# HQ / Federated Controller Layer

See overview: System Architecture Overview

The **HQ / Federated Controller Layer** provides **multi-farm oversight, analytics, and management**. It sits above Farm Controllers in the AOFS hierarchy, enabling federation, global reporting, and configuration distribution while **never bypassing Field Controller safety rules**.

## 1. Purpose

The HQ Controller:

- Aggregates telemetry and logs from multiple Farm Controllers.
- Provides management dashboards, reporting, and analytics.
- Supports configuration distribution to Farm Controllers.
- Ensures Field Controller safety authority is always respected.
- Maintains an audit trail of all multi-farm operations and synchronization events.

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## 2. Responsibilities

1. **Telemetry Aggregation**

- Collect irrigation events, sensor data, flow measurements, and operator logs from all Farm Controllers.
- Normalize and store data for reporting and analytics.

2. **Analytics & Reporting**

- Multi-farm dashboards for water usage, energy consumption, irrigation efficiency, and crop outcomes.
- Alerts for anomalies across farms (e.g., persistent irrigation failures, abnormal flows, power shortages).

3. **Configuration Distribution**

- Push authorized configuration changes or irrigation schedules to Farm Controllers.
- Ensure updates **do not violate local Field Controller safety rules**.

4. **Audit Logging**

- Record all pushes, pulls, operator actions, and synchronization events.
- Preserve audit logs for regulatory compliance and traceability.

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# 3. Federation / Push-Pull Model

The HQ Controller operates as part of AOFS' **decentralized federation network**:

- **Pull from Farm Controllers:**
  1. Retrieve logs, sensor data, irrigation events, and audit trails.
  2. Updates occur automatically or on-demand, queued if connectivity is unavailable.
- **Push to Farm Controllers:**
  1. Deliver configuration updates, irrigation schedules, or software/firmware updates.
  2. Changes are applied **only after Field Controller validation**.
- **Multi-HQ federation (optional):**
  1. HQ Controllers can sync with each other to share aggregated data, analytics, or best-practice configurations.
  2. Conflicts resolved via deterministic rules and logged.

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# 4. Authority Rules

- **Safety authority:**
  - Field Controllers retain full authority for all safety-critical operations.
  - HQ Controller cannot directly actuate pumps, valves, or override irrigation cutoffs.
- **Supervisory authority:**
  - HQ Controller may propose schedules, thresholds, and configurations.
  - Farm Controllers apply changes according to local rules and validation.
- **Conflict resolution:**
  - Timestamp precedence and operator approval at the farm level.
  - Any conflicts that violate Field Controller rules are **blocked and logged**.

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# 5. Human Interface

- Web-based dashboards for multi-farm monitoring.
- Reporting modules for energy, water efficiency, and crop outcomes.
- Interfaces for authorized managers to submit configuration updates.
- Visualization of alerts, events, and historical performance.
- No interface may bypass Field Controller safety rules.

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## 6. Offline Operation

- HQ Controller may be offline; farm autonomy is **never compromised**.
- Logs and updates queue until connectivity is restored.
- HQ can continue analytics and dashboards locally with last synced data, but **cannot control irrigation in real-time** without live connection.

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## 7. Hardware & Integration

- Hardware: industrial servers, cloud instances, or on-prem appliances.
- Communication protocols: secure LAN, WiFi, cellular, or VPN tunnels.
- Data storage: structured, versioned, and secure for multi-farm ingestion.
- Security: encryption for all communications; multi-factor authentication for operators.
- Scalability: supports hundreds of farms, multiple Farm Controllers per farm.

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## 8. Compliance Notes

- HQ Controller **must never override Field Controller safety rules**.
- All multi-farm pushes, pulls, and operator actions must be logged.
- Deterministic conflict resolution must be implemented for configuration and schedule synchronization.
- Failure to respect authority hierarchy **invalidates AOFS compliance**.

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## 9. References

- System Architecture Overview
- Farm Controller Layer (Local / Federated)
- Hydraulic & Water Systems
- Electrical & Control Interfaces
- Measuring, Monitoring & Documentation Systems