Fox ML Infrastructure – System Architecture Diagram

This document provides a visual and textual representation of the Fox ML Infrastructure system architecture. This architecture diagram is essential for enterprise technical reviews and integration planning.

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1. Executive Summary

Fox ML Infrastructure is a client-hosted, modular ML research infrastructure platform.

Key architectural principles: - **Client-hosted** – Software runs entirely on client infrastructure - **Modular design** – Clear separation of concerns across modules - **Configuration-driven** – All runtime parameters from centralized configs - **Pipeline-based** – Data flows through well-defined pipeline stages - **Extensible** – Easy to add new models, features, and strategies

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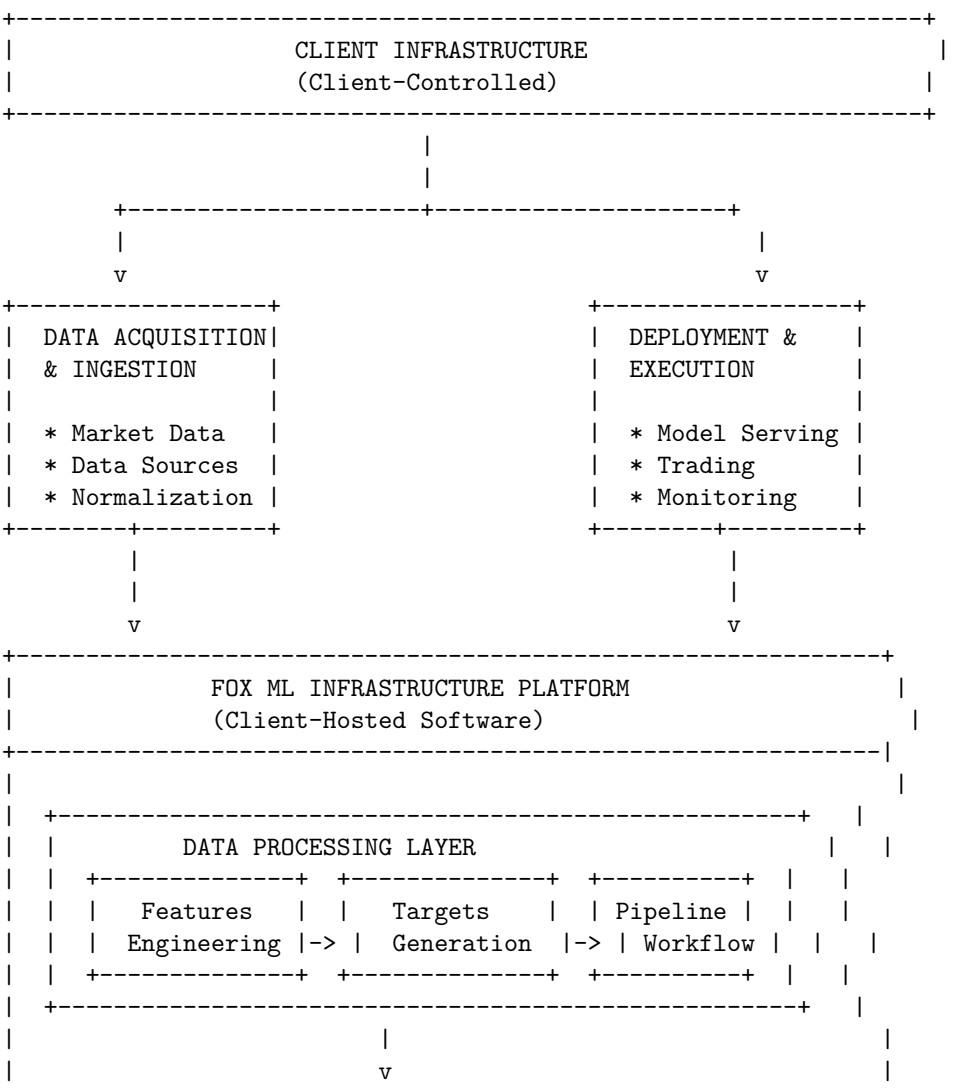
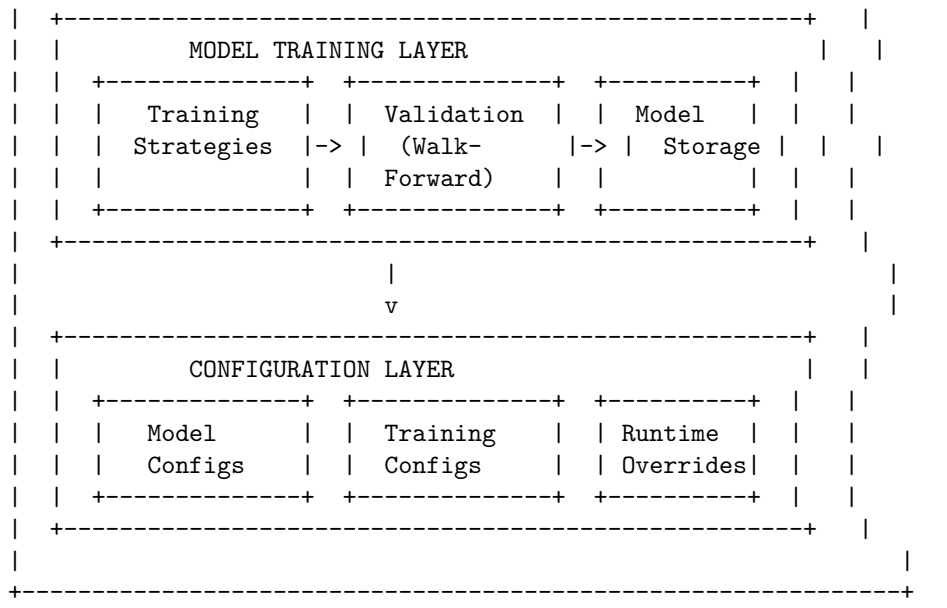
2. High-Level Architecture

2.1 System Overview





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3. Component Architecture

3.1 Data Processing Layer

Purpose: Transform raw market data into ML-ready features and targets.

Components:

```
DATA_PROCESSING/
+-- features/
|   +-- SimpleFeatureComputer      # Basic technical indicators
|   +-- ComprehensiveFeatureBuilder # 200+ feature engineering
|   +-- StreamingFeatureBuilder    # Streaming/online features
+-- targets/
|   +-- BarrierTargetBuilder       # Barrier-based targets
|   +-- ExcessReturnsBuilder      # Excess return targets
|   +-- HFTForwardReturnsBuilder  # High-frequency targets
+-- pipeline/
|   +-- DataNormalization          # RTH alignment, grid correction
|   +-- FeaturePipeline           # End-to-end feature workflow
|   +-- TargetPipeline            # End-to-end target workflow
+-- utils/
    +-- MemoryManagement          # Efficient memory handling
    +-- Logging                   # Structured logging
    +-- Validation                # Data sanity checks
```

Data Flow:

```
Raw Market Data
    v
Normalization (RTH alignment, grid correction)
    v
Feature Engineering (200+ technical features)
    v
Target Generation (barrier, excess returns, HFT)
```

```
    v
Labeled Dataset (features + targets)
```

3.2 Model Training Layer

Purpose: Train and validate ML models using walk-forward validation.

Components:

```
TRAINING/
+-- model_fun/
|   +-- LightGBMTrainer           # Gradient boosting
|   +-- XGBoostTrainer            # Gradient boosting
|   +-- MLPTrainer                # Deep learning
|   +-- TransformerTrainer        # Transformer models
|   +-- EnsembleTrainer           # Model ensembles
|   +-- MultiTaskTrainer          # Multi-task learning
|   +-- [13+ additional trainers] # Probabilistic, advanced models
+-- strategies/
|   +-- SingleTaskStrategy        # One model per target
|   +-- MultiTaskStrategy         # Shared model for targets
|   +-- CascadeStrategy           # Sequential dependencies
+-- walkforward/
|   +-- WalkForwardValidator      # Time-series validation
|   +-- PurgedTimeSeriesSplit     # Leakage-safe splitting
+-- memory/
    +-- MemoryManager             # Memory optimization
    +-- BatchProcessing           # Efficient batch handling
```

Training Flow:

```
Labeled Dataset
    v
Walk-Forward Validation (time-series split)
    v
Model Training (17+ model types)
    v
Model Validation (performance metrics)
    v
Trained Models (serialized)
```

3.3 Configuration Layer

Purpose: Centralized, version-controlled configuration management.

Components:

```
CONFIG/
+-- model_config/
|   +-- lightgbm.yaml             # LightGBM configs (3 variants)
|   +-- xgboost.yaml              # XGBoost configs (3 variants)
|   +-- mlp.yaml                  # MLP configs (3 variants)
|   +-- [14+ additional configs]  # All model types
+-- training_config/
|   +-- walkforward.yaml          # Walk-forward parameters
```

```
|   +-- feature_selection.yaml    # Feature selection configs
|   +-- first_batch_specs.yaml    # Training specifications
+-- config_loader.py
    +-- load_model_config()       # Load model configs
    +-- list_available_configs()  # List available configs
    +-- apply_overrides()         # Runtime overrides
```

Configuration Flow:

```
Base Config (YAML)
    v
Variant Selection (conservative/balanced/aggressive)
    v
Runtime Overrides (environment variables, CLI args)
    v
Final Configuration (validated, applied)
```

3.4 Model Output & Artifacts Layer

Purpose: Generation and storage of trained models, predictions, and performance metrics.

Components:

```
outputs/                          # Model artifacts and outputs
+-- models/                       # Serialized trained models
|   +-- lightgbm/                # LightGBM model artifacts
|   +-- xgboost/                 # XGBoost model artifacts
|   +-- [other model families]   # Additional model types
+-- predictions/                  # Model predictions
|   +-- validation/              # Validation set predictions
|   +-- test/                    # Test set predictions
+-- reports/                      # Performance reports
    +-- metrics/                 # Performance metrics
    +-- diagnostics/             # Model diagnostics
```

Output Flow:

```
Trained Models
    v
Model Serialization (standard formats)
    v
Signal Generation (trading signals)
    v
Risk Management (safety guards, position sizing)
    v
Order Execution (broker integration)
    v
Performance Tracking (PnL, metrics)
```

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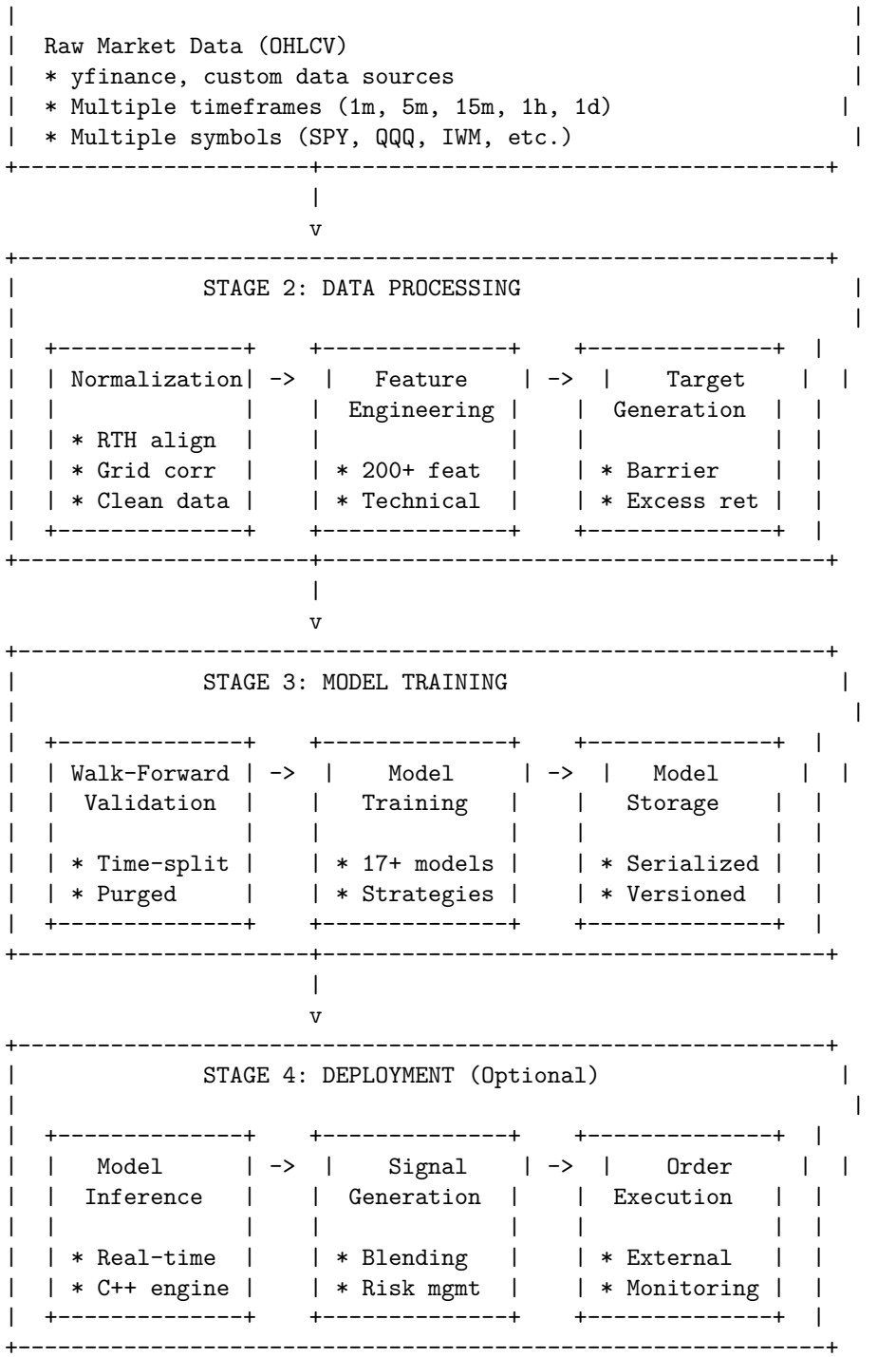
4. Data Flow Architecture

4.1 End-to-End Pipeline

```
+-------------------------------------------------------------+
|                    STAGE 1: DATA INGESTION                  |
```



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5. Module Dependencies

5.1 Dependency Graph

```
CONFIG (Configuration Management)
    ^
    | (used by)
```

```
    |
DATA_PROCESSING (Feature Engineering)
    ^
    | (produces)
    |
TRAINING (Model Training)
    ^
    | (uses)
    |
CONFIG (Model Configs)
    ^
    | (optional)
    |
External Trading Systems (Optional Integration)
```

5.2 External Dependencies

Core Dependencies: - **Python 3.9+** – Core runtime - **NumPy, Pandas** – Data processing - **Scikit-learn** – ML utilities - **LightGBM, XGBoost** – Gradient boosting models - **PyTorch** – Deep learning models (optional)

Trading Dependencies: - **ib_insync** – Interactive Brokers API - **alpaca-trade-api** – Alpaca API

Infrastructure: - **Git** – Version control - **GitHub** – Repository hosting - **YAML** – Configuration format

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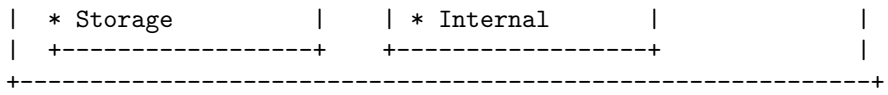
6. Deployment Architecture

6.1 Client-Hosted Deployment

```
+-------------------------------------------------------------+
|                    CLIENT INFRASTRUCTURE                    |
|                                                             |
|  +------------------+    +------------------+              |
|  |   Development    |    |    Production    |              |
|  |   Environment    |    |    Environment   |              |
|  |                  |    |                  |              |
|  | * Code repo      |    | * Model serving  |              |
|  | * Training       |    | * Trading        |              |
|  | * Testing        |    | * Monitoring     |              |
|  +------------------+    +------------------+              |
|                                                             |
|  +------------------+    +------------------+              |
|  |   Data Storage   |    |   Model Storage  |              |
|  |                  |    |                  |              |
|  | * Raw data       |    | * Trained models |              |
|  | * Processed data |    | * Configs        |              |
|  | * Features       |    | * Results        |              |
|  +------------------+    +------------------+              |
|                                                             |
|  +------------------+    +------------------+              |
|  |   Compute        |    |   Networking     |              |
|  |                  |    |                  |              |
|  * CPU/GPU          |    | * Market data    |              |
|  * Memory           |    | * Broker APIs    |              |
```



6.2 No Vendor Infrastructure

Important: Fox ML Infrastructure does not operate: - [X] Vendor-hosted servers - [X] Vendor-hosted databases - [X] Vendor cloud services - [X] Vendor network infrastructure

All infrastructure is client-controlled and client-managed.

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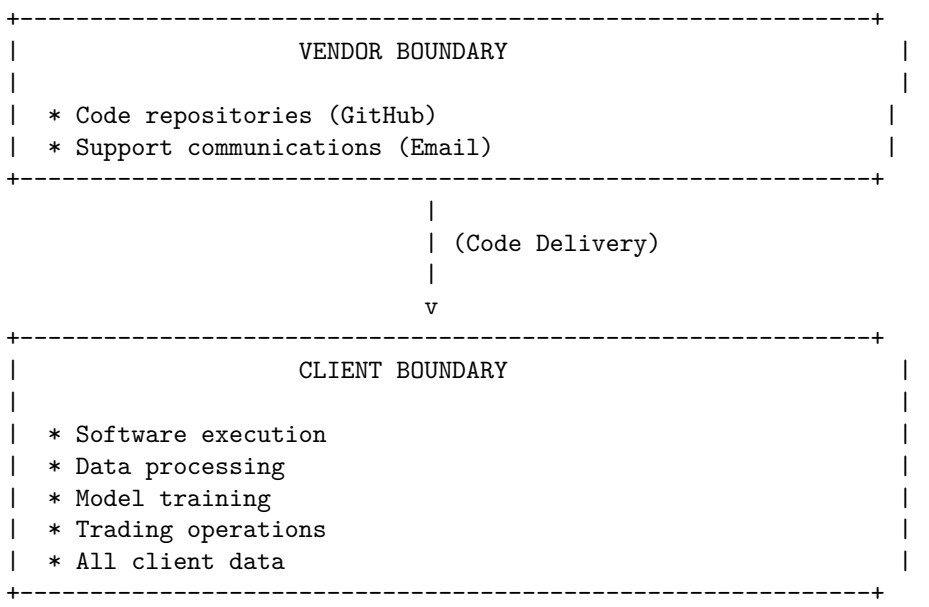
7. Security Architecture

7.1 Security Boundaries



7.2 Security Controls

Vendor-side: - Repository access controls (2FA, SSH keys) - Code integrity (version control, signed commits) - Supply chain integrity (no telemetry, explicit dependencies)

Client-side: - Infrastructure security (client-managed) - Data security (client-managed) - Network security (client-managed) - Access control (client-managed)

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8. Scalability Architecture

8.1 Horizontal Scalability

Scalable components: - **Data processing** – Parallel processing of multiple symbols/timeframes - **Model training** – Distributed training (if configured) - **Feature engineering** – Batch processing for large datasets - **Inference** – Parallel inference for multiple models

8.2 Vertical Scalability

Resource requirements: - **CPU** – Multi-core processors (8+ cores recommended) - **RAM** – 16GB+ (32GB+ for large datasets) - **GPU** – Optional but recommended for deep learning - **Storage** – Sufficient for datasets and models

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9. Integration Points

9.1 Data Integration

Data sources: - **yfinance** – Equity market data (default) - **Custom adapters** – Client-specific data sources - **File-based** – CSV, Parquet, HDF5 files

9.2 Model Integration

Model deployment: - **Serialized models** – Pickle, joblib, PyTorch formats - **REST API** – Model serving via REST API (if configured)

9.3 Model Integration

Integration points: - Models can be integrated with external trading systems - Standard formats for model serialization - Performance tracking and monitoring interfaces

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10. Configuration Architecture

10.1 Configuration Hierarchy

```
Base Config (YAML)
    v
Variant Selection (conservative/balanced/aggressive)
    v
Environment Overrides (environment variables)
    v
Runtime Overrides (CLI arguments)
    v
Final Configuration (validated, applied)
```

10.2 Configuration Sources

Configuration sources: - **YAML files** – `CONFIG/model_config/*.yaml` - **Environment variables** – Runtime overrides - **CLI arguments** – Command-line overrides - **Code defaults** – Fallback defaults

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11. Monitoring and Observability

11.1 Logging

Logging components: - **Structured logging** – JSON-structured logs - **Log levels** – DEBUG, INFO, WARNING, ERROR - **Contextual information** – Run IDs, symbols, fold numbers - **Client-managed** – Logs stored and managed by client

11.2 Metrics

Metrics tracked: - **Performance metrics** – Training time, inference latency - **Model metrics** – Accuracy, loss, validation scores - **Pipeline metrics** – Data processing throughput - **Client-managed** – Metrics collected and stored by client

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12. Contact

For architecture questions or integration planning:

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Subject: *Architecture Inquiry – Fox ML Infrastructure*

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13. Related Documents

- `docs/00_executive/ARCHITECTURE_OVERVIEW.md` – Detailed architecture overview
- `docs/03_technical/design/ARCHITECTURE_DEEP_DIVE.md` – Deep technical dive
- `LEGAL/ENTERPRISE_DELIVERY.md` – Repository structure and delivery model
- `LEGAL/CLIENT_ONBOARDING.md` – Client onboarding and integration guide

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14. Summary

Key Architectural Principles:

1. **Client-hosted** – Software runs entirely on client infrastructure
2. **Modular** – Clear separation of concerns across modules
3. **Configuration-driven** – All runtime parameters from configs
4. **Pipeline-based** – Data flows through well-defined stages
5. **Extensible** – Easy to add new models, features, strategies
6. **Scalable** – Horizontal and vertical scalability
7. **Secure** – Security boundaries and controls clearly defined

This architecture provides a comprehensive foundation for ML research and quantitative workflows.