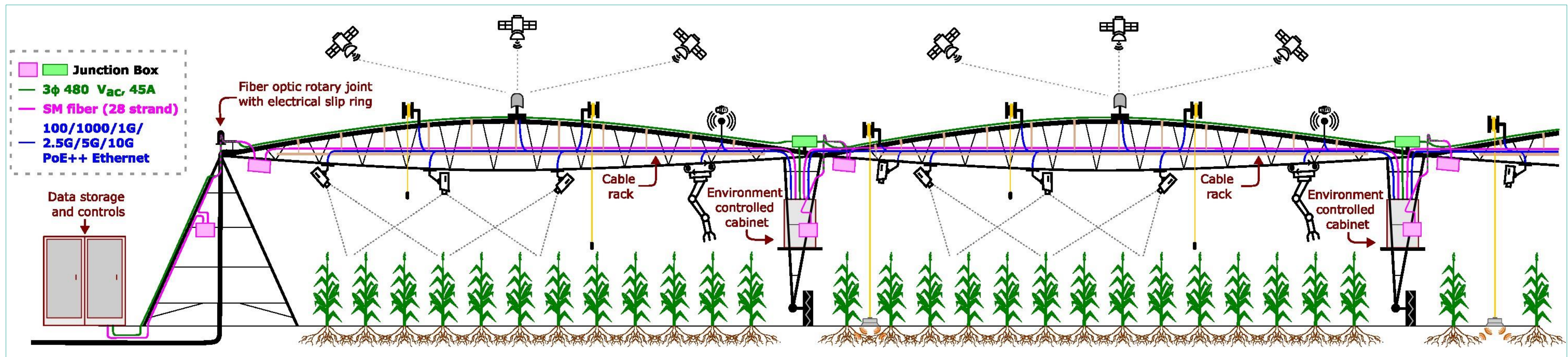


MIDWESTERN PIVOT+ ARRAY FOR AUTONOMOUS AGRICULTURAL SENSING AND CONTROL AT SCALE

Sneha Jha, Andrew D. Balmos, James V. Krogmeier, Dennis R. Buckmaster, and David J. Love

Project 16

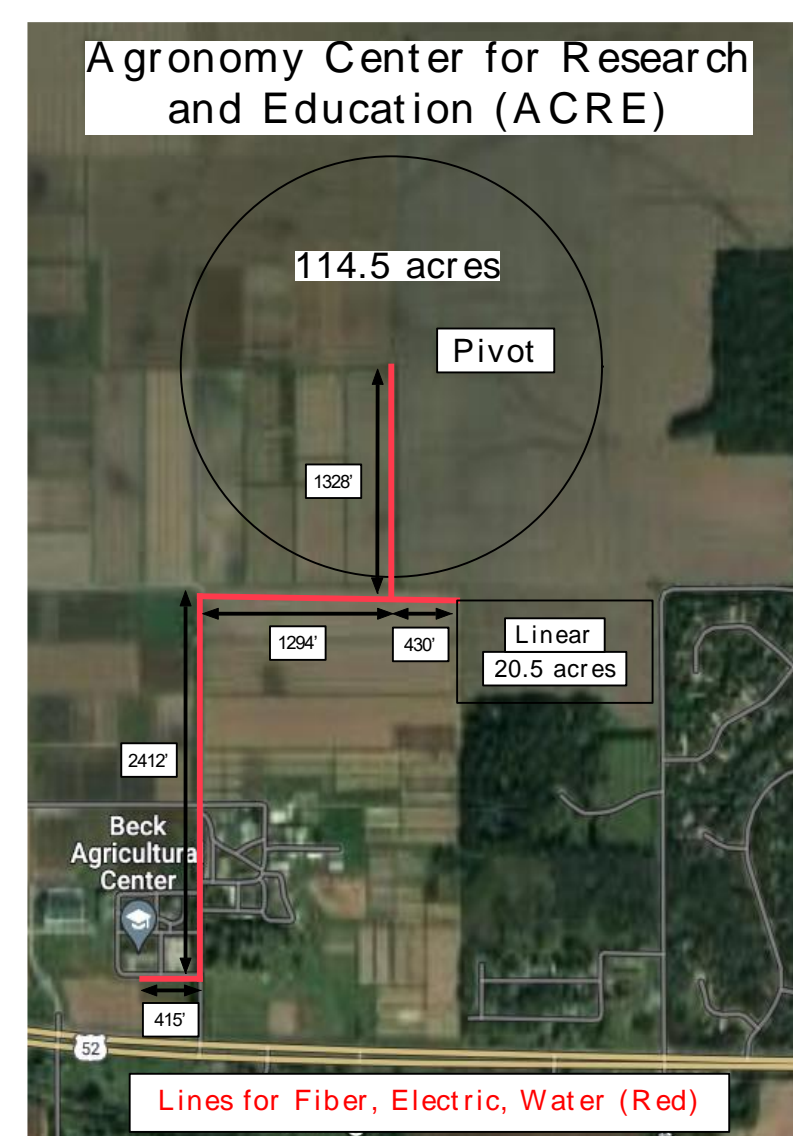


THE PROPOSED INSTRUMENT: PIVOT+

Commercially available irrigation system upgraded as a moveable platform for

- Sensing: soil, water, plant, micro-climate, robotic scouting and tissue sampling
- Actuation: water, fertilizer, crop protection, spot tillage or weeding

The land below equipped with a dense drainage tile system instrumented for water and soil sensing, drainage control, underground comms.



SUBSYSTEMS OF PIVOT+

Gantry: Valley 8000 Series, 7 towers, 180 ft. spans, minimum 12 ft. clearance (115 acres), 90 min. revolution, speed, direction controllable in 2degree sectors, 480 V 3-phase at 45 A per phase

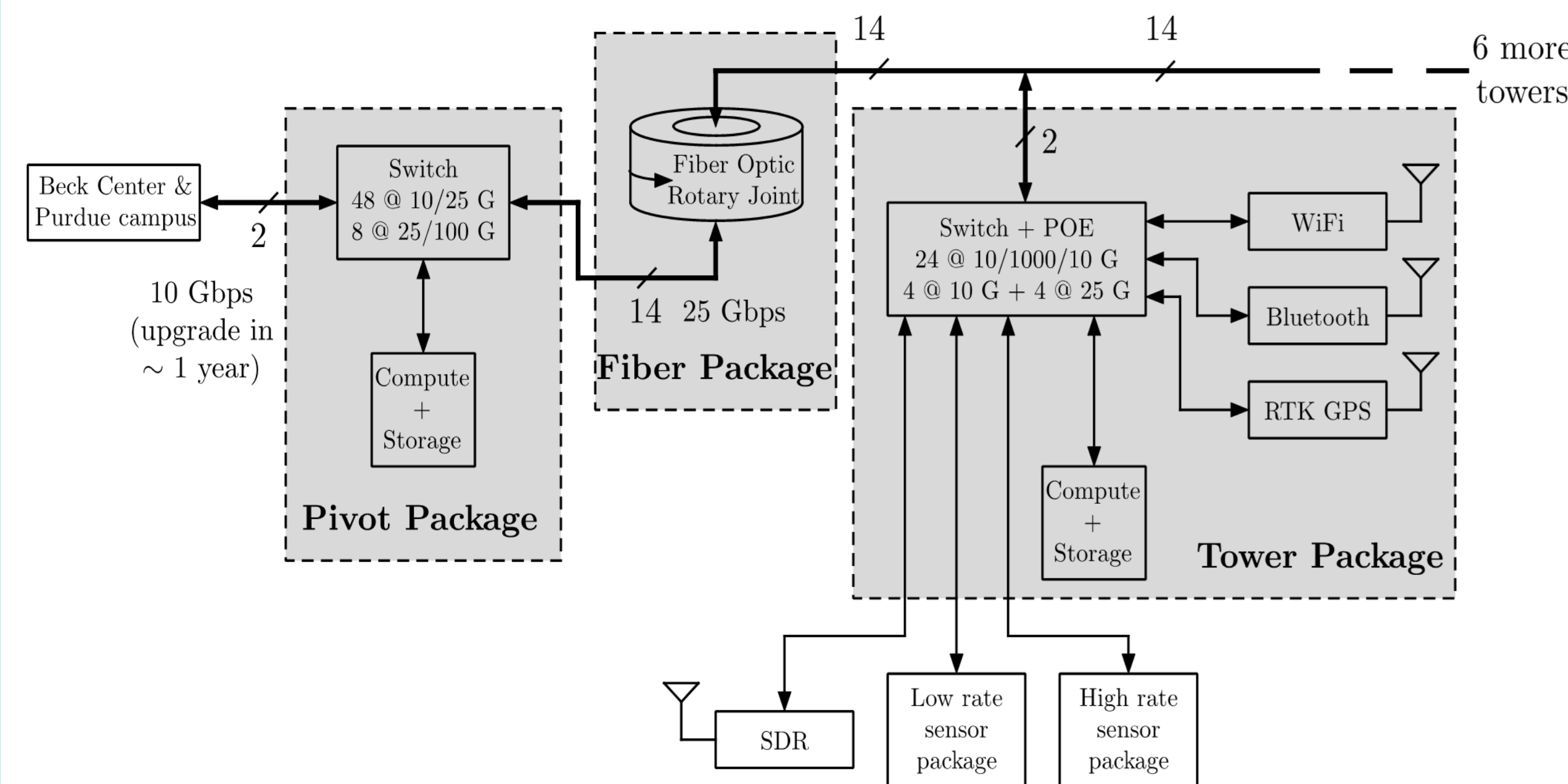
Tower Package: Networking along the gantry

- Each of 7 towers has a climate controlled 26 RU cabinet with optical patch panel and step-down transformer for HVAC, servers, switches, PoE etc.

- Each tower: WiFi AP, ISOBlue + Avena, RTK GPS
- Switch provisioned with 24 – 100/1000 Gbps ports, 4 – 10 Gbps ports, and 4 – 25 Gbps uplink ports



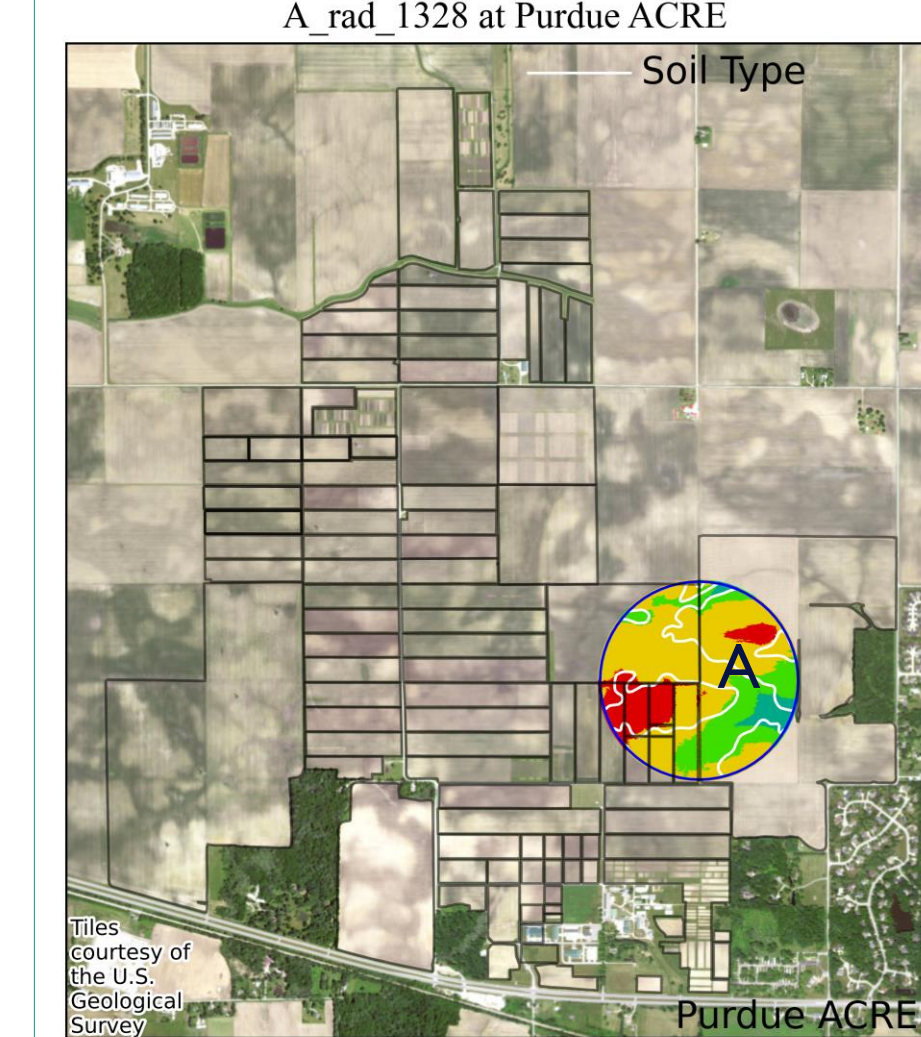
- Fiber Trunk:** Fiber Cable and fiber optic rotary joint
 - an integrated fiber/electrical slip ring to pass 28 fiber strands
- Pivot Package:** network interface at the pivot point
 - Switch, server, network attached storage
 - Pre-process data to compress, detect events, compute sufficient statistics
 - Reduce aggregate bandwidth for event-adaptive sensing and robotics
- Research Packages:** provided by individual researchers



Subsystem	Vendor(s)	Cost
Center Pivot Gantry	Valley High Profile, X-tec	\$219,240
Fiber Trunk	Moflon, LANshack, etc.	\$24,425
Tower Package (x 7)	American Products, Maddox, FS, Emliid, Dell, etc.	\$200,783
Pivot Package	American Products, Maddox, FS, Dell, etc.	\$50,300
Total		\$494,748

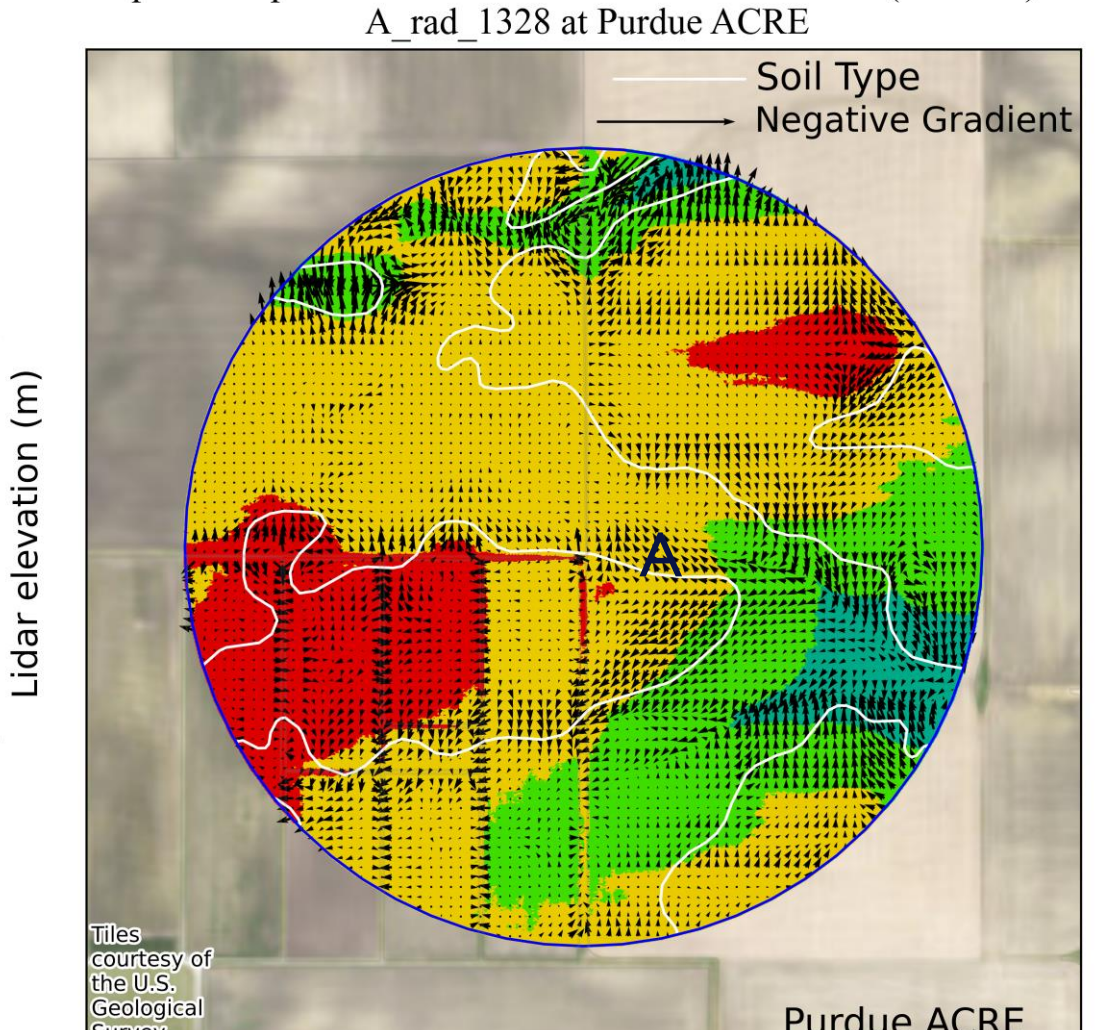
DESIGN OF STATISTICAL FIELD EXPERIMENTS IN PIVOT AREA

Slope visualization with 4 elevation zones (hist bins) in A_rad_1328 at Purdue ACRE



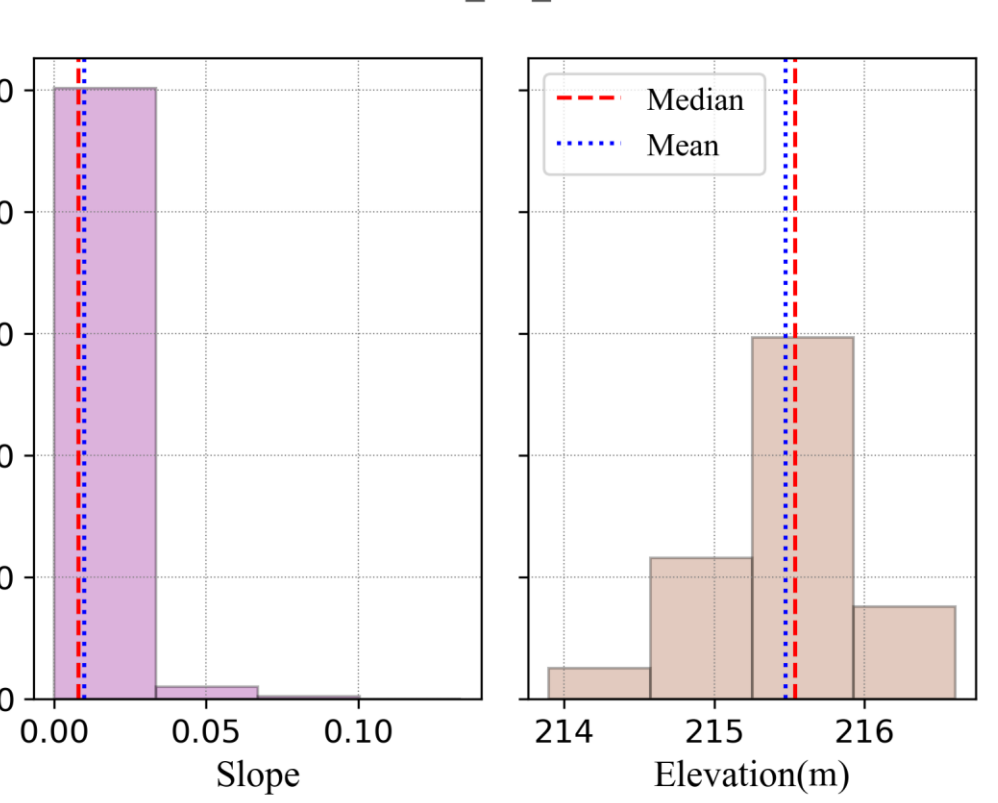
Purdue university farm, ACRE is approximately 3.5km x 3.5km. Figure shows the dimensions of an example Pivot installation in ACRE.

Slope and aspect visualization with 4 elevation zones (hist bins) in A_rad_1328 at Purdue ACRE



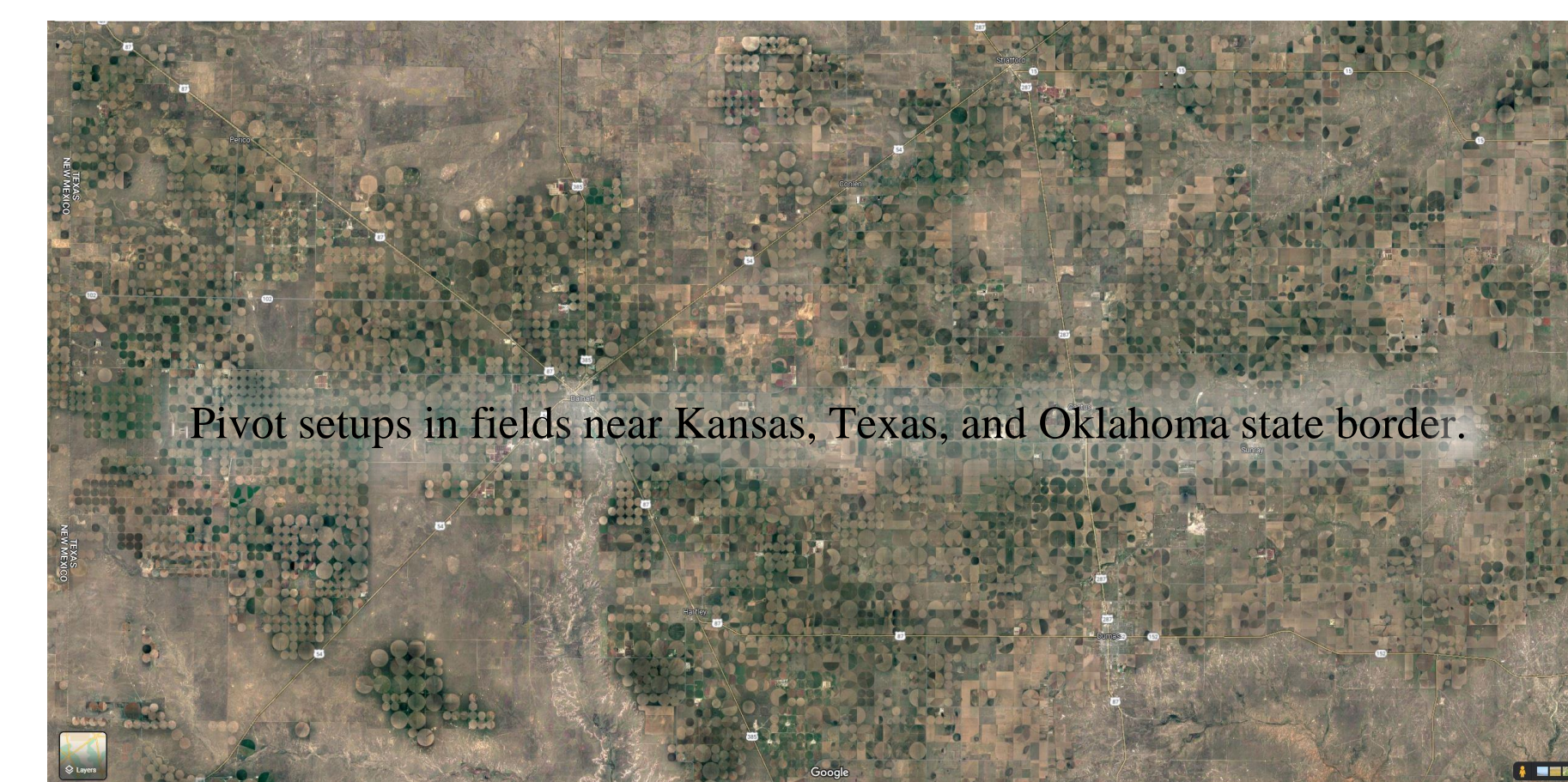
Grouping high resolution elevation data for whole ACRE into categories layered with soil map and gradient visualization. Design of field trials on variable soil types, slope, aspect etc. in pivot of area= $(\pi \times 1328^2) = 114.5$ ac

Histograms of Slope and Elevation with 4 bins in Purdue Acre at A_rad_1328.



Histogram of Slope and Elevation in this figure. The slope histogram shows that the area under pivot is mostly flat.

ML/AI CONTEST FOR CROP PRODUCTION UNDER CONSTRAINTS



- A contest for teams designing algorithms for operating the robotic pivot in a growing season for crop production
- At the beginning of the year teams write code to operate the sensors and actuators.
 - To give statistical significance to the ranking we randomize and replicate. "Teams" are the treatments.
 - Apply constraints in rules. Measure runoff. Limit water.
 - After planting all sensing/scouting must be carried out with the shared platform. Collaboration is required.
 - Water/nutrient application post planting must use pivot platform.