Eagle AI Labs Forward Curve System

Technical Whitepaper v1.0

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Executive Summary

The Eagle AI Labs Forward Curve System is a proprietary cryptocurrency price prediction and visualization platform that generates real-time forward curves for Bitcoin (BTC). Similar to forward curves in traditional commodities and fixed-income markets, our system projects expected prices across multiple time horizons, providing traders and analysts with actionable intelligence on anticipated price movements.

This whitepaper provides a comprehensive technical overview of the system architecture, prediction models, data flows, and operational mechanics.

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1. Introduction to Forward Curves

1.1 What is a Forward Curve?

A forward curve is a graphical representation of expected future prices for an asset at various points in time. In traditional finance, forward curves are commonly used in:

- **Commodities markets** (oil, natural gas, agricultural products)
- **Fixed income** (yield curves for bonds)
- **Foreign exchange** (forward rate agreements)

The Eagle AI Forward Curve applies this concept to cryptocurrency markets, specifically Bitcoin, using machine learning models to generate price predictions across multiple time horizons.

1.2 Why Forward Curves for Crypto?

Cryptocurrency markets operate 24/7 with high volatility and complex market microstructure. Traditional technical analysis often fails to capture:

- Cross-exchange arbitrage dynamics
- Derivatives market influence (futures, options, perpetuals)
- On-chain metrics and whale movements
- Macro liquidity cycles

Our forward curve system synthesizes these diverse data sources into a unified predictive framework.
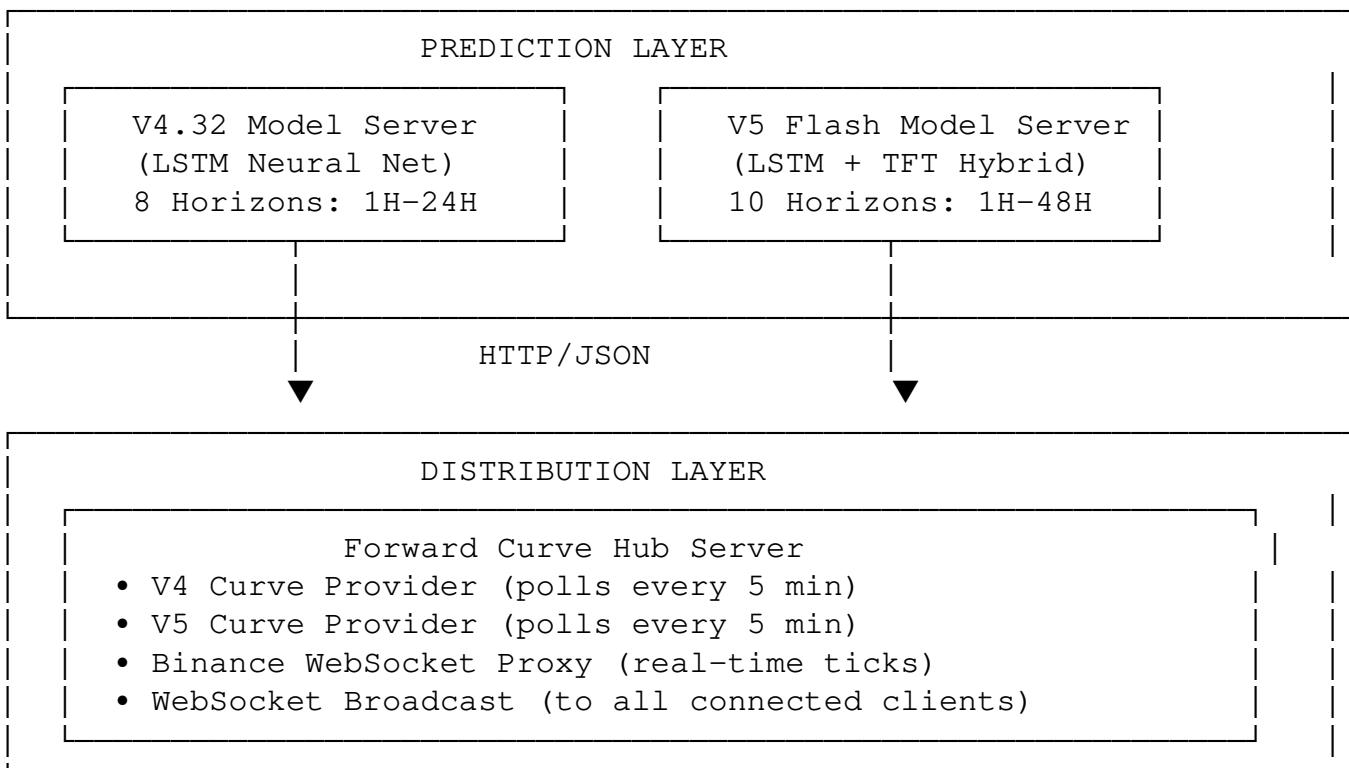
1.3 Key Terminology
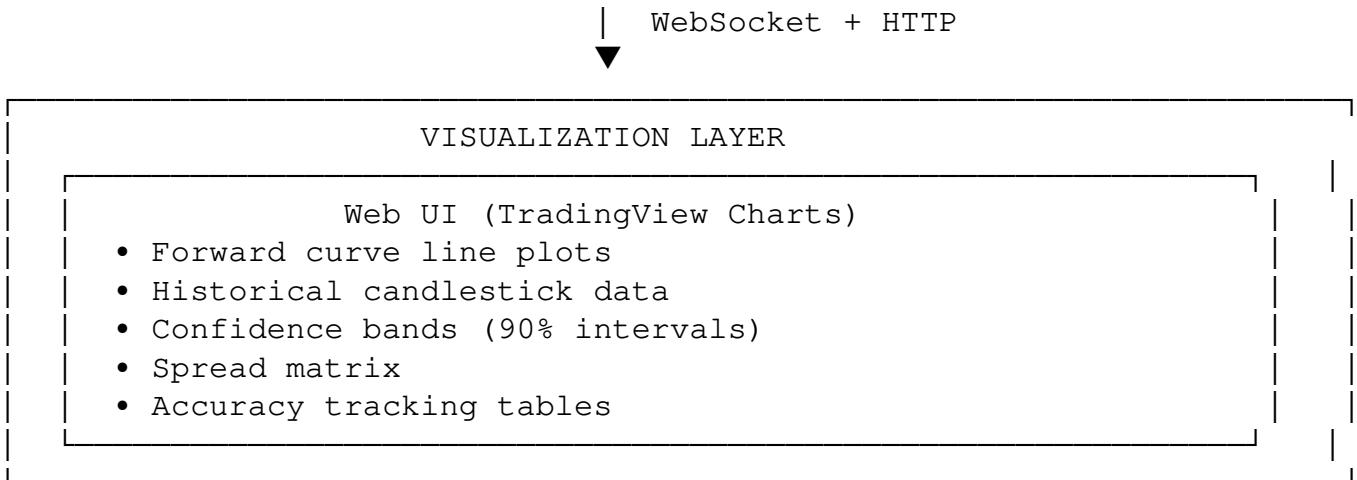
| Term	Definition
Horizon	A specific future time point (e.g., +1H, +2H, +4H)
Anchor	The reference timestamp from which predictions are made
Liquidity Fixing	Daily anchor point at 13:00 UTC
Curve Point	A single price prediction at a specific horizon
Confidence Band	Upper/lower bounds representing prediction uncertainty
Stabilized Prediction	Final prediction before a horizon becomes actual

2. System Architecture

2.1 High-Level Overview

The Forward Curve System consists of three primary layers:

```
┌─────────────────────────────────────────────────────────────────┐
│                      PREDICTION LAYER                             │
│                                                                   │
│  ┌───────────────────────────┐   ┌───────────────────────────┐   │
│  │   V4.32 Model Server      │   │   V5 Flash Model Server   │   │
│  │   (LSTM Neural Net)       │   │   (LSTM + TFT Hybrid)     │   │
│  │   8 Horizons: 1H-24H      │   │   10 Horizons: 1H-48H     │   │
│  └───────────────────────────┘   └───────────────────────────┘   │
│                │                             │                    │
│                │                             │                    │
└────────────────│─────────────────────────────│──────────────────┘
                 │         HTTP/JSON           │
                 ▼                             ▼
┌─────────────────────────────────────────────────────────────────┐
│                      DISTRIBUTION LAYER                           │
│                                                                   │
│  ┌───────────────────────────────────────────────────────────┐   │
│  │              Forward Curve Hub Server                      │   │
│  │    • V4 Curve Provider (polls every 5 min)                │   │
│  │    • V5 Curve Provider (polls every 5 min)                │   │
│  │    • Binance WebSocket Proxy (real-time ticks)            │   │
│  │    • WebSocket Broadcast (to all connected clients)       │   │
│  │                                                           │   │
│  └───────────────────────────────────────────────────────────┘   │
│                                                                   │
└─────────────────────────────────────────────────────────────────┘
```

```
                              │   WebSocket + HTTP
                              ▼
┌──────────────────────────────────────────────────────────────────┐
│                      VISUALIZATION LAYER                           │
│  ┌──────────────────────────────────────────────────────────┐  │  │
│  │                Web UI (TradingView Charts)                 │  │  │
│  │      • Forward curve line plots                            │  │  │
│  │      • Historical candlestick data                        │  │  │
│  │      • Confidence bands (90% intervals)                   │  │  │
│  │      • Spread matrix                                       │  │  │
│  │      • Accuracy tracking tables                           │  │  │
│  └──────────────────────────────────────────────────────────┘  │  │
│                                                                    │
└──────────────────────────────────────────────────────────────────┘
```

2.2 Component Responsibilities

Prediction Layer

- Runs machine learning inference
- Generates raw price predictions
- Calculates confidence intervals
- Exposes predictions via HTTP API

Distribution Layer

- Aggregates predictions from multiple models
- Proxies real-time market data from Binance
- Manages WebSocket connections to clients
- Handles historical data requests

Visualization Layer

- Renders interactive charts
- Displays real-time updates
- Provides user controls for curve visibility
- Shows accuracy metrics and spread analysis

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3. Prediction Models
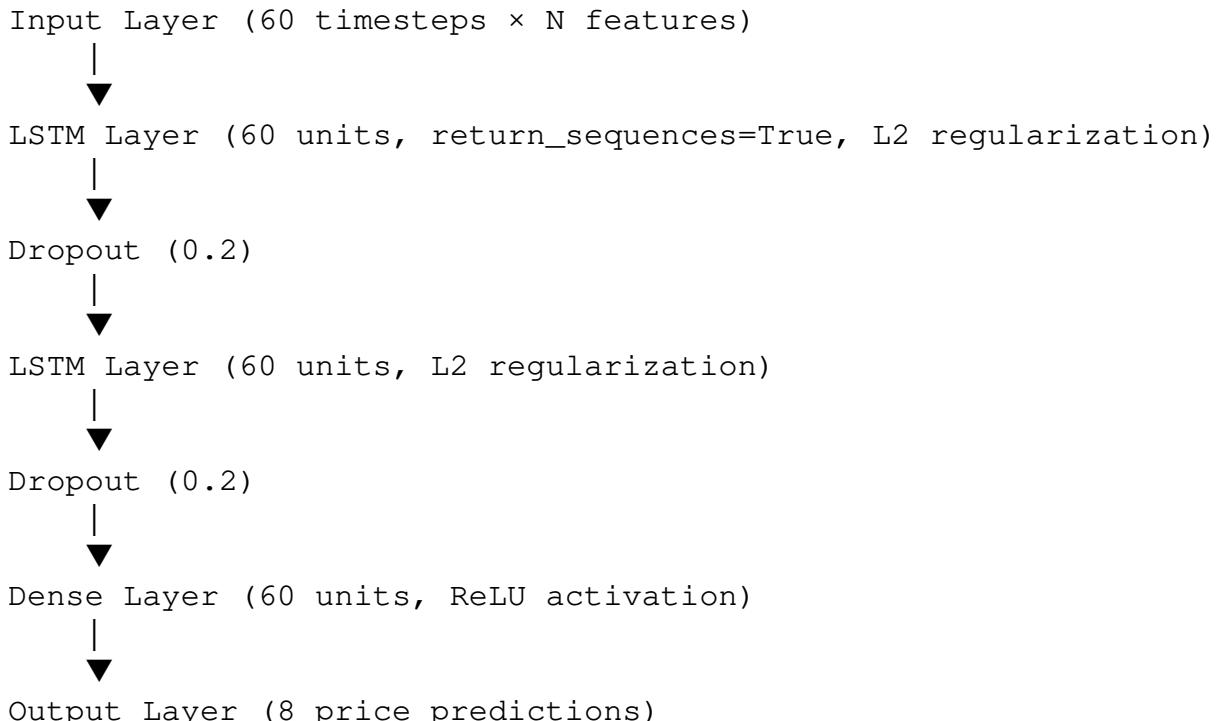
3.1 V4.32 Model (EAI Forward Reference Curve)

The V4.32 model is the primary production model, designated as the **EAI Forward Reference Curve**.

Architecture

- **Type:** Long Short-Term Memory (LSTM) Neural Network
- **Framework:** TensorFlow/Keras
- **Input Window:** 60 time steps (configurable)
- **Output:** Multi-horizon price predictions

Model Structure

```
Input Layer (60 timesteps × N features)
     |
     ▼
LSTM Layer (60 units, return_sequences=True, L2 regularization)
     |
     ▼
Dropout (0.2)
     |
     ▼
LSTM Layer (60 units, L2 regularization)
     |
     ▼
Dropout (0.2)
     |
     ▼
Dense Layer (60 units, ReLU activation)
     |
     ▼
Output Layer (8 price predictions)
```

Input Features

The V4.32 model ingests the following feature categories:

Price-Based Features:

- OHLCV data (Open, High, Low, Close, Volume)
- Returns at multiple timeframes
- Volatility measures (ATR, Bollinger Band width)

Technical Indicators:

- RSI (Relative Strength Index)
- MACD (Moving Average Convergence Divergence)
- Stochastic Oscillator
- ADX (Average Directional Index)
- Multiple EMAs (9, 21, 50 period)

External Data:

- Long/Short ratio trends
- Funding rates
- Open interest changes

Prediction Horizons
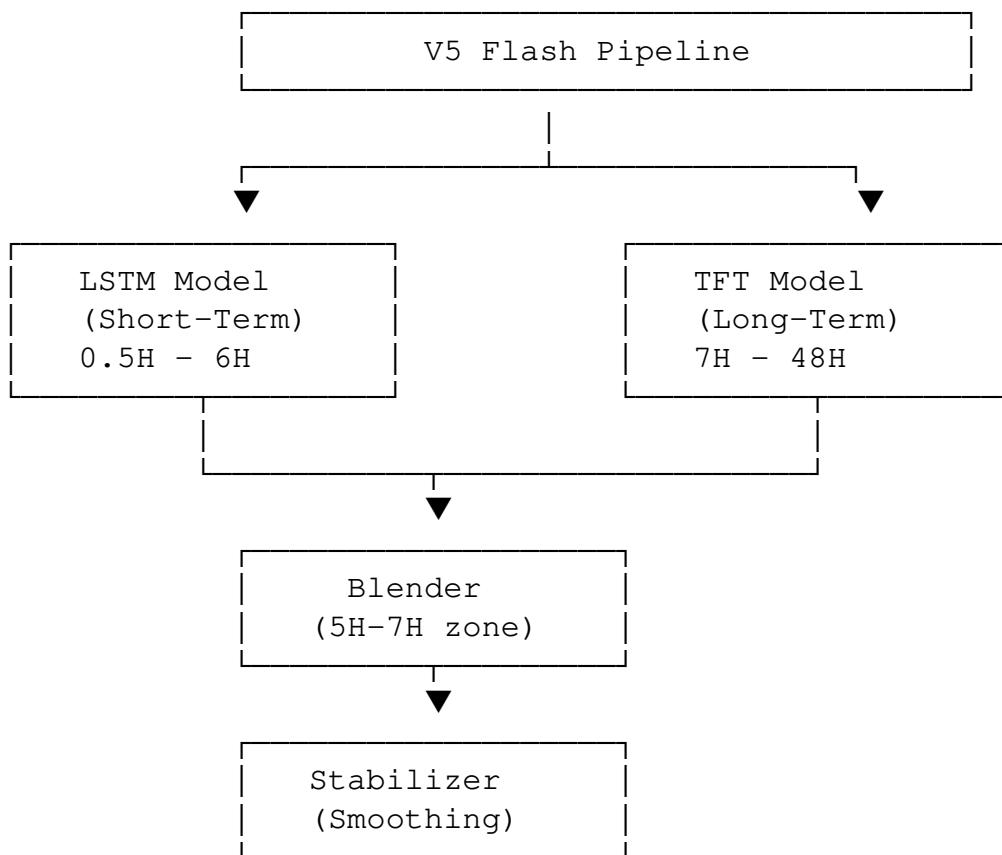
Horizon	Time Offset	Description
+1H	1 hour	Short-term momentum
+2H	2 hours	Intraday trend
+4H	4 hours	Session trend

+6H	6 hours	Half-day outlook
+8H	8 hours	Extended session
+12H	12 hours	Overnight/next session
+18H	18 hours	Next day early
+24H	24 hours	Full day forecast

3.2 V5 Flash Model (LSTM + TFT Hybrid)

The V5 Flash model represents the next generation of prediction technology, combining two specialized architectures.

Dual-Architecture Design

```
              ┌────────────────────────────────┐
              │       V5 Flash Pipeline         │
              └────────────────────────────────┘
                             │
            ┌────────────────┴────────────────┐
            ▼                                  ▼
  ┌───────────────────┐            ┌───────────────────┐
  │  LSTM Model       │            │  TFT Model        │
  │  (Short-Term)     │            │  (Long-Term)      │
  │  0.5H - 6H        │            │  7H - 48H         │
  └───────────────────┘            └───────────────────┘
            │                                  │
            └────────────────┬────────────────┘
                             ▼
                  ┌───────────────────┐
                  │     Blender       │
                  │   (5H-7H zone)    │
                  └───────────────────┘
                             ▼
                  ┌───────────────────┐
                  │    Stabilizer     │
                  │   (Smoothing)     │
                  └───────────────────┘
```

LSTM Component (Short Horizons)

- Optimized for capturing short-term price dynamics
- Higher sensitivity to recent price action
- Faster adaptation to regime changes

TFT Component (Long Horizons)

- Temporal Fusion Transformer architecture
- Better at capturing long-range dependencies
- Incorporates attention mechanisms for feature importance

Blending Zone (5H-7H)

The transition between LSTM and TFT predictions is smoothed using weighted averaging:

```
For horizon h in [5H, 6H, 7H]:
    weight_lstm = (7 - h) / 2
    weight_tft = (h - 5) / 2
    prediction = weight_lstm × lstm_pred + weight_tft × tft_pred
```

Feature Engineering (69 Features)

The V5 model uses an extensive feature set from multiple data sources:

Data Sources:

Source	Data Type	Features
CCData	Price data	OHLCV, returns, volatility
CryptoQuant	On-chain	Exchange flows, whale alerts
Coinglass	Derivatives	Funding, OI, liquidations
Deribit	Options	IV, put/call ratio, skew
Binance	Market data	Order book, trades

Extended Horizons

Horizon	Time Offset
+1H	1 hour
+2H	2 hours
+4H	4 hours
+6H	6 hours
+8H	8 hours
+12H	12 hours
+18H	18 hours
+24H	24 hours
+36H	36 hours
+48H	48 hours

4. The Liquidity Fixing Anchor

4.1 Concept

The **Liquidity Fixing** (formerly "Anchor") is a critical concept in the V4.32 model. It establishes a fixed reference point each day at **13:00 UTC** from which all predictions are measured.

4.2 Why 13:00 UTC?

This timestamp was chosen based on market microstructure analysis:
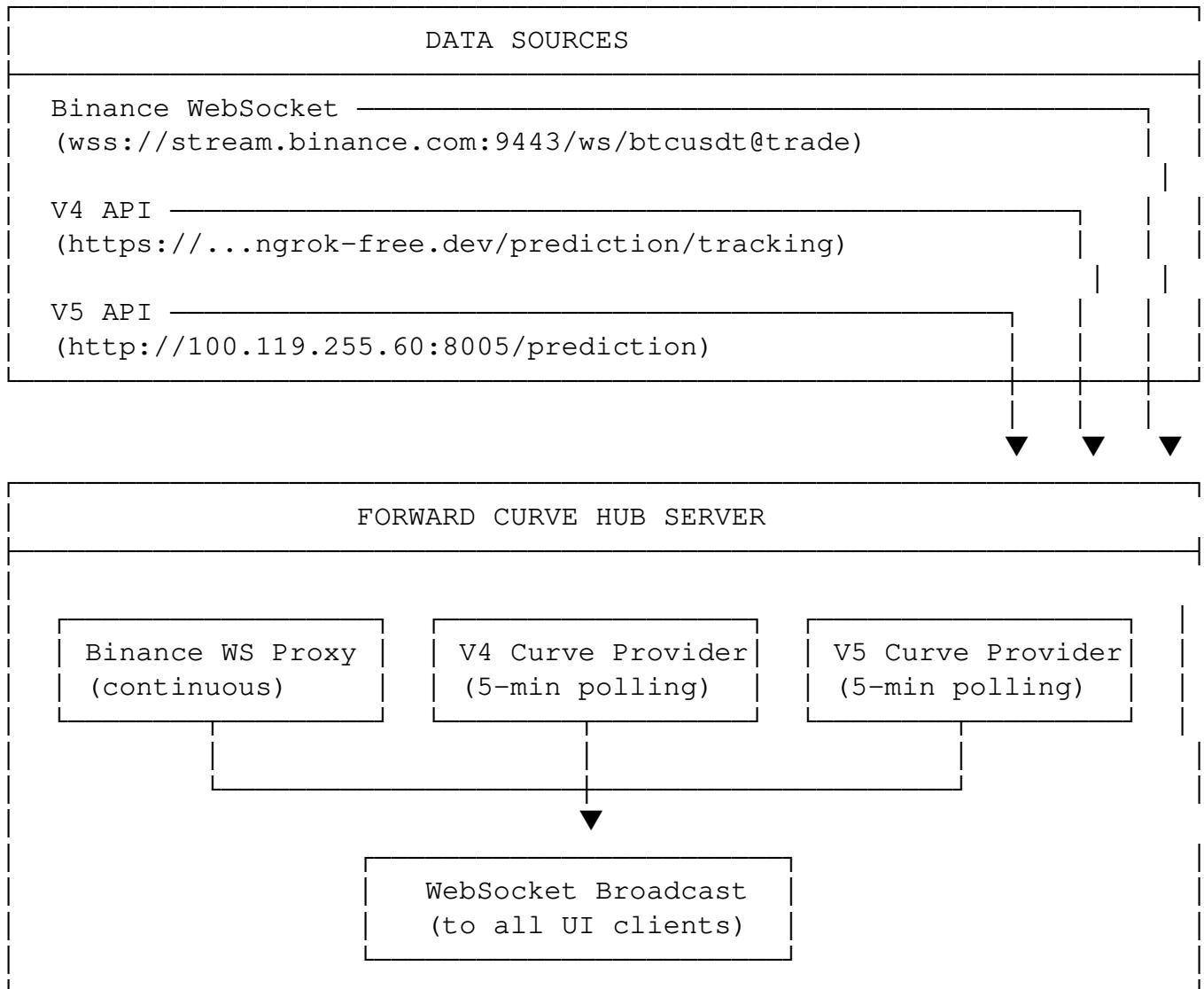
| Timezone	Local Time	Significance

This allows analysis of:

1. How accurate the original prediction was
2. How much the model refined its prediction over time
3. Whether tracking improves or degrades accuracy

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5. Data Pipeline

5.1 Real-Time Data Flow

```
┌─────────────────────────────────────────────────────────────────┐
│                        DATA SOURCES                               │
├─────────────────────────────────────────────────────────────────┤
│                                                                   │
│  Binance WebSocket ─────────────────────────────────────┐  │     │
│  (wss://stream.binance.com:9443/ws/btcusdt@trade)        │  │     │
│                                                          │        │
│  V4 API ─────────────────────────────────────────┐      │  │     │
│  (https://...ngrok-free.dev/prediction/tracking)  │      │  │     │
│                                                │  │      │  │     │
│  V5 API ─────────────────────────────────┐     │  │     │  │     │
│  (http://100.119.255.60:8005/prediction) │     │  │     │  │     │
│                                           │     │  │     │  │     │
└───────────────────────────────────────────────────────────────────┘
                                           │     │  │     │  │
                                           ▼     ▼        ▼
```

```
┌─────────────────────────────────────────────────────────────────┐
│                  FORWARD CURVE HUB SERVER                         │
├─────────────────────────────────────────────────────────────────┤
│                                                                   │
│   ┌───────────────────┐  ┌───────────────────┐  ┌───────────────────┐ │
│   │ Binance WS Proxy  │  │ V4 Curve Provider│  │ V5 Curve Provider│ │
│   │ (continuous)      │  │ (5-min polling)   │  │ (5-min polling)   │ │
│   └───────────────────┘  └───────────────────┘  └───────────────────┘ │
│             │                     │                     │          │
│             └─────────────────────┼─────────────────────┘          │
│                                   ▼                                │
│                    ┌───────────────────────────┐                  │
│                    │   WebSocket Broadcast      │                  │
│                    │   (to all UI clients)      │                  │
│                    └───────────────────────────┘                  │
│                                                                   │
└───────────────────────────────────────────────────────────────────┘
```

5.2 Polling Schedule

Both curve providers align their polling to 5-minute marks:

```
:00 ── V5 polls (+2s buffer)
:00 ── V4 polls (+5s offset from V5)
:05 ── V5 polls
:05 ── V4 polls
:10 ── V5 polls
:10 ── V4 polls
```

```
... (continues every 5 minutes)
```

The offset prevents simultaneous API calls and ensures staggered updates.

5.3 Message Types

The WebSocket broadcasts the following message types:

Trade Message (Real-time)

```
{
  "type": "trade",
  "data": {
    "e": "trade",
    "E": 1706889600000,
    "s": "BTCUSDT",
    "p": "98500.00",
    "q": "0.001",
    "T": 1706889600000
  }
}
```

V4 Forward Curve Message

```
{
  "type": "v4_forward_curve",
  "timestamp": "2026-02-04T13:05:00Z",
  "generated_at": "2026-02-04T13:00:00Z",
  "anchor_timestamp": "2026-02-04T13:00:00Z",
  "hours_elapsed": 0.083,
  "current_price": 98500.00,
  "direction": "bullish",
  "regime": "trending",
  "curve_quality": 0.85,
  "curve": [
    {
      "horizon": "+1H",
      "target_price": 98650.00,
      "pct_change": 0.15,
      "lower_90": 98400.00,
      "upper_90": 98900.00,
      "is_actual": false,
      "original_price": 98600.00,
      "stabilized_price": null
    }
  ],
  "model": "V4.32"
}
```

V5 Forward Curve Message

```
{
```

```json
  "type": "forward_curve",
  "timestamp": "2026-02-04T13:05:02Z",
  "model_timestamp": "2026-02-04T13:05:00Z",
  "current_price": 98500.00,
  "direction": "UP",
  "confidence_level": "HIGH",
  "confidence_score": 0.78,
  "curve": [
    {
      "horizon": "+1H",
      "target_price": 98680.00,
      "pct_change": 0.18,
      "lower_90": 98350.00,
      "upper_90": 99010.00
    }
  ],
  "model": "V5 Flash (LSTM+TFT)"
}
```

Heartbeat Message

```json
{
  "type": "heartbeat",
  "data": {
    "instance_name": "ForwardCurveHub",
    "instance_id": "hostname-pid-timestamp",
    "heartbeat_at": "2026-02-04T13:05:05Z"
  }
}
```

6. Horizon Predictions

6.1 Understanding Horizons

Each horizon represents a specific future time point relative to the current moment (for V5) or the anchor time (for V4.32).
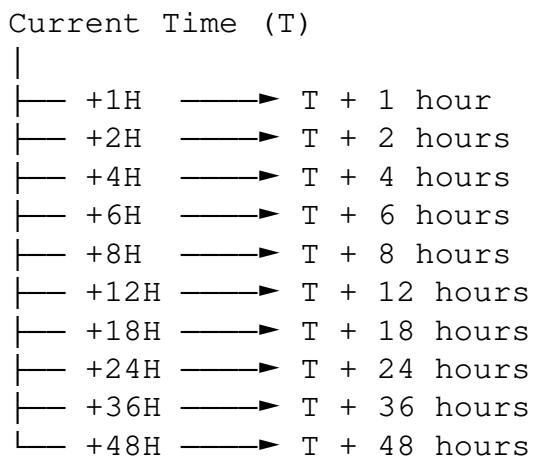
V4.32 Horizons (Anchor-Relative)

```
Anchor (13:00 UTC)
|
├── +1H  ──────► 14:00 UTC (1 hour after anchor)
├── +2H  ──────► 15:00 UTC (2 hours after anchor)
├── +4H  ──────► 17:00 UTC (4 hours after anchor)
├── +6H  ──────► 19:00 UTC (6 hours after anchor)
├── +8H  ──────► 21:00 UTC (8 hours after anchor)
├── +12H ──────► 01:00 UTC next day
├── +18H ──────► 07:00 UTC next day
└── +24H ──────► 13:00 UTC next day (next anchor)
```

V5 Horizons (Rolling)

V5 predictions are rolling - they always represent time from "now":

```
Current Time (T)
|
|── +1H  ─────► T + 1 hour
|── +2H  ─────► T + 2 hours
|── +4H  ─────► T + 4 hours
|── +6H  ─────► T + 6 hours
|── +8H  ─────► T + 8 hours
|── +12H ─────► T + 12 hours
|── +18H ─────► T + 18 hours
|── +24H ─────► T + 24 hours
|── +36H ─────► T + 36 hours
└── +48H ─────► T + 48 hours
```

6.2 Prediction Components

Each horizon prediction includes:

Field	Description
target_price	The predicted price at this horizon
pct_change	Percentage change from current price
lower_90	Lower bound of 90% confidence interval
upper_90	Upper bound of 90% confidence interval
is_actual	Whether this horizon has passed (V4 only)

6.3 Confidence Intervals

The 90% confidence interval represents the range within which the model expects the actual price to fall with 90% probability.

Interpretation:

- Narrow bands = High confidence in prediction
- Wide bands = Higher uncertainty
- Asymmetric bands = Directional bias in uncertainty

Calculation Method: The confidence intervals are derived from:

1. Historical prediction error distribution
2. Current market volatility regime
3. Model-specific uncertainty quantification

6.4 Spread Analysis

The **spread** between horizons provides insight into expected price trajectory:

```
Spread Matrix Example:
```

	+1H	+2H	+4H	+6H
Current	+$150	+$280	+$450	+$520

+1H	–	+$130	+$300	+$370
+2H	–	–	+$170	+$240

Spread Interpretation:

- **Positive spreads:** Model expects price to rise
- **Negative spreads:** Model expects price to fall
- **Accelerating spreads:** Momentum building
- **Decelerating spreads:** Momentum fading

---

7. Accuracy Tracking & Validation

7.1 Accuracy Metrics

The system tracks prediction accuracy using multiple metrics:

Mean Absolute Error (MAE)

```
MAE = (1/n) × Σ|predicted_price - actual_price|
```

Measures average absolute deviation in dollar terms.

Mean Absolute Percentage Error (MAPE)

```
MAPE = (1/n) × Σ|predicted_price - actual_price| / actual_price × 100
```

Measures average percentage deviation.

Direction Accuracy

```
Direction_Accuracy = (correct_direction_predictions / total_predictions
```

Measures how often the model correctly predicts up/down movement.

Stabilization Accuracy

Compares the "stabilized" prediction (last prediction before horizon becomes actual) against the actual price. This measures the model's final refined prediction.

7.2 Accuracy by Horizon

Typical accuracy patterns:

Horizon	Expected MAPE	Direction Accuracy
+1H	0.3% - 0.5%	55% - 60%
+2H	0.5% - 0.8%	53% - 58%
+4H	0.8% - 1.2%	52% - 56%

+6H	1.0% - 1.5%	51% - 55%
+8H	1.2% - 1.8%	50% - 54%
+12H	1.5% - 2.2%	50% - 53%
+18H	1.8% - 2.8%	49% - 52%
+24H	2.0% - 3.5%	48% - 52%

Note: Accuracy varies significantly based on market regime (trending vs. ranging).

7.3 Regime-Dependent Performance

The models perform differently across market regimes:

Regime	Characteristics	Model Performance
Trending	Clear directional moves	Higher direction accuracy
Ranging	Sideways consolidation	Lower direction accuracy, tighter MAPE
Volatile	Large swings, reversals	Wider confidence bands, lower accuracy
Low Volatility	Compressed ranges	Tighter predictions, higher accuracy

7.4 Validation Methodology

Backtesting

- Historical data replay with walk-forward validation
- No look-ahead bias in feature engineering
- Out-of-sample testing on unseen data

Live Tracking

- Real-time comparison of predictions vs. actuals
- Rolling accuracy windows (24h, 7d, 30d)
- Automatic alerting on accuracy degradation

8. Visualization Layer

8.1 Chart Components

The UI renders the following visual elements:

Forward Curve Line

- **V4.32 Curve:** Cyan/teal color (#22d3ee)
- **V5 Curve:** Amber/orange color (#f59e0b)
- Plotted from current time extending into future horizons

Historical Candles

- Standard OHLC candlesticks

- Green (up) / Red (down) coloring
- 48 hours of historical data from Binance

Confidence Bands

- Semi-transparent fill between upper_90 and lower_90
- Provides visual representation of prediction uncertainty

NOW Marker

- Vertical line or marker indicating current time
- Separates historical data from predictions

Spot Price Display

- Real-time BTC price from Binance
- Updates with each trade tick

8.2 Information Panels

V4.32 Info Box

Displays:

- Current price
- Each horizon with target price and % change
- Regime indicator
- Curve quality score
- Time since anchor

V5 Info Box

Displays:

- Current price
- Each horizon with target price and % change
- Direction indicator
- Confidence level and score

8.3 Spread Matrix

Interactive matrix showing price differentials between horizons:

- Color-coded cells (green = positive, red = negative)
- Flash animation on significant changes
- Integer-only flash updates (reduces noise)

8.4 Accuracy Table

Historical accuracy display:

- Per-horizon accuracy metrics

- Stabilization accuracy percentage
  - Color-coded performance indicators

---

9. API Reference

9.1 HTTP Endpoints

Get Current V5 Curve

```
GET /api/curve/current
```

Returns the latest V5 forward curve prediction.

Get Curve History

```
GET /api/curve/history?limit=10
```

Returns historical curve snapshots.

Get Curve Summary

```
GET /api/curve/summary
```

Returns a quick summary of current predictions.

Get Binance Klines

```
GET /api/binance-klines?symbol=BTCUSDT&interval=1h&limit=48
```

Proxies Binance klines API for historical candle data.

9.2 WebSocket Connection

Connect

```
ws://[host]:[port]/ws
```

Message Flow

1. Client connects
2. Server sends initial V5 curve (if available)
3. Server sends initial V4 curve (if available)
4. Server broadcasts updates:

   - Trade ticks (continuous)
   - V4 curve updates (every 5 min)
   - V5 curve updates (every 5 min)
   - Heartbeats (every 5 sec)

9.3 External Model APIs

V4.32 API Endpoints
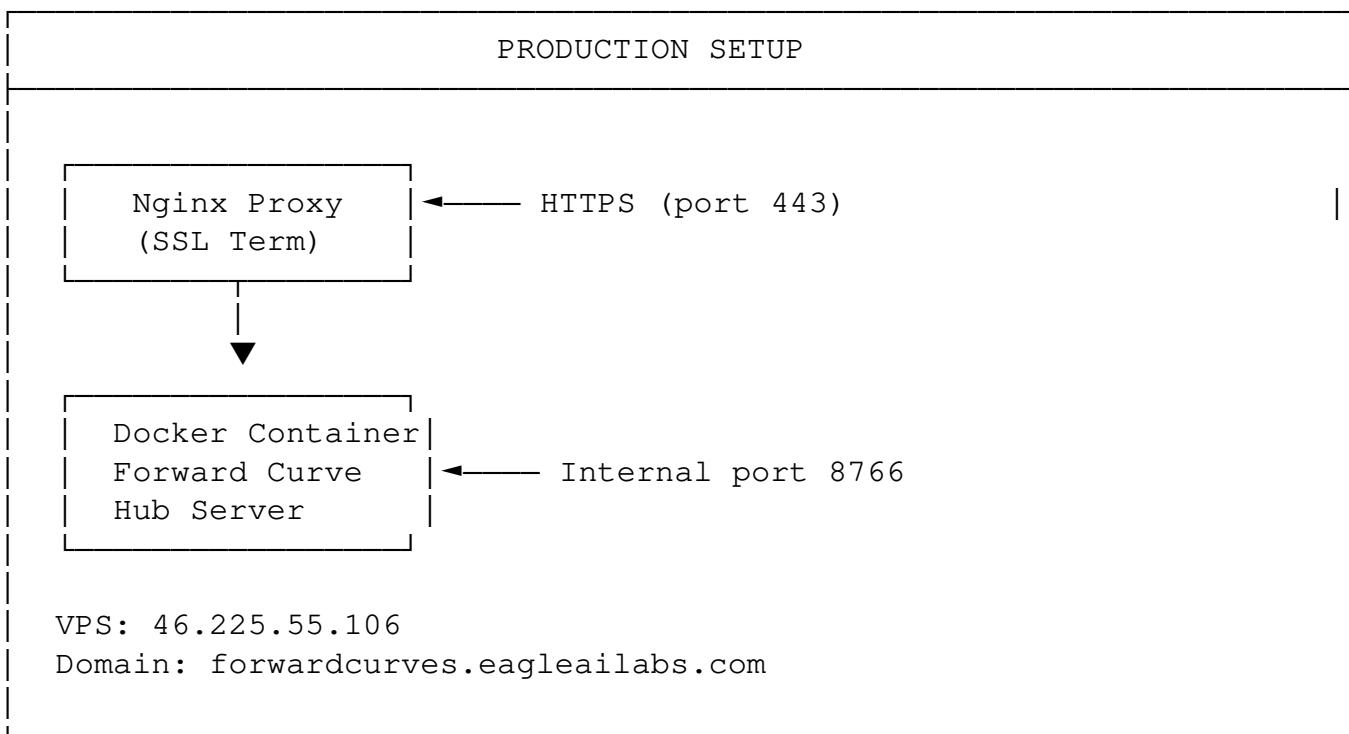
| Endpoint	Description
`/prediction/tracking`	Current tracking predictions
`/prediction/yesterday`	Yesterday's predictions (for comparison)
`/history?limit=N`	Historical prediction snapshots

V5 API Endpoints

Endpoint	Description
`/prediction`	Current forward curve
`/prediction/summary`	Quick summary
`/history?limit=N`	Historical predictions

10. Operational Considerations

10.1 Deployment Architecture

```
┌─────────────────────────────────────────────────────────────┐
│                      PRODUCTION SETUP                        │
├─────────────────────────────────────────────────────────────┤
│                                                             │
│   ┌─────────────────┐                                       │
│   │  Nginx Proxy    │◄─────── HTTPS (port 443)              │
│   │  (SSL Term)     │                                       │
│   └─────────────────┘                                       │
│            │                                                │
│            ▼                                                │
│   ┌─────────────────┐                                       │
│   │  Docker Container│                                      │
│   │  Forward Curve  │◄─────── Internal port 8766            │
│   │  Hub Server     │                                       │
│   └─────────────────┘                                       │
│                                                             │
│   VPS: 46.225.55.106                                        │
│   Domain: forwardcurves.eagleailabs.com                     │
│                                                             │
└─────────────────────────────────────────────────────────────┘
```

10.2 Monitoring

Key metrics to monitor:

- WebSocket connection count
- API response times (V4, V5)
- Prediction freshness (time since last update)
- Error rates
- Memory/CPU usage

10.3 Failure Modes

Failure	Impact	Mitigation
V4 API down	No V4 curve updates	Graceful degradation, show last known
V5 API down	No V5 curve updates	Graceful degradation, show last known
Binance WS disconnect	No live ticks	Auto-reconnect with backoff
Server crash	Full outage	Docker restart policy, health checks

10.4 Security

- Basic authentication on UI (eagle / EagleAI2026!)
- HTTPS via Nginx SSL termination
- No sensitive data exposed in API responses
- Rate limiting on API endpoints

Appendix A: Glossary

Term	Definition
LSTM	Long Short-Term Memory neural network
TFT	Temporal Fusion Transformer
Horizon	Future time point for prediction
Anchor	Fixed reference timestamp (13:00 UTC)
Liquidity Fixing	Daily anchor point
Confidence Band	Range of expected prices (90% CI)
Spread	Price difference between horizons
Regime	Market condition (trending, ranging, etc.)
Stabilized	Final prediction before becoming actual
Tracking	Continuously updated prediction

Appendix B: Version History

Version	Date	Changes
1.0	Feb 2026	Initial whitepaper release

Appendix C: Contact

Eagle AI Labs Technical Support: engineering@eagleailabs.com Website: https://eagleailabs.com