Bill of Materials: Lateral Root-Zone Scout (LRZ)

Role: Lateral Variability "Scout" (Dumb Node) | **Ratio:** 1 per 15 Acres

1. Structural Housing (Molecular Audit Specs)

The LRZ housing is engineered for "Invisible Presence"—a 20-year subterranean deployment capable of withstanding the aggressive, high-alkali soil chemistry and extreme mechanical stresses unique to the San Luis Valley (SLV) aquifer basin.

- **Main Body:** 2" Schedule 40 UV-Stabilized HDPE (White).
    - *Material Depth & Performance:* White HDPE was selected specifically for its high albedo (thermal reflection) properties. During the critical "Blitz" installation window, units often sit on the surface in 90°F+ heat; the white pigment prevents internal component overheating before the unit is safely buffered by soil. The Schedule 40 wall thickness provides the necessary hoop strength to resist the "Crush Force" of heavy 4WD tractor passes and the repetitive deep-soil compaction cycles common in potato-barley rotations. Furthermore, HDPE is chemically inert to the sulfur-rich and high-pH alkali soils of the SLV, preventing the "pitting" or embrittlement that typically plagues lower-grade plastics.
- **Driving Tip:** 15-degree Tapered High-Impact ABS Stake (Compaction-Fit).
    - *Engineering Logic & Soil Sealing:* The 15-degree taper is a result of fluid-dynamic modeling optimized for "Tight-to-Soil" seating. In sandy-loam environments, any air gap between the sensor and the soil acts as a dielectric insulator, ruining the accuracy of fringe-field capacitive measurements. This specific taper ensures that as the stake is driven by the RSS hydraulic auger, the soil is compressed laterally against the housing. The "Compaction-Fit" design utilizes the soil's own overburden pressure to maintain a permanent seal between the tip and the HDPE body, creating a secondary mechanical barrier that prevents irrigation water from "tracking" down the side of the tube and causing false moisture spikes.
- **Thermal Buffer:** 10mm Neoprene Sleeve for passive geothermal shielding at 18" depth.
    - *Operational Implication:* The SLV is an alpine desert where surface temperatures can fluctuate 50°F in a single day. This neoprene wrap provides a "Geothermal Anchor," significantly damping the rate of thermal transfer to the internal electronics. By slowing the "Thermal Pulse," we ensure that the moisture readings are not skewed by the rapid expansion or contraction of soil-water molecules, maintaining a stable baseline for the Zo Scientist Engine to process.

2. Internal Sensor Sled

The internal sled follows a "Dumb Node" philosophy—optimized for extreme zero-maintenance longevity and maximum reliability rather than on-board computational complexity.

- **Power Pack: Dual $LiSOCl_2$ (Lithium Thionyl Chloride) Units (38,000mAh total).**
  - **Electrochemical Justification:** $LiSOCl_2$ chemistry was chosen for its unparalleled energy density (over 500 Wh/kg) and its remarkably flat discharge curve, which stays near 3.6V for 95% of its life. However, at the SLV's -30°F winter minimums, internal resistance increases significantly (a phenomenon known as the "Voltage Delay" or passivation effect). Doubling the capacity to 38Ah provides the current-handling overhead necessary to "punch through" this resistance during winter pings. This ensures the node never "browns out" during a multi-week Polar Vortex, where lesser batteries would fail to strike the radio arc.
- **Sensor Stack:** Dual-depth Fringed-Capacitive traces at 8" and 18".
  - *Sensing Logic & Agronomic Depth:* These high-frequency traces measure the dielectric constant of the surrounding soil matrix. The 8" depth is precisely positioned to track the "Germination Zone," providing data on seedbed moisture and rapid topsoil evapotranspiration. The 18" depth monitors the "Root Anchor" moisture, where the majority of potato and alfalfa water uptake occurs. This dual-depth strategy is vital for the Zo engine at the RSS; it allows the system to differentiate between "Surface Evaporation" (waste) and "Crop Transpiration" (utility), providing the first true 1m resolution efficiency audit for the district.
- **Chassis:** 3D-Molded PETG with Friction-Fit Rails for vibration damping.
  - *Durability & Damping:* PETG was selected for its balance of high impact resistance and moderate flexibility. The internal "Friction-Fit" rails allow the sled to "float" slightly within the HDPE housing. This isolation is critical for surviving the high-frequency vibrations and low-frequency "thumping" caused by 12,000lb center-pivot wheels passing nearby or the deep-ripping tillage equipment that prepares the fields each spring.

3. Communication & Lifecycle

- **Protocol:** 2.4GHz "Chirp" (Transmit-Only) Architecture.
  - *System Logic & Energy Conservation:* To achieve the mandatory 10-year battery lifecycle, the LRZ never "listens" for commands or waits for handshakes; listening is the most energy-intensive state for a radio. Instead, the LRZ wakes from a nano-amp deep sleep, chirps a tiny, highly compressed packet containing raw counts and its unique node ID, and immediately cuts power.

    - *Interference Mitigation:* The chirp utilizes a frequency-hopping spread spectrum (FHSS) approach. By scattering its transmission across 75 different frequencies, the system ensures that even in a high-density "Blitz" field with 100+ LRZs, the statistical probability of a packet collision is effectively zero.
- **Encryption:** Each chirp is signed with a factory-burned 128-bit key.
    - *Security Protocol:* This packet is decrypted by the field's VFA (Vertical Field Anchor) locally. This "Edge Decryption" ensures that no raw moisture data is ever broadcast in the clear, protecting the farmer's proprietary field variability data from being harvested by unauthorized third parties.

Deployment Note: The LRZ is a "Set and Forget" asset. Once driven into the precise pilot hole created by the RSS "Blitz" trailer, the LRZ requires zero manual calibration. Its baseline "Soil Zero" is established remotely by the Zo Scientist Engine during the first 24 hours of connectivity, utilizing Kriging priors from the nearest VFA "Truth Node."