 for attendance and participation in the annual meeting, expected to be in the Fall.

IoT4Ag will provide to the board members, in a timely fashion:

- Relevant sections of the NSF Annual Report in advance of the annual site visit.

- Slides to be presented during the NSF Site Team Visit in advance of the visit and slides that are presented in response to the NSF Site Team questions that arise at the annual meeting.
- Online access to research project briefs and research results to help keep the board members informed and facilitate comments as appropriate.
- Periodic updates listing new publications and presentations emanating from the different research projects.

DIVERSITY AND CULTURE OF INCLUSION ADVISORY BOARD

BOARD COMPOSITION:

The Diversity and Culture of Inclusion Advisory Board (DCIAB) will be comprised of one (1) representative from each partner institution, two (2) external academic members, and two (2) graduate students from the Center membership for a total of eight (8) members.

LENGTH OF SERVICE:

External members are expected to serve a 2-year minimum term. It is preferred that members from partner institutions serve throughout the duration of the project, so long as they remain employed at the partner university. Student members should plan to serve at least one year, though multi-year engagement is desired.

CHARGE:

The role of the Diversity and Culture of Inclusion Advisory Board (DCIAB) is:

- To advise the Diversity and Culture of Inclusion (DCI) Directors and the IoT4Ag Executive Committee on DCI's recruitment, education, and retention of students, faculty, and Advisory Board members, and realize a sustained positive impact on science and engineering
- To provide feedback and contribute to Center assessment, specifically as it relates to the DCI pillar.
- To contribute to Center and NSF DCI presentations, as time permits.
- To perform yearly SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the IoT4Ag DCI program

RESPONSIBILITY OF DIVERSITY AND CULTURE OF IINCLUSION ADVISORY BOARD (DCIAB):

The DCIAB will meet a minimum of two times a year, either virtually or in person. Attendance is expected at the annual NSF site visit in Philadelphia, PA each Fall. The DCIAB members, or a subset, may be asked to meet through video conference calls one to two times per year to provide specific guidance and advisement. Examples might include, but are not limited to the DCI co-Directors, Leadership Team, Assessment, and Student Leadership Council.

The DCIAB will provide guidance and advice to the DCI ERC Co-Directors on IoT4Ag DCI activities to facilitate a culture of inclusion and transformative impacts on engineering and science. The DCIAB will provide, at minimum, a SWOT analysis (Strengths, Weaknesses, Opportunities, and Weaknesses) of these efforts at the NSF site visit.

The DCI AB will review the evaluation and assessment tools and metrics to ensure that the Center captures relevant data and, thus, improve its efforts to attain diversity goals and to facilitate a culture of inclusion.

IoT4Ag OBLIGATIONS:

The Center for the Internet of Things for Precision Agriculture (IoT4Ag) will provide as much advance notice as possible of meetings and video conferences.

IoT4Ag will pay all travel expenses and provide board members with an honorarium of $500 for attendance and participation in the annual meeting, expected to be held in the Fall.

IoT4Ag will provide to DCIAB members, in a timely fashion:

- Relevant sections of the NSF Annual Report in advance of the annual site visit.
- Slide decks and written materials in advance of, and in response to, the annual NSF Site Team Visit.
- Online access to research project briefs, research results, demographic statistics, and other relevant information to keep the DCIAB informed and to facilitate input.
- Materials as requested by DCIAB members.

INDUSTRIAL/PRACTITIONER ADVISORY BOARD

BOARD COMPOSITION

The Industrial and Practitioner Advisory Board (IPAB) will be comprised of members representing industry, government and other innovation partners.

CHARGE:

The role of the Industrial and Practitioner Advisory Board (IPAB) is:

- To advise the IoT4Ag Innovation Ecosystem Directors, the IoT4Ag Executive Committee, and the Research Systems Integration, Thrust, and Testbed Directors on IoT4Ag's product definition and deployment and on IoT4Ag's intellectual property and commercial and entrepreneurial activity
- To collaborate in creating and maintain a Technology Outlook and Roadmap for Precision Agriculture
- To provide mentorship of IoT4Ag students
- To perform yearly SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the IoT4Ag products and outcomes for the stakeholder community, as well as programming to support the Innovation Ecosystem

RESPONSIBILITY OF INDUSTRIAL AND PRACTITIONARY ADVISORY BOARD (IPAB)

The IPAB will meet with the IoT4Ag leadership biannually to guide the research workforce and innovation activities of the Center.

The IPAB will develop an annual SWOT analysis and will present the analysis to the National Science Foundation (NSF) site visit team. The IPAB will participate in the annual meeting, expected to be held in the Fall.

The IPAB will review the progress on the Center's projects and will provide input on the Center's strategic plans.

The IPAB may provide mentorship to the Center's students.

IoT4Ag OBLIGATIONS

The Center of the Internet of Things for Precision Agriculture (IoT4Ag) will provide as much advance notice as possible of meetings and video conferences.

IoT4Ag will provide to the board members, in a timely fashion:

- Relevant sections of the NSF Annual Report to in advance of the annual site visit.
- Both the slides to be presented during the NSF Site Team Visit in advance of the visit and slides that are presented in response to the NSF Site Team questions that arise at the annual meeting.

- Online access to research project briefs and research results to help keep the board members informed and facilitate comments as appropriate.
- Periodic updates listing new publications and presentations emanating from the different research projects.

AG SYSTEMS ADVISORY BOARD

BOARD COMPOSITION:

The Ag Systems Advisory Board (ASAB) will be comprised of members from commodity producer boards (row, vegetable, fruit and nut crops), crop consultant associations, farm cooperatives with precision Ag advisors, and Ag and horticulture extension agents.

CHARGE:

The role of the Ag Systems Advisory Board (ASAB) is:

- To advise the IoT4Ag Innovation Directors, the IoT4Ag Executive Committee, and the Research Systems Integration, Thrust, and Testbed Directors on IoT4Ag's product definition, deployment, and adoption
- To participate in IoT4Ag technology demonstrations
- To provide mentorship of IoT4Ag students
- To perform yearly SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the IoT4Ag value proposition

RESPONSIBILITY OF AG SYSTEMS ADVISORY BOARD (ASAB):

The ASAB will meet with the IoT4Ag leadership biannually to guide the research, workforce, diversity/inclusion, and innovation activities of the Center. Meetings may be in-person or virtual.

The ASAB will develop an annual SWOT analysis and will present the analysis to the National Science Foundation (NSF) site visit team. The IPAB will participate in the annual meeting, expected to be held in the fall.

The ASAB will review the progress on the Center's projects and will provide input on the Center's strategic plans.

IoT4Ag OBLIGATIONS

The IoT4Ag Center will provide as much advance notice as possible of meetings and video conferences.

IoT4Ag will provide to the board members, in a timely fashion:

- Relevant sections of the NSF Annual Report in advance of the annual site visit.
- Both the slides to be presented during the NSF Site Team Visit in advance of the visit and slides that are presented in response to the NSF Site Team questions that arise at the annual meeting.
- Online access to research project briefs and research results to help keep the board

  members informed and facilitate comments as appropriate.
- Periodic updates listing new publications and presentations emanating from the different research projects.

Dissemination of products of the research

Results of this project will be made public through a variety of means, including publication in scientific journals, written or oral presentation at scientific meetings, postings on the IoT4Ag web site, personal conversations with colleagues during conferences, seminar visits, and through educational materials. We will post publications on freely available websites as allowed by policies set by journal publishers, and/or as mandated by agency rules.

Expected data

The data expected to be generated during the course of this collaborative project will largely be digital in nature concerning the characterization of agricultural systems; the fabrication, characterization and performance of physical systems (sensors, communication and energy devices, aerial- and ground-based drones); and the creation of cyber-physical systems (data, algorithms, models, software). Common data file types that will be produced through the research and educational activities include:

- written reports and presentations (primarily *.doc, *.pdf, *.tex, *.ppt)
- digital images (primarily *.jpeg, .*tif, *.png, and *.gif)
- point clouds (LAS)
- schematic and layout files (*.DXF or *.DWG or *.GDSII format)
- any proprietary read-only data files from common scientific instruments (i.e., scanning electron microscopes, x-ray diffraction, atomic force microscope, UV-visible-NIR spectrometers, physical property measurement systems, electrochemical workstations etc.) will be converted to standard digital files along with data files (primarily *.txt, *xls, *.doc, etc.), supporting standard multi-column data sets analyzable in Microsoft Excel or Origin Pro software platforms.
- measurements of agricultural or physical systems will be produced in ASCII format; we note that other common scientific instruments which generate raw data, will also be saved in ASCII or .csv (comma separated value) formats whenever possible
- audio and video files (*.mpeg, *.avi, etc.)
- data from some mobile platforms will be stored/shared using ROS bag files
- graph-based data in JavaScript Object Notation (JSON)
- socio-economic modeling (*.xls)
- code in Matlab, Python, R, Java, and C/C++

Creation of publicly available software

All code and software developed through the effort (including but not limited to code for simple simulations, data-fitted model design, and robotics calibration) will be made publicly available and posted on a public website. Whenever possible, software developed as part of this project will be published under the MIT Open Source License (or similar license), and hosted on a public code repository, such as GitHub. Code to operate the vehicle testbed that utilizes the open-source Robot Operating System (ROS) and will be made available online, along with a bill of materials and assembly instructions for the hardware, so

that other researchers will be able to recreate the testbed. Every code release (particularly any version discussed or referenced in publications) will be documented, posted and shared, and a DOI number will be obtained.

Creation of publicly available data sets

Simulations and field measurements will generate data sets. Appropriate data sets of this type will be made available in accepted formats. Processed data will be made available in standard CSV, JSON format, or other open standard where possible to enable maximum portability. Moreover, some raw image and video data will be made available to enable other researchers to process the data directly. All data sets will be paired with a datasheet to describe the collection mechanisms, their purpose and suggested use (e.g., As described here: https://arxiv.org/abs/1803.09010). Every data set release (particularly any set discussed or referenced in publications) will be documented, posted and shared, and a DOI number will be obtained.

A challenge, but one that will be addressed by this project, is to make the data accessible via API rather than always human-enabled download. Many of the data sets will: 1. Be too large to relay as CSV files, and 2. Have much more value in real-time than as "history". The real-time aspect would be for internal purposes initially, but the research and development toward IoT data accessible in real time is of real industry value. This will require publication of APIs with the data and continual attention toward standardizing those APIs with open source code.

Any human subject data that is generated will be kept confidential and managed in a manner consistent with relevant institutional IRBs.

Data storage

Data will be stored at all IoT4Ag Universities in both shared user/field-testing facilities and in equipment/systems housed in the individual investigators' laboratories. Data will also be stored in labs at our industrial and government partners. Data collected in shared user facilities and investigators labs will be stored on servers at the university of the individual investigator and subject to the individual university's data management policies. Data archiving is explained further below.

All presentations presented in IoT4Ag meetings will be archived on a secure IoT4Ag website and may be posted publicly when the data are sufficiently established and publication is planned. Presentations that are held virtually via Zoom or other web conference software will be recorded when appropriate and recordings will be stored on a protected on IoT4Ag site. Recorded presentations that are designed for public distribution will be stored via YouTube or a similar platform.

Data standards

All participants in the research will review and, if necessary, update this plan, and confirm their mutual commitment to follow the protocols established here and maintain high standards in the management of data.

The produced data and metadata, descriptions of experiments, process details, raw materials, computational codes, computer calculations, and input conditions that are produced during the course of the research will be provided following the professional standards according to which they are produced. Elements of metadata include the following: identifiers for discovery and citation (*e.g.*, title, creator, subject); rights and access information; methodology, equipment, conditions and variables involved; file formats and file structures; versions, data processing and other indications of data modification; checksums and other data verification methods. If necessary, University of Pennsylvania library staff members will work with the PI to find existing metadata standards and to suggest additional metadata.

For true mining of insights, the data must have the full backstory or context (metadata) associated with it. At times, the definition of metadata and data gets blurred. For example, the speed of the planter might be "the data" to be interpreted if the decision and actions are control, path planning, or logistics of keeping the planter boxes filled; later, when trying to ascertain impacts of practices on production, speed of the planter would be metadata or context (as one of many variables which might have influenced yield). This project will deal with a very wide variety of data that could be collected in cropping systems (Table 1). Those data elements have assorted resolutions in both space and time, highly varied accuracy levels and different origination points (several machines or sensor systems); this offers a wild frontier of opportunity for improvement in the design of data collection, storage, transfer, and access systems as well as improvement in decisions and actions on actual farms. This is part of the novelty of this project and therefore data structure/access research becomes part of the agriculture and IoT research.

Table 1. Some typical data elements for cropping systems as well as examples of value.

Data Element	**Examples of Potential Value**
Records of who/what/where/when	Critical context for later analytics on production and logistics
Imagery (RGB, LiDAR, hyper-spectral, multi-spectral, thermal)	Scouting, anomaly detection, support analytics for treatment comparisons or correlation to other sensor data
Machine sensors (location, fuel consumption, battery status, slip, crop or soil moisture, speed, spray rate, seed rate)	Improved control of the machine functions, improved system logistics, metadata for analytics regarding practices
Soil sensors (moisture, temperature, chemical/biological attributes)	Improved logistics planning, influence on production activities, context for deeper analytics on other data

One element of our data management plan targeting that frontier is the testing and refinement of a data architecture to accommodate disparate data coming from generally incompatible systems. While that architecture is yet to be fully designed, it may lean largely upon graph-structured (in JSON format) databases which are both time-indexed and geohash-indexed to maximize speed of access and utility of data. Doing so will require a publishing of the graph schemas.

Archiving & preservation of access to data and other research products

During the term of the grant, data will be stored on university servers at each partner site. Stored data will be protected by disk mirroring and frequent backups, including off-site backups. Full-time system administrators monitor the security and availability of the systems. When feasible, data collected by IoT4Ag researchers at our industrial and government partner facilities will be archived at IoT4Ag headquarters. At the least, links to data stored elsewhere will be complete in a listing held at the University of Pennsylvania. All investigators will also be responsible for backing up raw and analyzed data to a centrally managed IoT4Ag server or cloud-based storage systems maintained by their own institutions. Data will be retained for at least three years after conclusion of the award or three years after public release, whichever is later. Exceptions requiring longer retention may occur when data supports patents or a larger library or collection useful to the broader community.

The missions of the University of Pennsylvania, Purdue University, University of California-Merced, and University of Florida, include the dissemination of the results of research by faculty, employees, students, and guest scholars for the purpose of adding to the body of knowledge and serving the public interest. The data generated under this project will be made available to others in several ways, including as digital files or printed documents. Data will be generally available for public release immediately after publication.

Penn's Institutional Data Repository, the Scholarly Commons (https://repository.upenn.edu/), will be used to disseminate pre-publication manuscripts, data, and metadata. The Scholarly Commons is a digital collection that captures and preserves Penn's intellectual output via web pages, on a server operated by the Penn Library. The main papers are all in PDF. Supported formats for data and metadata include JPEG, PNG, GIF, TIFF (images), AIFF, MP3, DRM-free AAC (audio), MPEG (video), XML and CSV (data). This is a permanent scholarly repository. The Library expects to preserve the content of the repository by migrating it to new technological platforms when and if the obsolescence of current technologies makes it necessary to do so. In this, the produced data will effectively be made available for a longer period than 3 years. In addition to electronically stored data, students and postdoctoral associates will be encouraged and required to keep detailed laboratory notebooks.

ERC researchers can disseminate IoT4Ag data through Scholarly Commons at Penn, but also may use their own institutional data repositories. For example, researchers at Purdue may use the Purdue University Research Repository (https://purr.purdue.edu/kb) in place of Scholarly Commons. The Purdue University Research Repository digitally preserves data for public access with digital object identifiers and metadata and formatting oversight.

Policies and provisions for re-use, re-distribution, and the production of derivatives

The investigators will work with their technology transfer offices to transfer any inventions and innovative knowledge to outside organizations, as outlined in the Project Description. The technology transfer offices at each participating institution encourage invention disclosure, protect intellectual property, obtain and manage patents, copyrights and trademarks derived from academic research, and market and license intellectual property for commercialization.

Rights and obligations

The PI and site directors are responsible for the implementation of the Data Management Plan. If an investigator leaves a participating institution during or after the award, the dissemination of the research results for a minimum of three years after conclusion of the award or three years after public release, whichever is later, will be the responsibility of the PI or relevant site director.

CENTER-LEVEL RISK MANAGEMENT PLAN

The Executive Committee will be responsible for planning and managing Center risk. The Executive Committee will review quarterly in its meetings the status of risk through their life cycle of identification – analysis –response – monitoring – retirement. The Committee will also have generative discussion for early identification of new or yet unanticipated risks, of risk mitigation strategies, and the impact of risk on the output and outcomes of the Center.

Risk will be managed through a risk register. The Center, Site, and Convergent Research, Workforce Development, Diversity and Culture of Inclusion, and Innovation Ecosystem Directors will identify new and update the status of risks in the register at any time, and in advance of the quarterly Executive Committee meetings. The Directors will also review and hold generative discussions on risk for the Center as a whole and each of the four pillars once per year, and as needed, with all of the Center's Councils and Boards.

Risk will be categorized by its impact at the Center-level and to each of the four pillars of IoT4Ag Convergent Research (R), Workforce Development (W), Diversity and Culture of Inclusion (D), Innovation Ecosystem (I), and Center (C).

Risk will be scored by its probability of occurrence and its impact on Center programming.

IoT4Ag Risk Scoring Matrix

Scoring Matrix

Score	PROBABILITY	Product Requirements
HIGH	>50%	Key requirements are significantly compromised.
MEDIUM	10-50%	Primary (key) requirements are partially compromised and/or secondary requirements are significantly compromised.
LOW	<10%	Secondary requirements are partially compromised, but primary (key) requirements are not.

ID Numbering

R#	Research
W#	Workforce Development
D#	Diversity and Culture of Inclusion
I#	Innovation Ecosystem
E#	Evaluation and Assessement
C#	Center-Wide

Risk Score

Probability	Score
HH	20
MH	15
HM	14
LH	11
MM	10
HL	9
LM	6
ML	5
LL	1

IoT4Ag Risk Register

IDENTIFICATION						CURRENT ASSESSMENT				TREATMENT		RESIDUAL ASSESSMENT			REVIEW, CONTROL, COMMUNICATE	
ID	RAISED BY	DATE RAISED	CAUSE (IF…)	EFFECT (THEN…)	RISK OWNER	P	I	PI	Current Risk Score	STRATEGY	TREATMENT DESCRIPTION	P	I	Residual Risk Score	Commentary	Last Updated
	The originator of the risk	*When the risk was first identified*	*If uncertain event occurs due to (or because of) specified root cause(s). Tip: ask "why, why, why…" to drill down to root cause*	*then the ultimate impact to our objectives are. Tip: ask "so what, so what, …"*	*Single named owner*	*Probability of the event occurring*	*'Worst' impact*	*DO NOT MODIFY*	*Calculated risk score*	*Select overall approach to treatment (Mitigate or Accept)*	*Summary of the treatment responses (actions, controls, fallbacks) that treat the risk.*	*Probability of the event occurring*	*'Worst' impact*	*Calculated risk score*	*Any additional notes, comments or actions*	*Enter the last review or update date for the risk*
R1	Diane Rowland	23-Nov-20	Unanticipated interferences that limit new sensor chaff capabilities	Sensors do not meet design targets	***Thrust 1*** Rowland Ehsani	L	M	LM	6	Accept	Contingencies will be addressed by Thrust 1 team when deploying sensors and by sensor system design	L	L	1		
R2	Reza Ehsani	23-Nov-20	The sensors and autonomous platforms' accuracy and performance may be affected by local extreme environmental factors and conditions	Significant errors in performance	***Thrust 1*** Rowland Ehsani	M	M	MM	10	Mitigate	Evaluate sensors by extensive field tests under different control scenarious and consider limitations in re-design	M	L	5		
R3	Diane Rowland	23-Nov-20	Lack of adaptibility of mobile robot platforms to different planting practices for different crops	limited application for different croping systems	***Thrust 1*** Rowland Ehsani	M	M	MM	10	Mitigate	Add flexibility in the design of the system to be used for different crops and planting practices	M	L	5		
R4	Diane Rowland	23-Nov-20	Emerging abiotic/biotic stressors	New emerging stressors not yet previously experienced	***Thrust 1*** Rowland Ehsani	M	H	MH	15	Mitigate	Risk varies depending on region; for high risk regions develop a Rapid Response procedure to address any noted emerging stressors	M	L	5		
R5	Mark Allen	27-Nov-20	Accumulation of biodegradation products	Sensors and power sources in the soil have adverse effects on agricultural products	***Thrust 1/2*** Ehsani Rowland Allen Love	M	L	ML	5	Mitigate	Adjust degradation profile, materials set, and increase spatial sparsity of sensors	M	L	5		
R6	Mark Allen	27-Nov-20	Energy harvesters	Insufficient energy to allow cahff sensors to operate or communicate effectively	***Thrust 2*** Allen Love	M	H	MH	15	Mitigate	Utilize beamed power approaches, use robots to more effectively transfer power to harversters, increase harverster size	M	L	5		
R7	David Arnold	25-Nov-20	Connectivity	Connectivity between sensors and robots/base stations cannot be maintained	***Thrust 2*** Allen Love	M	H	MH	15	Mitigate	Increase diversity of communication paradigms, including optical, narrowband RF, and wideband approaches; increase power expenditures withing system communication components	M	L	5		
R8	Mark Allen	27-Nov-20	Backhaul communications	Infrastructure is insufficient for reliable data processing and distribution	***Thrust 2*** Allen Love	M	H	MH	15	Mitigate	Incorporation of additional, commercial backhaul communications products and software-defined radio approaches	M	L	5		
R9	Mark Allen	27-Nov-20	Robot batteries	Insufficient to allow efficient robot coverage of large-area agricultural fields	***Thrust 2*** Allen Love	L	H	LH	11	Mitigate	Increase density of charging stations distributed throughout the field; increase use of irrigation and ground-based equipment as robot recharging stations	L	L	1		
R10	Dennis Buckmaster	23-Nov-20	Model integration	Some biophysical models may have long on-ramp effort required to be interoperable with systems generated by Center	***Thrust 3*** Buckmaster Mangharam Pappas	M	M	MM	10	Mitigate	Center will collaborate openly with "key holders"	M	L	5		

R11	Catherine Keske	1-Dec-20	High costs	Components or system isn't considered economically feasible at large scale	***Thrust 3*** Buckmaster Mangharam Pappas	H	H	HH	20	Mitigate	Continued, focused, integrated economic feasibility study with all tasks	H	M	14		
R12	George Pappas	3-Dec-20	Data availability	Delays development of data driven approaches and learning-based control systems	***Thrust 3*** Buckmaster Mangharam Pappas	M	M	MM	10	Mitigate	Develop relevant approaches from data available in related sectors while IoT4Ag data is collected	M	L	5		
R13	George Pappas	3-Dec-20	Biophysical Model complexity	Impacts development of agricultural response systems	***Thrust 3*** Buckmaster Mangharam Pappas	M	M	MM	10	Mitigate	Rely more on data driven techniques as well as simplied biophysical models	L	L	1		
R14	Diane Rowland	24-Nov-20	Asynchronous development in the three thrusts	Lack of full integration across teams at each step of research - problem conception, research design, data analysis & synthesis	***Systems Integration*** Crawford	L	M	LM	6	Mitigate	Targeted leadership to focus on structure, processes and systems integration	L	L	1		
R15	Diane Rowland	23-Nov-20	Diversity in type and variety of crops	Could limit generalization of approaches	***Systems Integration*** Crawford	L	M	LM	6	Mitigate	Focus traditional crops in the system; initially generalize across varieties and environments; collect existing data from outside sources when considering new crops	L	L	1		
R16	Diane Rowland	23-Nov-20	New emerging, competing technologies	New technologies not used in the ERC over the lifespan of the Center	***Systems Integration*** Crawford	M	H	MH	15	Mitigate	ERC team must maintain vigilence regarding emerging technologies not a part of the current ERC; determine potential impacts. Systems staff responsible for integrating for team	L	M	6		
R17	Diane Rowland	23-Nov-20	Weather	Impact the degree of crop stress and the yield or quality consequences in each growing environment	***Testbed*** Ehsani Small Vyn	L	M	LM	6	Accept	Thrusts will work closely to identify and proactively address threats for consistent data collection and communication	L	L	1		
R18	Ian Small	1-Dec-20	Availability and functionality of equipment required to conduct testing	Inability to effectively test technology developed by the center	***Testbed*** Ehsani Small Vyn	M	M	MM	10	Mitigate	Use of commercial "off the shelf" (COTS) test equipment that can be purchased/replaced. Purchasing from trusted vendors means on-going maintenance and design support for future standards is taken care of by the vendor.	M	L	5		
R19	Ian Small	1-Dec-20	Lack of expertise required to effectively evaluate IoT4Ag technology at testbeds	Inability to effectively test technology developed by the center	***Testbed*** Ehsani Small Vyn	M	M	MM	10	Mitigate	Identify expertise required and facilitate a solution that brings in the expertise into the center through hiring or collaboration	L	L	1		
R20	Ian Small	1-Dec-20	Limtation on technology testing due to regulatory restrictions e.g. airspace restrictions	Testing of systems requiring appropriate regulatory approval would limited	***Testbed*** Ehsani Small Vyn	L	M	LM	6	Mitigate	Conduct an early stage assessment of potential regulatory requirements for technologies that are being developed. Initiate early planning and seek regulatory approvals for testing at the appropriate test location.	L	L	1		

W1	Dave Cappelleri	23-Nov-20	COVID restrictions impact on outreach activities	Prevents outreach activities with Deaf Kids Code and K-12 programs	***WFD Precollege*** Cappelleri	H	H	HH	20	Mitigate	Focus on kit development and modifications for scaling; instructions manual / kit development to conduct research at home	H	L	9		
W2	Dave Cappelleri	23-Nov-20	COVID restrictions impact with WFD partners	Prevents activities with Community College partners	***WFD University*** Bidstrup-Allen	H	H	HH	20	Mitigate	Create virtual module content that can be delivered live or recorded and accessed on-demand	H	L	9		
W3	Dave Cappelleri	23-Nov-20	COVID restrictions impact on summer programs	Prevents on-campus summer REU student participation	***WFD University*** Bidstrup-Allen	M	H	MH	15	Mitigate	Dependent on vaccine timeline, Center may set up REU projects for remote participation	M	L	5		
W4	David Arnold	25-Nov-20	Tech and Ag professional buy-in	Reluctance to integrate IoT4Ag technologies into practice	***WFD Professiona l*** Small Vyn	M	H	MH	15	Mitigate	Feedback surveys, early and often stakeholder involvement/input, Ag Systems Advisory board recommendations	L	M	6		
D1	Catherine Keske	20-Nov-20	Unforeseen student vulnerabilities, especially in underserved populations	Student attrition	***Diversity & Inclusion*** Keske Arratia	M	M	MM	10	Mitigate	Refine how vulnerabilities are identified, and assessment instruments	M	M	10		
D2	Catherine Keske	2-Dec-20	Travel restrictions that impede intra-ERC personnel interactions	Remote contact and communication	***Diversity & Inclusion*** Keske Arratia	H	H	HH	20	Accept	Adapt learning environments, acquire assistive equipment, create policy accommodations, or modify international student recruitment	H	L	9		
I1	David Arnold	23-Nov-20	Corporate cost-cutting puts pressure on industry membership fees	Loss of industry board members	***Innovation Ecosystem*** Arnold Weiner	L	H	LH	11	Mitigate	If necessary, temporarily reduce or waive membership fees	L	L	1		
I2	David Arnold	23-Nov-20	Competing initiatives for IoT4Ag , e.g. by major foundations	Loss of stakeholder engagement and limited long term impact	***Innovation Ecosystem*** Arnold Weiner	M	M	MM	10	Mitigate	Stay alert for new initatives at the IoT4Ag intersection and seek to partner with them, e.g. propose that interested foundations join and co-sponsor the Center	L	M	6		
E1	David Arnold	23-Nov-20	Noncomprehensive evaluation and assessment tools	Assessment doesn't adequately capture inclusion	***Evaluation & Assessment*** Miller	M	M	MM	10	Mitigate	Anonymous reporting, refine activity based upon feedback	M	L	5		
C1	Cherie Kagan	24-Nov-20	Disciplinary and demographic diversity of participants and stakeholders in research, education, diversity and culture of inclusion, and innovation	Limits Center identification as a leader in IoT and Ag by some groups	***Center*** Kagan	M	M	MM	10	Mitigate	Assess and revise Center approaches and establish new relationships for dissemination, communication, and publicity of IoT4Ag products and programs	L	L	1		

CORE INSTITUTION AGREEMENT

Amended and Restated IoT4Ag Engineering Research Center Core Institution Member Agreement

This IoT4Ag Engineering Research Center Core Institution Member Agreement ("Agreement") is made as of September 21, 2020 ("Effective Date") between **The Trustees of the University of Pennsylvania**, a non-profit, tax-exempt educational institution organized and existing under the laws of the Commonwealth of Pennsylvania, with an address at Penn Center for Innovation, 3600 Civic Center Blvd, 9th Floor, Philadelphia, PA 19104-4310 ("PENN"), on behalf of the Center for the Internet of Things for Agriculture ("the Center"), and the following member institutions: **University of Florida Board of Trustees**, a public body corporate of the state of Florida, having offices at 207 Grinter Hall, Gainesville, FL 32611-5500, **The Regents of the University of California, Merced**, a non-profit, tax-exempt educational institution organized and existing under the laws of the State of California, with an address at 5200 Lake Road, Merced, California 95343, and **Purdue University**, a non-profit, tax-exempt educational institution organized and existing under the laws of the State of Indiana, with an address at 610 Purdue Mall, West Lafayette, IN 47907-2040 (each of which may be referred to herein individually an "Institution Member" or in any combination as "Institution Members"). PENN and the Institution Members form the "Core Institution Members".

WHEREAS, PENN has received funding from the National Science Foundation ("NSF") to act as the "Lead Institution" under the Engineering Research Center ("ERC") program and has joined together with the Institution Members to establish the Center, headquartered at PENN for the purpose of stimulating industrial innovation in the area of precision agriculture;

WHEREAS, the Center has also sought industry members (each of which may be referred to herein as an "Industry Member" or collectively as the "Industry Members") who have agreed to support the Center and have signed a copy of the IoT4Ag Industry Member Agreement. The Industry Members and the Core Institution Members may each be referred to herein as a "Center Member" or collectively as the "Center Members"; and

WHEREAS, the Core Institution Members previously executed an IoT4Ag Engineering Research Center Core Institution Member Agreement effective September 21, 2020. This Amended and Restated IoT4Ag Engineering Research Center Core Institution Member Agreement shall amend and restate that original Agreement in its entirety.

NOW, THEREFORE, the Core Institution Members hereby agree to the following terms and conditions.

1. CENTER ORGANIZATION

1.1 Definitions

a. "Affiliate(s)" as used herein means companies, controlled by, controlling or under common control as a party to the Agreement, with control being defined as direct or indirect ownership of over fifty percent (50% of the outstanding voting securities of an entity).
b. "Center Director" as used herein means Professor Cherie Kagan ("Center Director"), a faculty member at PENN.
c. "Core Research" as used herein means research that the Executive Committee (as defined below) determines shall be: (a) conducted through the Center by faculty, students and staff from Core Institution Members, and (b) financially supported by funds from NSF ERC program, Core Institution Members *via* cost sharing, and from Membership Fees.

d. "Executive Committee" as used herein refers to the leadership of the Center, led by the Center Director (as defined below) and compromised of representatives from each of the Core Institution Members. The Executive Committee is responsible for management and administration of the Center under the direction of the Center Director, including addressing issues concerning the effectiveness of the Center and selecting, overseeing, and managing the Core Research to be conducted by the Center.
e. "IPAB" as used herein means the Industry and Practitioners Advisory Board. Every Industry Member can select a representative to serve on the IPAB. The IPAB is responsible for advising the Executive Committee on the direction of Core Research and the operational policies of the Center. The IPAB shall communicate with the Executive Committee via an Industrial and Practitioner Executive Committee ("IPEC") elected by the IPAB. The Executive Committee and the IPEC shall meet at least biannually. A quorum of the IPAB shall consist of a simple majority of the Industry Members. In all matters before the IPAB, a simple majority is needed for any vote to pass. The meeting logistics and other operating procedures of the IPAB are outside of this Agreement and will be determined separately by the IPAB.
f. "Research Results" as used herein means all data and information which are generated by or on behalf of a Core Institution Member in the performance of the Core Research during the term of this Agreement. Research Results expressly excludes Intellectual Property.
g. "Intellectual Property" as used herein means all inventions, whether patentable or not, conceived and first reduced to practice (as determined by United States patent law) by or on behalf of a Core Institution Member in the conduct of the Core Research, including all United States and foreign patent applications claiming said patentable inventions, including any divisional, continuation, continuation-in-part (to the extent that the claims are directed to said patentable inventions), and foreign equivalents thereof, as well as any patents issued thereon or reissues or reexaminations thereof. Intellectual Property also includes all significant copyrights and copyrightable software authored (as determined by United States copyright law) by a Core Institution Member in the conduct of the Core Research.
h. "Life of the Center" as used herein means from the Effective Date until the expiration or termination of the NSF award for the Center.
i. "Non-Commercial Entities" as used herein means Governmental agencies, government offices, government organizations duly authorized by the United States Government or government of any State or Nation, and legally recognized non-profit organizations other than the Core Institution Members who are not representatives or affiliates of any for-profit entities, except where an entity is deemed a Commercial Entity by its Industry Member Agreement.

1.2 Center activities were funded by the NSF ERC program on September 1, 2020. The Center is managed and administered under the direction of the Center Director and supported jointly by Institution Members, Industry Members, and by PENN personnel selected by the Center Director from PENN faculty and staff. At the discretion of the Center Director, additional personnel from Institution Members and Industry Members may be added at any time to assist in management and administration of the Center; provided that any such personnel who will be temporarily in residence at PENN as researchers for the Center will be considered Visiting Scholars and may be asked to sign a separate Visiting Scholars Agreement before such residency shall begin.

1.3 Each Industry Member (excluding Non-Commercial Entities) will provide payment of its annual membership fees in accordance with its Industry Member Agreement ("Membership Fees"). Core Research supported by Industry Membership Fees is not subject to facilities and administrative costs. Membership in the Center does not preclude any Core Institution Member from entering into separate research agreements with Industry Members who participate in the Center.

2. RESEARCH RESULTS; REPORTS

2.1 Core Institution Members engaged in Core Research shall provide the Executive Committee and the IPAB with interim reports detailing preliminary Research Results and the status and progress of the Core Research as requested by the Executive Committee. Core Institution Members engaged in Core Research shall also provide the Executive Committee and the IPAB a final report summarizing the Research Results at the conclusion of a Core Research project. The interim reports and final reports shall together be referred to herein as "Reports".

2.2 Center Members shall have the right to use Research Results disclosed to them in Reports for any lawful purpose, and are hereby granted a royalty-free, nontransferable, non-exclusive right to copy, reproduce and distribute said Reports, provided that: (a) a Center Member shall need to obtain a license to use Research Results from the Center Member(s) who generated such Research Results if such use would infringe any copyright or any claim of a patent application or issued patent owned by the Center Member(s) that authored the Report; (b) Center Members shall maintain the Research Results confidentially pending publication in accordance with Section 4.6; (c) Center Members may not charge fees for said research reports, use said research reports for advertising or promotional activities, or alter or modify said research reports without the prior written permission of the Center Member(s) who authored the Report.

3. INTELLECTUAL PROPERTY

3.1 Ownership of Intellectual Property shall follow inventorship in accordance with United States patent law or authorship in accordance with United States copyright law, as applicable.

3.2 The owner(s) of Intellectual Property in accordance with Section 3.1 hereby grant the other Center Members (excluding Non-Commercial Entities) a non-exclusive, royalty-free, non-transferable, non-sublicensable license to practice such Intellectual Property for only non-commercial, internal research use for the Life of the Center (hereinafter an "Internal Use License"), provided that (a) such Intellectual Property was conceived and first reduced to practice, or first authored, during the Center Member's membership in the Center; (b) with respect to Industry Members, the Industry Member has paid its annual Membership Fee; and (c) Center Member acknowledges the Center and the NSF Engineering Research Center (ERC) program in any publication based on use of this license.

3.3 Core Institution Members shall provide the IPAB with prompt written notice of any Intellectual Property reasonably considered patentable or, in the case of Intellectual Property consisting of software or data collections, is reasonably considered to be technologically valuable ("IP Disclosure").

a. The IPAB will have thirty (30) days following receipt of an IP Disclosure ("Review Period") to make a recommendation with respect to the filing and prosecution of a patent application claiming such Intellectual Property.
b. If the IPAB makes a recommendation during the Review Period in support of filing and prosecution of a patent application claiming the disclosed Intellectual Property, the owner of the Intellectual Property shall control the preparation and prosecution of such patent application and the costs associated with preparation and filing fees (initial U.S. application only) will be reimbursed by the Center from Industry Membership Fees, provided sufficient funds are available. In the event sufficient funds are not available the costs associated with such preparation and filing fees will be borne equally by the Industry Members voting in favor of filing and prosecution of a patent application.
c. If the IPAB does not respond within the Review Period or makes a recommendation during the Review Period against filing and prosecution of a patent application claiming the disclosed Intellectual Property, the owner of the Intellectual Property may decide independently to proceed with patent filing and prosecution at its own expense and such Intellectual Property shall not be subject to the Option as described below.

3.4 Industry Members (excluding Non-Commercial Entities) shall have sixty (60) days from receipt of an IP Disclosure ("Option Period") to elect to exercise an option to negotiate a royalty-bearing non-exclusive license to practice the Intellectual Property described in such IP Disclosure for commercial purposes ("Option"). The Option is non-transferable and is personal to the Industry Member.

3.5 Any Industry Members (excluding Non-Commercial Entities) who exercise their Option during the Option Period will negotiate with the owner of the Intellectual Property in good faith to determine the terms of a license agreement. If a license agreement is not executed within six (6) months after the Industry Member's election of the Option, the owner of the Intellectual Property shall be free to license Intellectual Property to any Center Member, or to any non-member small business or start-up upon such terms as it deems appropriate, without any further obligation to the Industry Member(s). If, at the conclusion of the Option Period, only one Industry Member seeks a license, that Industry Member may negotiate to obtain from the Owner of the Intellectual Property a royalty-bearing license that is exclusive, except that the license is subject to the rights of the federal government under the Bayh-Dole Act.

3.6 Center Members' respective rights under this Article 3 shall be subject to the Center's and the Core Institution Members' obligations to and the rights of the United States Government, if any, as subject to the provisions of 35 U.S.C. 200, et seq., 37 C.F.R. Part 401, and other applicable laws and regulations.

4. CONFIDENTIALITY AND PUBLICATION

4.1 From time to time Center Members may have the need to exchange Confidential Information in connection with the performance of Core Research. The Core Institution Members shall be a "Disclosing Party" and/or a "Receiving Party" of Confidential Information as context dictates. The Industry Members shall be a "Receiving Party" only. "Confidential Information" means any of a Core Institution Member's confidential or proprietary information- that is necessary to be disclosed to another Center Member in connection with performance of the Core Research and is marked "confidential" or "proprietary" or, if disclosed orally, is summarized in writing sufficiently for identification and is designated in writing as confidential

within thirty (30) days following disclosure. Failure to mark any Confidential Information as confidential or proprietary will not affect its status as Confidential Information under this Agreement if it is information that a reasonable person with expertise in the field would consider the Disclosing Party's Confidential Information hereunder based upon the nature of the information and the circumstances of the disclosure. Confidential Information shall not include information:

a. that is or becomes generally known or available to the public without breach of this Agreement;
b. that is known to the Receiving Party at the time of disclosure, as evidenced by written records of the Receiving Party;
c. that is independently developed by the Receiving Party, as evidenced by written records of the Receiving Party; or
d. that is disclosed to the Receiving Party by a third party without an obligation of confidentiality owed by Receiving Party to such third party; or
e. that is required to be disclosed by law, in which case Receiving Party shall promptly inform the Disclosing Party and shall cooperate with the Disclosing Party to minimize the extent of the disclosure.

4.2 Receiving Party will be permitted to make all disclosures of Disclosing Party's Confidential Information required by law or regulation. Receiving Party shall use reasonable efforts to provide prompt written notice to Disclosing Party to allow Disclosing Party to offer its objections to the production of Confidential Information. The Confidential Information that is disclosed pursuant to this paragraph shall remain confidential for all other purposes in accordance with the terms and conditions of this Agreement.

4.3 Receiving Party will take all reasonable measures to protect the secrecy of, and avoid the unauthorized disclosure or use of, Confidential Information. Such measures will include the highest degree of care that Receiving Party utilizes to protect Receiving Party's own confidential information of a similar nature, but no less than a reasonable degree of care. Receiving Party will not use Confidential Information for any purpose, other than as necessary to carry out the Core Research. Specifically, Receiving Party will not use Confidential Information to file patent applications or for experimental activity. No licenses or other rights are granted. Receiving Party may disclose Confidential Information to Affiliates, employees, agents or consultants on a need to know basis only if such persons are bound to obligations of non-use or non-disclosure at least as restrictive as those set forth in this Agreement. Recipient will not disclose any Confidential Information to any other Affiliates, employees, agents, consultants, or to any third parties. Receiving Party will promptly notify Disclosing Party in writing of any misuse or misappropriation of any Confidential Information that may come to Receiving Party's attention. Receiving Party will be responsible for any breach of this Agreement by its Affiliates, employees, agents, or consultants.

4.4 Disclosing Party represents that it has the right to make the disclosures of Confidential Information made hereunder. Except as expressly set forth in this Section 4.4, Disclosing Party is providing Confidential Information on an "*As Is*" basis for use by Receiving Party at its own risk without express or implied warranties of any kind.

4.5 Receiving Party's obligations as to any item of Confidential Information will survive during the term of this Agreement and shall continue for five (5) years following the expiration or

termination of this Agreement. Upon the written request of Disclosing Party, Receiving Party will destroy or return to Disclosing Party all Confidential Information received from Disclosing Party, except that Receiving Party may maintain a single copy of any written Confidential Information for Receiving Party's records. Notwithstanding the foregoing, the obligation to return or destroy Confidential Information does not include Confidential Information that has been backed up as part of the Receiving Party's normal business procedures, and the Receiving Party may reproduce Confidential Information in the process of backing up computer systems in the normal course of business.

4.6 The Core Institution Members shall have the first right to publish, present or otherwise publicly disclose the Research Results developed under this Agreement ("Publish"). Any Core Institution Member wishing to Publish shall furnish the Executive Committee and IPAB with a copy of the proposed publication, presentation, or other public disclosure (each a "Publication") at least thirty (30) days in advance of the date of such presentation or disclosure, or the submission of said proposed publication, in order for the Executive Committee and IPAB to review and comment on said proposed Publication to (a) determine whether such Publication contains any Confidential Information of any of the other Core Institution Members; and (b) enable the Industry Members to identify any Intellectual Property for which it wishes to seek intellectual property protection. If within the thirty (30) day review period (i) a Core Institution Member requests deletion of Confidential Information from the proposed Publication, the Core Institution Members at issue will cooperate to modify the disclosure to ensure Confidential Information is not disclosed; or (ii) an Industry Member requests that the Proposed publication be delayed to allow for intellectual property protection on certain items of Intellectual Property in the proposed Publication, the publishing Core Institution Member shall delay the proposed Publication for up to sixty (60) days to allow for intellectual property protection to be sought.

5. DISCLAIMER OF WARRANTIES; INDEMNIFICATION

5.1 NO CORE INSTITUTION MEMBER MAKES ANY WARRANTIES, EXPRESS OR IMPLIED, AS TO ANY MATTER WHATSOEVER, INCLUDING, WITHOUT LIMITATION, WARRANTIES WITH RESPECT TO THE CONDUCT, COMPLETION, SUCCESS OR PARTICULAR RESULTS OF THE CORE RESEARCH, OR THE CONDITION, OWNERSHIP, MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE OF THE CORE RESEARCH OR ANY INTELLECTUAL PROPERTY OR RESEARCH RESULTS, OR THAT USE OF INTELLECTUAL PROPERTY OR RESEARCH RESULTS WILL NOT INFRINGE ANY PATENT, COPYRIGHT, TRADEMARK OR OTHER INTELLECTUAL PROPERTY RIGHT OF A THIRD PARTY. EXCEPT AS SET FORTH IN SECTION 5.2 NO CORE INSTITUTION MEMBER SHALL BE LIABLE FOR ANY DIRECT, INDIRECT, CONSEQUENTIAL, PUNITIVE OR OTHER DAMAGES SUFFERED BY ANOTHER CORE INSTITUTION MEMBER RESULTING FROM THE CORE RESEARCH OR THE USE OF ANY INTELLECTUAL PROPERTY, ANY RESEARCH RESULTS OR ANY PRODUCTS RESULTING THEREFROM.

5.2 To the extent permitted under state and federal statutes, constitutional provisions and other law, each party shall be responsible for its own negligent acts or omissions and the negligent acts or omissions of its officers, directors, trustees, employees and agents that arise out of or are related to the performance of the obligations under this Agreement This provision is intended to be an allocation of risk between the parties, and shall not constitute an indemnification.

6. MISCELLANEOUS

6.1 No Center Member shall use the name, logo, seal, trademark, or service mark (including any adaptation of them) of any other Center Member, including any school, organization, employee, student or representative thereof, without the prior written consent of that Center Member. No Center Member except PENN shall use the name of the Center without the prior written consent of PENN. Notwithstanding the foregoing, Center Members may use the name of the Center in a non-misleading, factual manner to state Center Members' participation in the ERC without PENN's consent.

6.2 For purposes of this Agreement and membership in the Center, the Center Members shall be independent contractors and none shall at any time be considered an agent or an employee of the other. No joint venture, partnership or like relationship is created between any of the Center Members by their membership in the Center or this Agreement.

6.3 The terms and provisions hereof shall inure to the benefit of, and be binding upon, the Center Members and their respective successors and permitted assigns. No Center Member may assign or transfer this Agreement or any of its rights or obligations created hereunder, by operation of law or otherwise, without the prior written consent of the other Parties. Any assignment not in accordance with this Section 6.3 shall be void. However, transferring a Center Member's licensing and intellectual property obligations to their respective office of technology commercialization, office of tech transfer or other similar Center Member office, shall not be a breach of this provision.

6.4 A waiver by a Center Member of any of the terms and conditions of this Agreement in any instance shall not be deemed or construed to be a waiver of such term or condition for the future, or of any other term or condition hereof. All rights, remedies, undertakings, obligations and agreements contained in this Agreement shall be cumulative and none of them shall be in limitation of any other remedy, right, undertaking, obligation or agreement of a Center Member.

6.5 When possible, each provision of this Agreement will be interpreted in such manner as to be effective and valid under law, but if any provision of this Agreement is held to be prohibited by or invalid under law, such provision will be ineffective only to the extent of such prohibition or invalidity, without invalidating the remainder of this Agreement. The Center Members shall make a good faith effort to replace the invalid or unenforceable provision with a valid one which in its economic effect is most consistent with the invalid or unenforceable provision.

6.6 This Agreement constitutes the entire agreement between the Core Institution Members with respect to its subject matter, and supersedes all previous communications and agreements, whether oral or written, between the Core Institution with respect to the subject matter hereof. This Agreement may be waived, modified, or amended only by an instrument in writing and signed by duly authorized representatives of all Core Institution Members.

6.7 This Agreement may be executed in counterparts, each of which will be deemed an original, and all of which together will be deemed to be one and the same instrument. A portable document format (PDF) or electronic copy of this Agreement, including the signature pages, will be deemed an original.

[SIGNATURE PAGE FOLLOWS]

IN WITNESS WHEREOF, the duly authorized representatives of the Parties hereby execute this Agreement as of the date first written above.

THE TRUSTEES OF THE UNIVERSITY OF PENNSYLVANIA

By: DocuSigned by: Jacqueline Rodriguez 1918F5E35A114D8...

Name: Jacqueline Rodriguez

Title: Assoc. Dir., Corp. Contracts

PURDUE UNIVERSITY

By: DocuSigned by: Daniel J. Reed 243A7B4252B243A...

Name: Daniel J. Reed

Title: Lead Analyst

UNIVERSITY OF FLORIDA BOARD OF TRUSTEES

By: DocuSigned by: Lisa Stroud 2D71F3703C75450...

Name: Lisa Stroud

Title: Associate Director

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA,MERCED

By: DocuSigned by: Jue Sun F1BC694BB10349F...

Name: Jue Sun

Title: Director, Sponsored Projects Office

ACKNOWLEDGED AS READ AND UNDERSTOOD BY CENTER DIRECTOR AND LEAD PRINCIPAL INVESTIGATORS:

By: DocuSigned by: Cherie Kagan 376EEDB84E4B4C2...

Name: Cherie Kagan

Center Director, University of Pennsylvania

By: DocuSigned by: F2BD761DFF414EF...

David Arnold

Lead Principal Investigator, University of Florida

By: DocuSigned by: David J. Cappelleri 3543BFB990694D2...

Name: David Cappelleri

Lead Principal Investigator, Purdue University

By: DocuSigned by: Catherine Keske C5A91446B99A4A8...

Catherine Keske

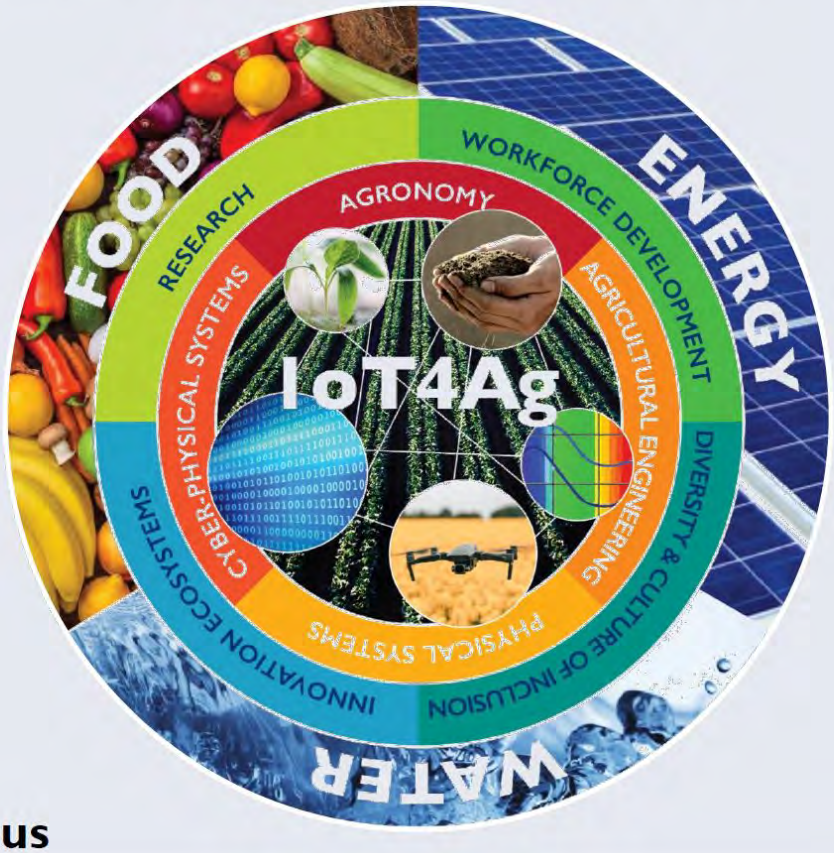
Lead Principal Investigator, University of California, Merced

IoT4Ag™
NSF ENGINEERING RESEARCH CENTER
FOR THE INTERNET OF THINGS
FOR PRECISION AGRICULTURE

NSF
Established 2020

Industrial Membership Program

Partnership to revolutionize US agriculture:
Create and translate to practice precision agriculture technologies to ensure food, energy, and water security



iot4ag.us

Penn | PURDUE UNIVERSITY | UNIVERSITY OF CALIFORNIA MERCED | UF UNIVERSITY of FLORIDA

IoT4Ag

Need: Food, Energy, and Water Security

By 2050, the US population is estimated to grow to 400 million and the world population to 9.7 billion. Current agricultural practices account for 70% of global water use, energy use accounts for one of the largest costs on a farm, and inefficient use of agrochemicals is altering Earth's ecosystems. With finite arable land, water, and energy resources, ensuring food, energy, and water security will require new technologies to improve the efficiency of food production, create sustainable approaches to supply energy, and prevent water scarcity.

Opportunity: Create the Future of Agriculture with IoT4Ag!

IoT4Ag is an NSF-funded Engineering Research Center (ERC) uniting academia, industry, and government in a partnership to engineer transformational, high-value, integrated systems with significant societal impact. Industry partners are integral to guiding and developing the strategic directions of the ERC and translating results to practice.

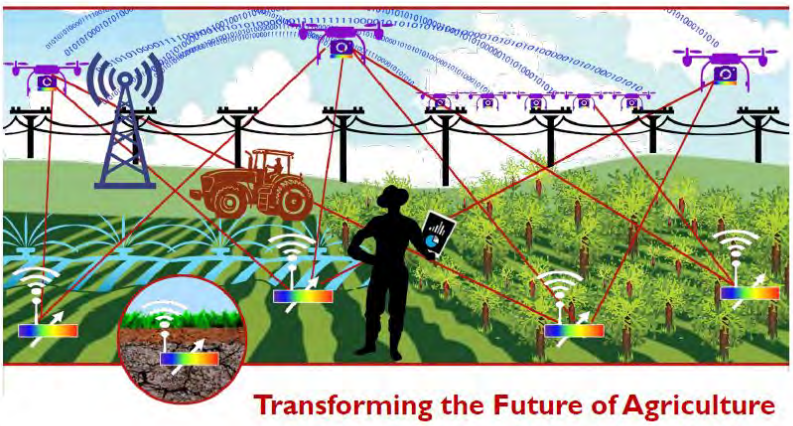
Join this innovation ecosystem as an industry member and harness the collective insight, expertise, and resources of academic, industry, investment, and government partners. Collaboratively define and realize the future of precision agriculture and enable and educate a diverse workforce that will address the societal grand challenge of food, energy, and water security for decades to come.

Vision: Sustainable, Efficient, High-Output Precision Agriculture

IoT4Ag is dedicated to dramatically and sustainably improving agricultural crop production while minimizing the use of energy and water resources and the environmental impact of agricultural practices. We will create novel, integrated systems that capture the microclimate and spatially, temporally, and compositionally map heterogeneous stresses for early detection and intervention to better outcomes in agricultural crop production. The Center will create internet of things (IoT) technologies to optimize practices for every plant; from sensors, robotics, and energy and communication devices to data-driven models constrained by plant physiology, soil, weather, management practices, and socio-economics.

Solutions: Breakthrough IoT Technology

- Multi-mode, low-cost, distributable, environmental and soil sensor technologies
- Autonomous aerial and ground-based robots
- Energy storage and delivery technologies for field-scale operation
- Ag-specific communications
- Biophysically-constrained data analytics to produce decision Ag interventions and improve outcomes in agricultural fields



Transforming the Future of Agriculture

Membership Benefits

Industrial Practitioner Advisory Board (IPAB) – Exclusive seat on the IPAB. Meet with **IoT4Ag** leadership twice annually and provide the highest level of strategic guidance on **IoT4Ag** research directions. Elect a 10-member industrial practitioner executive committee (IPEC) to communicate IPAB recommendations to the **IoT4Ag** Executive Committee.

Research and Development – Leverage National Science Foundation (NSF) federal funding, university cost share, and pooled membership fees to support research and development in strategic areas of Internet of Things (IoT) technologies and precision agriculture.

Early Access to Research – Receive early exposure to unpublished and innovative ideas through direct contact with **IoT4Ag** researchers, the internal **IoT4Ag** website (open to **IoT4Ag** members only), the annual **IoT4Ag** technical meeting, quarterly newsletters, workshops, short courses, and webinars.

Intellectual Property and Licensing – Receive early notification of **IoT4Ag** innovations. Have a right to recommend IP filings and an option to negotiate a license.

Sponsor-driven Research Projects – Sponsor specific research projects that leverage the resources and expertise of **IoT4Ag** but with a focus that is set by the sponsor. **IoT4Ag** offers a streamlined process for sponsored research agreements.

Visiting Scientists – Work at **IoT4Ag** multi-user facilities.

Knowledge Exchange – Have access to technical experts and educational programs in agronomy; sensor, energy, and communication technologies; robotics; information and decision systems; precision agriculture; and food security from academia, industry, and government.

Sector Leadership – Be part of defining the technology outlook and roadmap for precision agriculture.

Promotion – Brand visibility to **IoT4Ag** university, industry, innovation, and government partners; professional organizations; and the NSF.

Recruiting – Unique access to talented, highly-educated, and collaborative **IoT4Ag** undergraduate and graduate students and postdoctoral fellows.

Education and Diversity and Inclusion – Contribute to education and inclusion programs to develop a diverse workforce of K-12 students and teachers, university researchers, and agricultural professionals, crop advisors, extension agents, and growers.

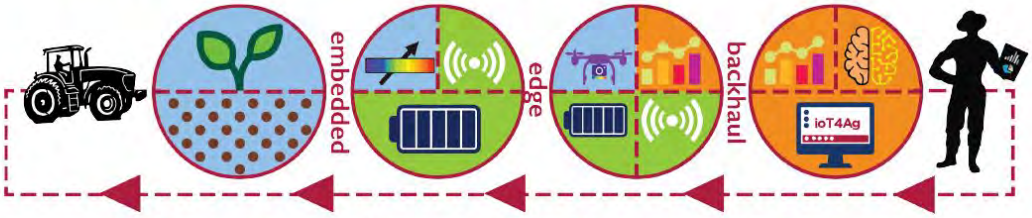
Type of Entity	No. of Employees	Annual Fees*	IPAB Votes
Large	≥500	$30,000	3
Medium	100-499	$15,000	2
Small	11-99	$2,500	1
Very Small	≤10	$1,000	1
Government**	unlimited	$0	0

*Up to 50% of annual fees may be in the form of in-kind contributions, at the discretion of the Center Director. These contributions shall be limited to tangible contributions (i.e., materials, capital equipment, etc.).
**Government agencies, offices, or organizations authorized by the US or any State or Nation, including 501(c)(3) non-profit organizations.

IoT4Ag Value Proposition

Ensuring a food, energy, and water secure future requires new agricultural technologies. IoT4Ag will meet this need by creating transformative science and engineering advances, achieving novel, integrated systems that capture the microclimate; spatially, temporally, and compositionally map heterogeneous stresses; and enable early detection and intervention. IoT4Ag will deliver IoT technology – sensors, robotics, energy and communication devices, and data-driven models – to optimize agriculture for each plant.

Join IoT4Ag's innovation ecosystem and network with academic, industry, investment, and government partners; work with and recruit a diverse, well-trained workforce; and collaboratively build the future of precision agriculture!



Deliver more crop for every drop of water and Joule of energy.

IoT4Ag Leadership

Director
Cherie Kagan, Penn

Site Directors
David Arnold, UF
David Cappelleri, Purdue
Catherine Keske, Merced
Kevin Turner, Penn

Research Leaders

Systems Integrator
Melba Crawford, Purdue

Thrust 1 Leaders
Reza Ehsani, Merced
Diane Rowland, UF

Thrust 2 Leaders
Mark Allen, Penn
David Love, Purdue

Thrust 3 Leaders
Dennis Buckmaster, Purdue
Rahul Mangharam, Penn

Testbed Leaders
Reza Ehsani, Merced
Ian Small, UF
Tony Vyn, Purdue

Education Leaders

Pre-College Education Director
David Cappelleri, Purdue

University Education Director
Sue-Ann Bidstrup Allen, Penn

Professional Education Directors
Ian Small, UF
Tony Vyn, Purdue

Diversity & Inclusion Leaders

Recruiting
Paulo Arratia, Penn

Climate
Catherine Keske, Merced

Innovation Ecosystem Leaders

Industry/University Partnerships
David Arnold, UF

Tech Transfer
Steven Weiner, Penn

Administrative Director

Robert Brier, Penn

Assessment

David Miller, UF

Contact IoT4Ag™ to learn more about getting involved and becoming a member:

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Suite 318
Philadelphia, PA 19146
www.iot4ag.us
iot4ag@seas.upenn.edu
215-746-3243

IoT4Ag
NSF ENGINEERING RESEARCH CENTER
FOR THE INTERNET OF THINGS
FOR PRECISION AGRICULTURE