Master Specification: Corner-Swing Auditor (CSA) V1.0

Role: Dual-Node Kinematic & Hydraulic Auditor for Swing-Arm Pivots | **Network Density:** 2 PMT Units per Corner Pivot (Subdistrict 1)

The Corner-Swing Auditor (CSA) is a specialized dual-node configuration of the FarmSense PMT system, specifically engineered for center-pivots equipped with swinging corner arms (swing-spans) or end-gun extensions. In a standard pivot, a single PMT can calculate the circular application area. However, a swinging pivot introduces a non-linear "elbow" joint that extends the irrigation reach into the corners of square fields. To maintain the **Enterprise (1m) Resolution** required for the Digital Water Ledger, the CSA utilizes two synchronized PMT units—a **Primary Span Tracker (PST)** and a **Swing-Arm Tracker (SAT)**—to mathematically resolve the complex kinematics and hydraulic surges associated with corner irrigation.

The "Corner Reach" Data Gap: Corner irrigation is historically the most "unaudited" zone in agriculture. Because swing arms extend and retract based on soil boundaries and legal property lines, the water distribution is rarely uniform. The CSA closes this gap, providing the Zo Scientist Engine with the high-fidelity proof needed to audit every gallon sprayed into the high-value corner acres of Subdistrict 1.

1. Dual-Node Kinematic Architecture (The Elbow Logic)

The CSA operates on a "Master-Slave" kinematic relationship to resolve the pivot's exact footprint in real-time.

- **Primary Span Tracker (PST):** Mounted on the first or second tower of the main pivot span. It establishes the "Base Vector" of the machine. It tracks the primary rotation angle (0-360°) and the bulk flow entering the main pipe from the wellhead.

- **Swing-Arm Tracker (SAT):** Mounted on the distal end of the swinging corner arm. It tracks the "Swing Angle" relative to the main span. By comparing the GNSS and IMU data between the PST and SAT, the Zo Server can triangulate the exact position of every nozzle on the swing arm within 1 meter.

- **Kinematic Synchronization:** Both units utilize a sub-second BLE handshake. The SAT feeds its angular displacement data to the PST, which then packages a unified "Double-Kinematic" payload for the VFA. This allows the Zo Engine to calculate the "Crabbing" effect of the swing-arm tires independently of the main span, identifying structural stress caused by mud or terrain slope in the corners.

2. Advanced Hydraulic Auditing (End-Gun & Solenoid Pulse)

Corner spans often utilize high-pressure "End-Guns" that pulse on and off via solenoids as the arm swings. This creates massive pressure spikes and flow variability that a single meter cannot capture.

- **Dual-Flow Correlation:** The SAT unit is equipped with its own dedicated set of clamp-on ultrasonic transducers placed downstream of the swing-arm's main joint. This allows the system to differentiate between the **Main Span Flow** and the **Swing-Arm/End-Gun Flow**.

- **Solenoid Audit Logic:** The IMU in the SAT is specifically tuned to detect the "Hydraulic Hammer" (vibration signature) produced when the end-gun solenoid fires. By timestamping this mechanical vibration against the ultrasonic flow surge, the CSA provides the "Digital Ledger" with certified proof of exactly how much water was dumped into the corner zones, preventing over-application and nitrate leaching in these sensitive areas.

3. Structural Housing & "Cut-Less" Mounting (Subdistrict 1 Grade)

The CSA nodes utilize the same ruggedized housing as the standard PMT but are reinforced for the higher vibration and centrifugal forces experienced at the edge of the swing arm.

- **IP67 UV-Polycarbonate Puck:** Both nodes are housed in Polycase WP-21F enclosures. Polycarbonate is mandated due to its RF-transparency, ensuring the GNSS RTK lock is not interrupted by the massive steel trusses of the swing-arm extension.

- **Vibration Isolation (The Corner Whip):** The SAT unit is subject to a "whip effect" as the corner arm starts and stops. To protect the electronics, the SAT utilizes a double-layer Neoprene Friction Pad. This isolates the u-blox ZED-F9P chipset from the high-frequency metal-on-metal vibration of the swing joint, ensuring the GNSS lock remains stable even during aggressive machine maneuvers.

- **Zero-Impact Installation:** Like the standard PMT, the CSA is 100% "Cut-Less." It uses 304-SS Band-It straps for mounting and clamp-on transducers for flow. This allows the District's "Band-It Blitz" crews to install a full CSA system on a corner pivot in under 4 hours without any welding or structural modifications.

4. UI Logic & The "Corner Pop" Sales Funnel

The high-fidelity data generated by the SAT unit is the primary driver for **Enterprise (1m) Tier** conversions in fields with corner irrigation.

- **The Resolution Challenge:** In the Free (50m) and Basic (20m) tiers, the corner irrigation is often rendered as a simplified square block. However, when the farmer views their "Corner Health" on the interactive tile map, the system triggers a specialized **"Corner Pop." * The Enterprise Hook:** The UI showcases the real-time angular movement of the swing arm (audited by the SAT) and offers a preview of the 1m-resolution "Application Map." This proves to the farmer that they are wasting water in the corners or missing critical zones

due to end-gun malfunctions, providing a high-conversion incentive to upgrade to the Enterprise tier to unlock the full hydraulic audit.

5. Hyper-Granular CSA BOM & Project Costs (Dual-Unit Setup)

Because a corner pivot requires two full PMT nodes (PST + SAT), the cost is essentially doubled per machine. This ledger reflects the Subdistrict 1 volume pricing for the dual-unit hardware.

Category	Component Description	Supplier	Part # / Type	Unit Cost	Ext. Cost (x2)
Housing	IP67 UV-Polycarbonate Puck	Polycase	WP-21F	$45.00	$90.00
Mounting	304-SS Band-It Straps (x4)	McMaster	5530K34	$12.50	$25.00
Mounting	Neoprene Friction Pad (x2)	McMaster	8637K32	$5.50	$11.00
Computing	Cortex-M4 Processing Sled (x2)	Digi-Key	ATSAMD51	$65.00	$130.00
Position	u-blox ZED-F9P RTK GNSS (x2)	SparkFun	GPS-15136	$140.00	$280.00
Position	9-Axis IMU (Vibration/Tilt) (x2)	Bosch	BNO055	$32.00	$64.00
Hydraulic	Ultrasonic Transit-Time Pair (x2)	Badger Meter	TFX-5000	$648.00	$1,296.00
Power	10W Solar Lid + LiFePO4 Buffer (x2)	Renogy	Cust-10W	$95.00	$190.00
Power	LiSOCl2 5yr Hibernation Pack (x2)	Saft	LS14500	$25.00	$50.00
Radio	High-Gain BLE Whip Antenna (x2)	Linx	ANT-BLE	$30.00	$60.00
Fasteners	SS M4 Security Screws (x8)	McMaster	Security-M4	$2.00	$4.00
TOTAL	**Per Unit Hardware Cost (Dual PMT)**				**$2,200.00**

Total CSA Project Financials (Per Corner Pivot):

- **Hardware Total:** $2,200.00

- **Dual-Point Calibration & Audit:** $114.88 *(Requires a double-run with the Master Meter to verify both the main span flow and the swing-arm flow separately).*

- **Labor (Installation):** $200.00 *(Calculated at 4 hours total per corner pivot to handle the complex mounting on the swing arm).*

- **CSA PER-PIVOT TOTAL: $2,514.88**

6. Strategic Legal Value

The CSA provides the ultimate level of protection in **Water Court**. For Subdistrict 1 farmers, the corners are often the first areas to have their water rights curtailed during drought years.

- **Empirical Defense:** The CSA provides the only certified way to prove that water was delivered *only* within the permitted swing-arm boundaries and was not "oversprayed" onto non-irrigated land.

- **Worksheet Integration:** The **Zo Server** uses the dual-node data to update the field's "Swing Worksheet." If the SAT detects that the swing arm is not extending fully, it informs the **Zo Scientist**, who then adjusts the virtual sensor grid values for the corner tiles,