# Bill of Materials: Vertical Field Anchor (VFA)

**Role:** Field-Level Aggregator, "Truth" Node, & Edge Coordinator | **Ratio:** 1 per Field

### 1. Structural Housing (Molecular Audit Specs)

The VFA housing is engineered to maintain a hermetic seal for a 20-year deployment lifecycle in the high-alkali, high-freeze-thaw environment of the San Luis Valley (SLV).

- **Main Body:** 2" Schedule 40 UV-Stabilized HDPE (High-Density Polyethylene).
    - *Detail & Material Science:* Selected for its superior chemical resistance to aggressive fertilizer runoff (specifically nitrogen and phosphorus compounds) and its exceptional ductility at extreme sub-zero soil temperatures. Unlike PVC, which becomes glass-brittle below 0°F, HDPE maintains its structural integrity. The UV-stabilization package is a specific additive designed to prevent "chalking" and cross-link degradation from the intense high-altitude solar radiation characteristic of the 7,600ft SLV elevation.
- **Driving Tip:** Injection-Molded High-Impact ABS with reinforced internal ribs.
    - **Molecular Fix: Stainless Steel "Pin-and-Weld"** architecture. We utilize a dual-pin cross-locking mechanism where 316-Grade stainless steel pins are driven through the HDPE wall into the solid ABS core, then thermally sealed.
    - *Operational Implication:* This mechanical lock is critical to prevent "Frost-Heave Separation." In the SLV, the soil can freeze down to 48 inches; the divergent thermal expansion/contraction rates of HDPE and ABS cause standard chemical adhesives to shear and fail. This "Pin-and-Weld" ensures the tip stays attached during extraction or deep-freeze cycles.
- **Cap Base:** Custom "Nail Head" HDPE cap with integrated **Dual Viton (FKM) O-rings**.
    - **Molecular Justification:** While standard Nitrile (Buna-N) O-rings lose elasticity at 0°F and eventually crack, Viton (FKM) maintains its "memory" and sealing compression down to -40°F. This ensures a 5psi hermetic seal, protecting internal electronics from the "Pressure-Pump Effect"—a phenomenon where rapid barometric shifts during alpine storm fronts can force moisture-laden air into the housing through inferior seals.

### 2. Internal Alpha-Sled

The Alpha-Sled is the field's localized "Relay Intelligence," acting as the master coordinator for the data stream from up to 12 "Dumb" LRZ scouts while maintaining the regional "Audit Trail."

- **Core PCB:** NXP i.MX RT series MCU (Cortex-M7).

- *Edge Logic:* Executes AES-256 hardware-level encryption and proprietary data compression algorithms. It acts as the "Secure Gateway," ensuring that field-level moisture data is obfuscated and encrypted before it ever transmits over the 5GHz backhaul, protecting the farmer's proprietary field data from intercepted RF.

- **Expanded Power: Dual-Pack LiFePO4 (40,000mAh total capacity).**
  - *The 6-Day Buffer:* The San Luis Valley winters frequently feature high-altitude "Cold Caps" or inversions where solar input is nil for 4-6 days. This massive energy reserve, combined with advanced micro-sleep logic, allows the VFA to act as the district's "Blackout Beacon," maintaining 100% data fidelity for 144+ hours without a single watt of solar recharge.
- **Thermal Protection:** 5W Kapton heater + 8mm PE Closed-Cell Foam + Reflective Mylar wrap.
  - *Cold-Start Logic:* LiFePO4 chemistry is susceptible to permanent damage if charged below 32°F. The Kapton heater uses the "First Harvest" of morning solar energy to bring the internal "Sled" temperature up to 40°F. The 8mm foam and Mylar wrap create a localized "Thermos" effect, retaining heat from the day's processing cycles to reduce heater activation at night.
- **Redundancy:** 4GB Industrial eMMC "Blackout Cache."
  - *Implication:* If the 5GHz link to the District Hub is severed by weather or interference, the VFA stores every millisecond-accurate data packet locally. Once connectivity is restored, it performs a high-speed "burst" synchronization, ensuring the farmer's water conservation ledger remains 100% gapless for legal or regulatory reporting.

### 3. Truth Sensors (The Golden Profile)

The VFA provides the "Golden Truth" ground-truth points used to calibrate the 1m resolution Kriging models at the Regional Superstation (RSS).

- **Array:** Multi-stack TDR (Time Domain Reflectometry) probes.
  - *Mechanism:* TDR sensors measure the travel time of an electromagnetic pulse along a transmission line, providing the most accurate moisture measurement available, unaffected by soil salinity or texture.
- **Strategic Depths:**
  - **6" & 12":** Active root zone sensors for shallow-rooted crops and seedbed germination monitoring.
  - **24":** The "Pivot Point" sensor for mature root zone moisture management.
  - **The 66" Deep Percolation Anchor:** This deep-soil sensor is the most critical for legal and environmental auditing. By tracking moisture at 5.5 feet, it identifies water that has

escaped the root zone entirely.

- *Consequence:* This data is used for "Nitrate Leaching" prevention and "Aquifer Recharge" auditing. It provides the empirical data necessary for legal Water Court defensibility, proving that applied water was either used by the crop or lost to deep percolation.

- **Interface:** Low-power serial bus architecture connecting the sensors to the Alpha-Sled, allowing for synchronized moisture "pops" during active irrigation cycles to track the wetting front in real-time.

**Build-Out Note:** The VFA is designed for a "Field Blitz" installation workflow. Utilizing the RSS's 1" Hydraulic Auger, a 2-person crew can install, commission, and perform the initial RF-handshake for a VFA in under 45 minutes, regardless of soil compaction or thermal conditions.