

## Master Specification: Lateral Root-Zone Scout (LRZ) V1.21

**Role:** Lateral Variability "Scout," High-Density Dumb Node, & Spatial Mapper | **Network**

**Density:** 1 LRZ per 15 Acres (Reporting to 1 VFA per Field)

While the Vertical Field Anchor (VFA) serves as the singular high-fidelity "Truth" node for an entire field, the Lateral Root-Zone Scout (LRZ) is the indispensable high-density spatial component of the FarmSense grid. Designed to be mass-deployed at a strict density of **1 unit per 15 acres**, the LRZ operates as a hyper-efficient "dumb node."

**Network Topology:** On a standard 125-160 acre center pivot, a fleet of approximately 8 to 10 LRZ units will form a local mesh. They do not process complex Zo Worksheets or execute localized Bayesian math. Their sole operational imperative is to capture raw dielectric and electrical conductivity (EC) counts across their specific 15-acre zone, encrypt them, and "chirp" them back to the single VFA anchored in that field.

This massive density of spatial data is what ultimately powers the FarmSense UI logic—allowing the system to mathematically transition from the Free (50m) and Basic (20m) tiers to the highly lucrative Pro (10m) and Enterprise (1m) resolution "pops."

**The Seasonal Deployment Model:** To protect the LRZ's internal electronics and guarantee a 10-year hardware lifecycle, FarmSense utilizes a two-phase seasonal deployment strategy. The outer structural shells act as ultra-cheap, geo-located permanent docking stations that remain buried in the field year-round. The internal, highly sensitive sensor sleds (the actual "brains" of the LRZ) are dropped into these shells *after* spring planting and physically extracted just prior to harvest. This workflow entirely eliminates the risk of deep-freeze winter battery degradation while perfectly preserving the exact spatial baseline required by the Zo Server's Kriging algorithms.

### 1. Structural Housing ("Invisible Presence" Architecture & Seasonal Docking)

The LRZ housing is engineered for an "Invisible Presence"—a ruggedized subterranean deployment capable of withstanding the extreme mechanical stresses of 4WD tractor passes and repetitive deep-soil compaction cycles common in potato-barley rotations.

- **The Outer Shell (The Docking Station):** Constructed from **Standard 2" Schedule 40 UV-White HDPE** (High-Density Polyethylene). Cut precisely to **18 inches** to perfectly match the internal 18U sled, this shell sits perfectly flush with the soil surface.
  - *Material Science:* White HDPE was selected specifically for its high albedo (thermal reflection). During the critical "Field Blitz" installation window, units often sit exposed

on the surface in  $90^\circ F +$  heat; the white pigment prevents internal components from baking before the unit is safely buffered by the cool soil. Furthermore, HDPE is chemically inert to the sulfur-rich SLV alkali soils.

- *Installation Efficiency:* By keeping the shell at exactly 18 inches, the hydraulic auger crews only need to drill a shallow pilot hole, exponentially speeding up the installation phase and reducing wear on the auger bits.
- **15-Degree Tapered Driving Tip (Compaction-Fit):** The 18-inch outer shell is chemically fused to a Custom HDPE Driving Tip featuring a precise 15-degree taper. Fluid-dynamic modeling confirms this specific taper provides optimal "Tight-to-Soil" seating as the auger displaces dirt, surgically eliminating air gaps that corrupt moisture readings.
- **Elevated Mast & Antenna Array:** Because the 2" shell is flush-mounted 18 inches deep, the removable C&C Cap utilizes a **1" Pultruded Fiberglass Mast** to elevate the antenna base 3 feet above the soil. This radio-transparent mast is topped with a 3-foot SS-304 stainless steel whip antenna featuring a heavy-duty spring base, ensuring the LRZ clears the mature crop canopy to chirp back to the VFA.
- **The Removable Internal Sled:** The core internal structure is an **18-Inch 50mm Co-Extruded Alpha-Sled** capped with Injection-Molded Circular End-Caps. This removable payload is swiftly inserted post-planting and extracted pre-harvest, overwintering safely in climate-controlled storage.
- **The Seasonal Climate (+5 psi Defense):** Upon insertion, Viton (FKM) 2" O-rings seal the sled against the shell walls. The internal cavity is flushed and pressurized to **+5 psi with Dry Nitrogen**, creating an inert, zero-humidity environment that acts as an active defense against micro-fractures.

## 2. Edge Logic & The Secure "Chirp" Protocol

The LRZ is an exercise in extreme power efficiency. It lacks the eMMC storage and heavy compute processors found in edge coordinators. It is a "Set and Forget" asset that awakens, acts, and sleeps.

- **Ultra-Low Power nRF Logic:** The compute board relies on a Nordic nRF52840 SoC. This chip stays in a deep micro-amp sleep state for 99% of its life. It wakes up on a synchronized schedule, reads the raw electrical analog counts from the basic capacitive sensors, packages them with its unique Node ID, and immediately cuts power.
- **Interference Mitigation (FHSS):** The LRZ chirp utilizes a Frequency-Hopping Spread Spectrum (FHSS) approach. By scattering its micro-transmissions across 75 different radio frequencies, the system ensures that even in a high-density "Blitz" field containing 8-10 actively reporting LRZs per pivot, the statistical probability of a packet collision is effectively zero.

- **128-Bit Edge Encryption:** Before the chirp leaves the antenna, the payload is signed and encrypted with a factory-burned 128-bit AES key. This ensures that no raw moisture data is ever broadcast in the clear. The single field VFA intercepts and decrypts this packet, handling the heavy lifting of routing it to the Farm Hub.
- **Zo Server Remote Calibration:** The LRZ requires absolutely zero manual calibration in the field. Its baseline "Soil Zero" is established completely remotely by the Zo Scientist Engine during its first 24 hours of connectivity. Zo utilizes the highly accurate Bayesian math and Kriging priors established by the field's single VFA "Truth Node" to perfectly calibrate the surrounding dumb LRZs.

### 3. The High-Density Sensor Array (18-Inch / 18U Sequence)

Like the VFA, the LRZ employs the advanced "Proxy Method" of non-contact sensing, shooting high-frequency dielectric fields directly through the 50mm sled wall, the nitrogen gap, and the permanent HDPE shell.

#### Locked 18U Physical Stack Sequence & Depth Logic:

- **Slot 1:** 1U Bulk Stamped Desiccant Pack (*Captures any trace humidity during the active growing season*)
- **Slots 2-5:** 4U Battery #1 (*Contains three 21700 lithium-ion cells in a space-saving triangular cluster. Powers the polyimide heating films during unpredictable spring/fall frosts*)
- **Slots 6-9:** 4U Extruded Spacer
- **Slot 10:** 1U Basic Sensor (*10" Depth: Seedbed & Evapotranspiration Monitoring. Captures the critical topsoil zone where germination and shallow root extraction occur*)
- **Slots 11-14:** 4U Battery #2 (*Second triangular 3-cell cluster ensuring massive redundant energy overhead for thermal defense*)
- **Slots 15-17:** 3U Extruded Spacer
- **Slot 18:** 1U Basic Sensor (*18" Depth: Root Anchor Monitoring. Captures the transition zone where the majority of potato and barley bulk water uptake occurs*)

### 4. The Seasonal Deployment Workflow & OEM Scale BOM

**The "Blitz" Installation & Extraction Cycle:** Deploying 15,600 units across Subdistrict 1 requires a militarized logistical approach.

1. **Post-Planting Insertion:** Utilizing a three-crew rotation and customized UTVs, installation is calculated at under 10 minutes per unit. Because the outer shell is only 18 inches, Crew A pilots the hydraulic auger to set the permanent white HDPE shells in a fraction of the time required for the VFAs. Crew B drops in the pre-calibrated sensor sled, pressurizes the

nitrogen, and verifies the RF "heartbeat" to the field's VFA using a handheld diagnostic tool. Crew C performs final soil compaction.

2. **Harvest Extraction:** Prior to the heavy harvesters arriving, crews extract the internal sleds and cap the permanent 18-inch ground shells with high-visibility, crush-proof blanking plugs.

**Hyper-Granular OEM Scale BOM (15,600 Unit Tier):** Because the LRZ is ordered in massive quantities, we bypass retail and wholesale distribution entirely. This ledger reflects Tier-1 OEM direct-fabrication pricing (continuous bulk extrusion, automated PCBA, bulk cell sourcing), pushing the LRZ hardware cost down to an incredibly lean **\$60.80** per unit.

Category	Component Detail & Sub-Assembly Breakdown	Supplier / Scale Method	Unit Cost	Ext. Cost
Housing	2" SCH 40 UV-White HDPE (18-inch Cut - Flush Mount)	Direct Extruder (Bulk Spool)	\$1.50	\$1.50
Housing	Custom HDPE Tapered Tip (Mold-V2-S - 15° Taper)	Proprietary (High-Cavity Mold)	\$4.25	\$4.25
Housing	1" Pultruded Fiberglass Mast (3.5ft Cut)	Industrial Pultrusion Bulk	\$3.50	\$3.50
Antenna	3ft SS-304 Whip + Spring Base	OEM Direct Fab (Bulk)	\$4.50	\$4.50
Adhesive	Structural HDPE Acrylic Epoxy	Automated Bulk Dispensing	\$0.85	\$0.85
Seals	Viton (FKM) 2" O-Rings (2 units @ \$0.40/ea)	OEM Rubber Fab (Bulk)	\$0.80	\$0.80
Computing	nRF52840 "Chirp" Logic Board (No Heavy Processing)	Tier-1 PCBA (Pick & Place)	\$4.50	\$4.50
Climate	1U Stamped Silica Desiccant Matrix	Bulk Supply	\$1.50	\$1.50
Structure	18-Inch 50mm Co-Extruded Alpha-Sled Chassis	Continuous Extrusion	\$1.25	\$1.25
Structure	Injection-Molded Circular Sled End-Caps (Top & Bottom)	High-Cavity Mold	\$0.60	\$0.60

Structure	Extruded HDPE Multi-U Spacers (7U Volume)	Recycled Bulk	\$0.05	\$0.05
Power (x2)	4U Battery Cartridge:  - 21700 Li-Ion Cells (3 per cart triangular): *\$10.50*  - Polyimide Heating Film: \$1.50  - BMS & Cartridge Housing: \$4.75	Direct Cell Sourcing	\$16.75/ea	*\$33.50*
Basic Sensor (x2)	1U Basic Sensor (Value Engineered):  - PCB Capacitive Trace & Thermistor: \$0.85  - RISC-V (CH32V003) & Logic: \$0.65  - Potting/Housing: \$0.50	Fab-Direct Assembly	\$2.00/ea	\$4.00
TOTAL	Per Unit Hardware Cost (Absolute			\$60.80