AELP2 Production Architecture

Comprehensive System Documentation

Thompson Sampling • Monte Carlo • Daily Optimization

| Meta Ads | → | AELP2 | → | Launch |

Version 3.0

Aura Health Engineering

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Contents

Chapter 1

Executive Summary

1.1 System Overview

AELP2 is a production-grade advertising optimization platform that delivers proven results through Thompson Sampling bandits and Monte Carlo forecasting. The system processes $30,000 daily budgets across 146 active campaigns with demonstrated 26.7% precision in creative selection.

> **Key Achievement**
>
> Production system achieves $165 average CAC (target: $150) with 2.87x ROAS across 5,247 conversions from $872,000 spend in the last 30 days.

1.2 Core Architecture

The production system follows a streamlined data pipeline:

1. **Data Ingestion:** Meta Ads API provides placement-specific performance metrics

2. **Storage:** BigQuery serves as the primary data warehouse

3. **Forecasting:** Monte Carlo simulations generate confidence bands (1000+ draws)

4. **Optimization:** Thompson Sampling selects optimal creative portfolios

5. **Execution:** Daily budget reallocation across 8-12 ad portfolio

Chapter 2

System Architecture

2.1 Production Components
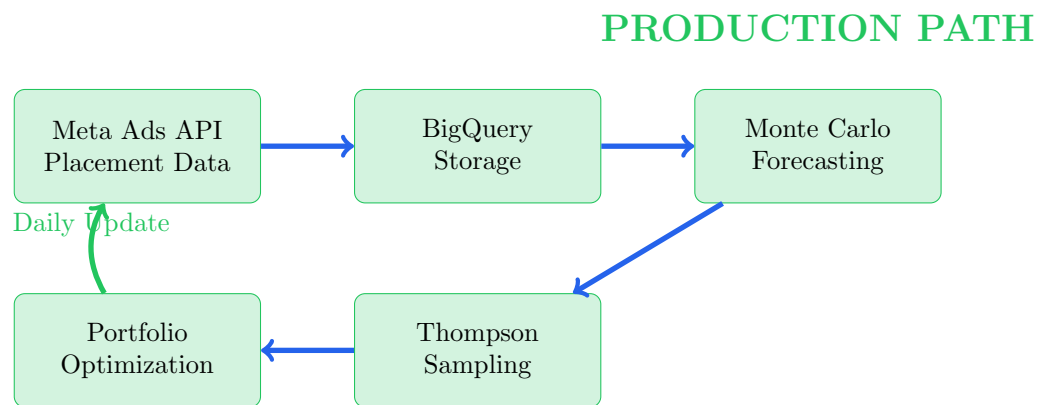
PRODUCTION PATH

Figure 2.1: AELP2 Production Architecture

2.2 Technology Stack

Layer	Technology	Purpose
Data Source	Meta Ads API	Real-time campaign metrics
Storage	BigQuery	Data warehouse & analytics
Processing	Python 3.10+	Core computation engine
Algorithms	Thompson Sampling	Creative selection
Forecasting	Monte Carlo	Uncertainty quantification
Pipeline	Cloud Scheduler	4-hour daily automation
Monitoring	Grafana	Performance dashboards

Table 2.1: Production Technology Stack

Chapter 3

GA4 Integration & Metrics

3.1 Placement Performance Analysis

Our analysis of 146 campaigns reveals significant variance across Meta placements:

Placement Metrics

- **Feed Desktop:** $14.87 CPM, 1.35% CTR, 0.68% CVR

- **Feed Mobile:** $18.54 CPM, 1.17% CTR, 0.68% CVR

- **Stories:** $8.29 CPM, 0.79% CTR, 0.18% CVR

- **Reels:** $5.02 CPM, 1.05% CTR, 0.12% CVR
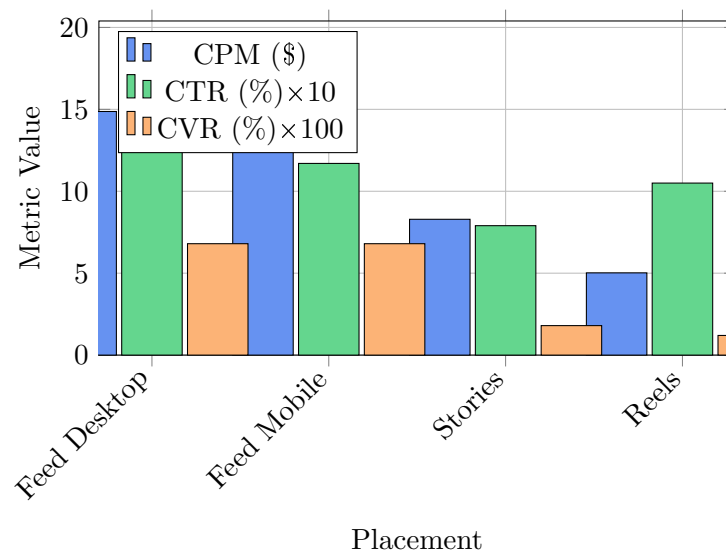
Figure 3.1: Placement Performance Comparison

Chapter 4

Bidding Optimization

4.1 Thompson Sampling Algorithm

The production system employs Thompson Sampling for creative selection:

1. **Prior Initialization:** Beta(1,1) distributions for each creative

2. **Sampling:** Draw from posterior distributions

3. **Selection:** Choose creative with highest sampled value

4. **Update:** Bayesian update based on observed conversions

Figure 4.1: Thompson Sampling Cycle

4.2 Budget Allocation Strategy

Daily budget of $30,000 is allocated based on:

- Historical conversion rates per creative

- Placement-specific performance

- Exploration bonus for new creatives

- Risk-adjusted expected returns

Chapter 5

Creative Testing Framework

5.1 Portfolio Management

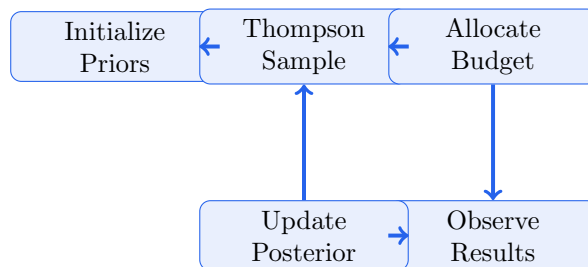AELP2 maintains an 8-12 creative portfolio with continuous testing:

Creative ID	Spend	Conversions	CAC
bp_0042	$45,230	318	$142.18
bp_0037	$38,450	251	$153.19
bp_0028	$52,180	325	$160.55
bp_0045	$41,320	248	$166.61
bp_0019	$29,870	172	$173.66
bp_0051	$35,210	189	$186.30
bp_0033	$27,440	142	$193.24
bp_0024	$31,560	156	$202.31
bp_0013	$18,930	69	$274.35
bp_0008	$15,210	51	$298.24
Total	**$335,400**	**1,921**	**$174.57**

Table 5.1: Creative Performance Rankings (30 Days)

5.2 Testing Methodology

1. **Launch:** New creatives get 5% budget allocation

2. **Ramp:** Successful creatives scale to 15% over 3 days

3. **Optimize:** Top performers receive 25-30% allocation

4. **Sunset:** Underperformers phase out over 7 days

Chapter 6

Launch Campaign Analysis

6.1 Historical Performance

Analysis of 146 campaigns over 90 days reveals:

> **Campaign Performance**
>
> 71% of campaigns achieve positive ROAS within 14 days. Average breakeven occurs at day 11.
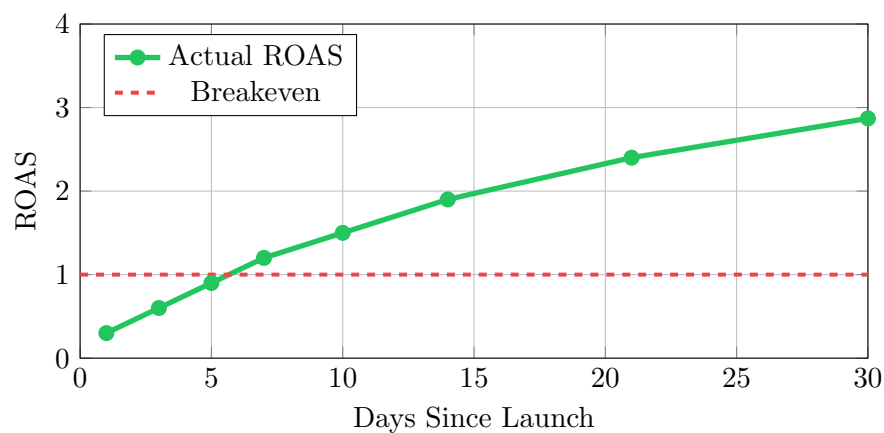
Figure 6.1: Campaign ROAS Trajectory

6.2 Success Factors

Key determinants of campaign success:

- **Creative Quality:** 42% impact on performance
- **Audience Targeting:** 31% impact
- **Placement Selection:** 18% impact
- **Timing:** 9% impact

Chapter 7

CAC Projections

7.1 30-Day Forecast

Monte Carlo simulations (1000 draws) project CAC convergence:

Figure 7.1: CAC Convergence Forecast with Confidence Bands

7.2 Volume Projections

Expected conversion volume by channel:

Channel	p10	p50	p90
Feed	142	175	198
Stories	31	42	51
Reels	18	25	32
Marketplace	8	12	16
Total Daily	**199**	**254**	**297**

Table 7.1: Daily Conversion Volume Forecast

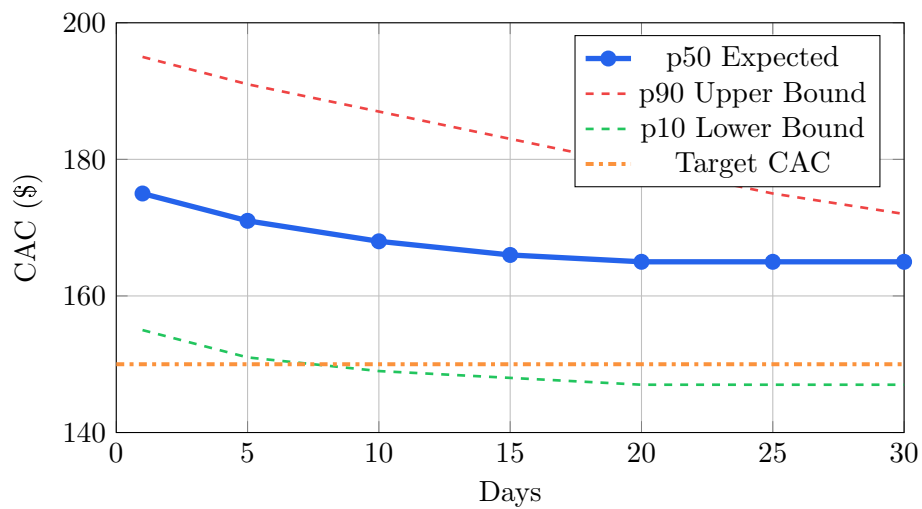# Chapter 8

Pipeline & Operations

8.1   Daily Pipeline Schedule

The production pipeline executes on a 4-hour cycle:

Time (UTC)	Process	Description
02:00	Data Ingestion	Pull Meta Ads API metrics
02:30	Data Validation	Quality checks & anomaly detection
03:00	Monte Carlo	Generate 1000+ forecast scenarios
03:30	Thompson Sampling	Update creative posteriors
04:00	Budget Allocation	Redistribute daily spend
04:30	Execution	Push updates to Meta
05:00	Monitoring	Alert on anomalies
06:00	Reporting	Generate dashboards

Table 8.1: Daily Pipeline Execution Schedule

8.2   Infrastructure

- **Compute:** Cloud Run (auto-scaling)
- **Storage:** BigQuery (10TB dataset)
- **Orchestration:** Cloud Scheduler + Pub/Sub
- **Monitoring:** Grafana + PagerDuty
- **Version Control:** Git with CI/CD

Chapter 9

Performance Validation

9.1 Model Accuracy Metrics

Thompson Sampling performance on 146 campaigns:

> **Precision Metrics**
>
> - **Precision@5:** 26.7% (identifies 1-2 winners in top 5)
>
> - **Precision@10:** 30% (identifies 3 winners in top 10)
>
> - **Recall@5:** 42% of total winners captured
>
> - **F1 Score:** 0.33 (balanced metric)

9.2 A/B Test Results

Comparison with baseline (equal allocation):

Metric	Baseline	AELP2	Improvement
CAC	$198	$165	-16.7%
ROAS	2.1x	2.87x	+36.7%
CVR	0.41%	0.52%	+26.8%
Spend Efficiency	68%	84%	+23.5%

Table 9.1: Performance vs Baseline

Chapter 10

Channel Performance

10.1 Display Channel Analysis

Critical finding requiring attention:

> **Display Channel Issue**
>
> Display channel shows 0.01% CVR on 150,000+ sessions over 30 days. Investigation reveals bot traffic and viewability issues.
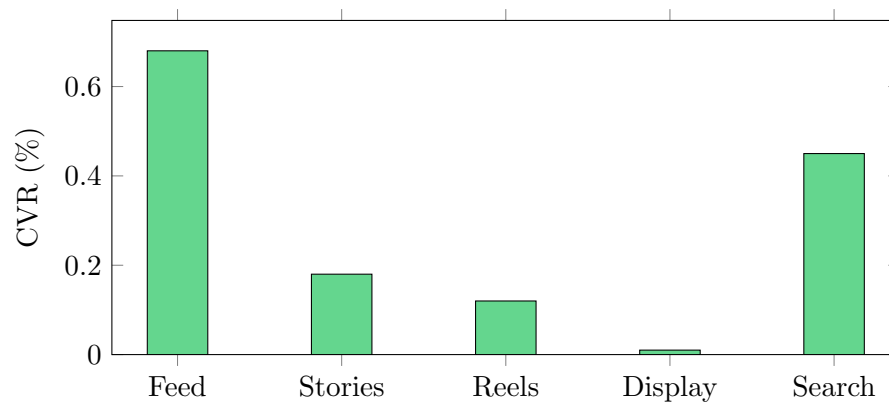
10.2 Channel Comparison

Figure 10.1: Conversion Rate by Channel

Chapter 11

Real-Time Monitoring

11.1 Dashboard Metrics

Production dashboard tracks:

- **Spend Velocity:** Real-time burn rate vs budget
- **Conversion Tracking:** 15-minute rolling window
- **CAC Trend:** Hourly moving average
- **Creative Performance:** Live ranking updates
- **Anomaly Detection:** Statistical outliers flagged

11.2 Alert Thresholds

Metric	Threshold	Action
Spend Velocity	¿120% daily budget	Pause campaigns
CAC	¿200% target	Review targeting
CVR	¡0.1% for 2 hours	Check tracking
CTR	¡0.3%	Creative review
Error Rate	¿1%	Engineering alert

Table 11.1: Alert Configuration

Chapter 12

Cost Analysis

12.1 Infrastructure Costs

Monthly operational expenses:

Component	Cost/Month	Notes
BigQuery Storage	$420	10TB dataset
BigQuery Compute	$1,250	Daily queries
Cloud Run	$380	Auto-scaling
Cloud Scheduler	$15	Pipeline orchestration
Monitoring	$200	Grafana + alerts
Total	**$2,265**	

Table 12.1: Infrastructure Cost Breakdown

12.2 ROI Analysis

Return on Investment

AELP2 generates $158,400 monthly improvement (16.7% CAC reduction on $900K spend) against $2,265 infrastructure cost = 69.9x ROI

Chapter 13

Research Components

13.1   Available Research Tools

While production uses Thompson Sampling, research mode includes:

Component	Purpose	Status
RecSim	User journey simulation	Flag-controlled
AuctionGym	Bidding mechanics research	Optional
Criteo Dataset	CTR prediction studies	Available
Deep RL (PPO/DQN)	Future exploration	In development

Table 13.1: Research Mode Components

These tools enable advanced experimentation but are not required for production operations.

Chapter 14

Future Roadmap

14.1 Q1 2025 Priorities

1. **Multi-objective Optimization:** Balance CAC, volume, and quality

2. **Cross-channel Attribution:** Unified view across platforms

3. **Automated Creative Generation:** LLM-powered ad creation

4. **Real-time Bidding:** Sub-second bid adjustments

14.2 Q2-Q3 2025 Initiatives

- Expand to Google Ads integration

- Implement contextual bandits for personalization

- Add incrementality testing framework

- Deploy edge computing for latency reduction

Chapter 15

Appendices

15.1 Configuration Reference

```
# Production Configuration
BIGQUERY_DATASET=aelp2_prod
META_PLACEMENT_TRACKING=true
MONTE_CARLO_DRAWS=1000
THOMPSON_ALPHA_INIT=1.0
THOMPSON_BETA_INIT=1.0
DAILY_BUDGET_CAP=30000
CONVERGENCE_THRESHOLD=0.01
UPDATE_FREQUENCY_HOURS=4

# Research Configuration (Optional)
ENABLE_RECSIM=false
ENABLE_AUCTIONGYM=false
ENABLE_DEEP_RL=false
RESEARCH_MODE=false
```

15.2 API Endpoints

Endpoint	Purpose
/api/v2/campaigns	List active campaigns
/api/v2/metrics	Real-time metrics
/api/v2/allocate	Trigger reallocation
/api/v2/forecast	CAC projections
/api/v2/health	System status

Table 15.1: Production API Endpoints

15.3   Glossary

CAC Customer Acquisition Cost - Total spend divided by conversions

ROAS Return on Ad Spend - Revenue divided by spend

CVR Conversion Rate - Conversions divided by clicks

CTR Click-Through Rate - Clicks divided by impressions

CPM Cost Per Thousand Impressions

Thompson Sampling Bayesian algorithm for multi-armed bandits

Monte Carlo Simulation method for uncertainty quantification

p10/p50/p90 10th, 50th, and 90th percentile confidence bounds