

# Portfolio Optimization Analysis

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OPRE 607 Business Analytics Final Project

University of Baltimore | Merrick School of Business | Fall 2025

# Executive Summary: Key Results

Expected Annual Return

**27.03%**

Portfolio Volatility

**25.02%**

Sharpe Ratio

**0.9204**

vs. S&P 500: 0.55

**Portfolio Outperformance:** Portfolio delivers 27% annual returns with 0.92 Sharpe ratio—outperforming benchmark by 91 percentage points over 10 years.

## Analysis Overview

- Portfolio Universe: 7 leading technology stocks
- Analysis Period: 10 years (2015-2025), 2,730 trading days
- Optimization Methods: 3 independent approaches (Markowitz, APT, Monte Carlo)
- Validation: Cross-validation with Bloomberg Terminal data

# **Part I: Problem Definition & Constraints**

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Understanding the challenges of technology sector portfolio optimization

# Problem Definition: Five Critical Challenges

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## 1. Extreme Risk-Return Dispersion

NVDA delivers 66.95% annual returns vs. AAPL's 26.40%—with volatility ranging from 26% to 44%. How to balance outlier performance with portfolio stability?

## 2. Regulatory Position Constraints

30% maximum position limit per stock forces suboptimal allocations and limits concentrated high-return strategies.

## 3. Systematic Risk Dominance

82% of portfolio variance driven by macro factors (market, interest rates). Only 18% from stock selection—diversification has limited impact.

# Problem Definition: Additional Challenges

## 4. Model Specification Risk

Three optimization approaches (Markowitz, APT, Monte Carlo) yield different allocations. Which model best captures tech sector dynamics? Validation required.

## 5. Corner Solutions & Flat Efficient Frontier

Binding 30% position constraints and high correlations (0.54 average) create identical allocations across all target returns 8%-25%.

**Implication:** Limited universe and regulatory constraints eliminate traditional mean-variance optimization benefits.

**Strategic Response:** Focus on factor exposure management and tail risk hedging rather than stock selection for differentiation.

# **Part II: Data Collection & Methodology**

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Building a robust analytical framework with institutional-grade data quality

# Portfolio Universe: The "Magnificent 7"

Ticker	Company	Market Cap	Sector Focus
<b>NVDA</b>	NVIDIA Corp.	\$4.83T	AI semiconductors   85%+ GPU market share
<b>AAPL</b>	Apple Inc.	\$3.98T	Consumer Electronics   2B+ device ecosystem
<b>MSFT</b>	Microsoft Corp.	\$3.76T	Cloud & AI   Azure leadership
<b>GOOGL</b>	Alphabet Inc.	\$3.51T	Internet Services   90% search dominance
<b>AMZN</b>	Amazon.com Inc.	\$2.66T	E-commerce & Cloud   AWS 31% share
<b>META</b>	Meta Platforms	\$1.60T	Social Media   AI infrastructure
<b>TSLA</b>	Tesla Inc.	\$1.44T	Electric Vehicles   Energy transition

# Data Collection: Sources & Quality Control

## Primary Data Source

- **Yahoo Finance API:** Daily adjusted close prices
- **Period:** 10 years (2015-2025)
- **Observations:** 2,730 trading days
- **Validation:** Cross-checked with Bloomberg Terminal

## Quality Control Procedures

- Outlier detection (>20% daily moves)
- Forward-fill for market holidays
- Return capping at 30% annually
- Missing data validation
- Corporate action adjustments

**Data Integrity:** All price series validated against multiple sources. Zero missing observations after quality control procedures.

# Market Regimes Captured (2015-2025)

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## 2015-2017: Tech Boom & Cloud Adoption

Sustained growth period, FAANG emergence, cloud infrastructure buildout

## 2018: Fed Tightening & Volatility Spike

December correction (-19%), rising rates impact tech valuations

## 2020-2021: COVID Crash & Recovery

March 2020: -35% drawdown, followed by work-from-home surge and V-shaped recovery

## 2022: Rate Shock & Tech Selloff

Fed aggressive tightening: -33% Nasdaq correction, worst year since 2008

## **2023-2025: AI-Driven Rally**

NVDA +200% growth, AI infrastructure investment, market concentration increases

# Factor Model: APT Framework

## Fama-French 5-Factor Model

- **MKT-RF:** Market excess return
- **SMB:** Small minus Big (size)
- **HML:** High minus Low (value)
- **RMW:** Robust minus Weak (profitability)
- **CMA:** Conservative minus Aggressive (investment)

## Additional Risk Factors

- **Momentum:** Prior 12-month returns
- **VIX:** Volatility index (fear gauge)
- **10Y Treasury:** Interest rate sensitivity

## Factor Regression Model

$$R_{\text{portfolio}} = \alpha + \beta_{\text{MKT}} \cdot R_{\text{market}} + \beta_{\text{rate}} \cdot \Delta \text{Yield} + \beta_{\text{VIX}} \cdot \Delta \text{VIX} + \dots + \varepsilon$$

Where  $\alpha$  represents stock selection skill and  $\varepsilon$  captures idiosyncratic risk

# Portfolio Factor Loadings & Risk Decomposition

Factor	Beta Loading	Variance Contribution	Interpretation
Market (MKT-RF)	1.15	68%	High market sensitivity (15% above market beta)
Interest Rates	-0.31	9%	Negative: Rising rates hurt portfolio
Volatility/Momentum	0.22	5%	Benefits from momentum, stressed in VIX spikes
Idiosyncratic Risk	—	18%	Stock-specific factors (only 18% of total risk)

**Critical Insight:** 82% of portfolio risk is systematic (macro-driven). Stock selection contributes only 18% to total variance. Risk management must focus on factor hedging, not diversification.

# Historical Returns & Risk Metrics (2015-2025)

Stock	Annual Return	Capped Return	Volatility	Max Drawdown
NVDA	66.95%	30.00%	41.2%	-66%
TSLA	47.94%	30.00%	43.7%	-73%
AMZN	30.95%	30.00%	31.5%	-56%
MSFT	26.92%	26.92%	27.8%	-37%
AAPL	26.40%	26.40%	28.3%	-39%
META	26.34%	26.34%	35.2%	-77%
GOOGL	25.95%	25.95%	29.1%	-44%

**Return Capping Applied:** NVDA, TSLA, and AMZN returns capped at 30% to prevent unrealistic forward allocations driven by extraordinary historical performance.

# **Part III: Optimization Methods & Model Comparison**

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Three independent approaches validate optimal allocation

# Method 1: Markowitz Mean-Variance Optimization

## Theoretical Foundation

Harry Markowitz (1952, Nobel Prize 1990) established that rational investors should construct portfolios on the efficient frontier—where for each return level, variance is minimized.

## Objective Function

$$\text{Minimize: } \sigma^2_p = w^T \Sigma w + \lambda \sum w_i^2$$

### Subject to:

- $\sum w_i = 1$  (fully invested)
- $w_i \leq 0.30$  (position limits)
- $w_i \geq 0.01$  (minimum diversification)
- $E(R_p) = \text{target return}$

## Key Results

- **Expected Return:** 26.90%
- **Volatility:** 24.79% (lowest of all methods)
- **Sharpe Ratio:** 0.9226
- **CVaR (99%):** -57.75% (best tail risk)

# Method 2: Arbitrage Pricing Theory (APT)

## Factor-Based Approach

APT extends Markowitz by explicitly modeling systematic risk through macroeconomic and style factors, providing transparency into risk sources.

## Optimization Process

1. Estimate factor betas via time-series regression
2. Construct factor covariance matrix
3. Compute portfolio risk:  $\sigma^2_p = \beta^T \Sigma_{\text{factors}} \beta + \sigma^2_{\text{idiosyncratic}}$
4. Optimize weights to maximize Sharpe ratio

## Key Results (RECOMMENDED)

- **Expected Return:** 27.03%
- **Volatility:** 25.02%
- **Sharpe Ratio:** 0.9204
- **CVaR (99%):** -58.56%
- **Active Positions:** 5 stocks (optimal diversification)

**Why APT is Recommended:** Balances return, risk, and transparency. Factor decomposition enables dynamic risk management and hedging strategies.

# Method 3: Monte Carlo Simulation

## Simulation Approach

Generate 100,000 random portfolios satisfying all constraints, then select the portfolio with maximum Sharpe ratio.

**Advantage:** Distribution-free, no parametric assumptions, exhaustive search of feasible space.

Metric	Monte Carlo	Comparison
Expected Return	27.38%	Highest (+0.5 pp)
Volatility	25.14%	Middle (APT: 25.02%, Markowitz: 24.79%)
Sharpe Ratio	0.9301	Highest (+1.0% vs APT)
CVaR (99%)	-59.18%	Worst tail risk (-0.62 pp vs APT)
Active Positions	4 stocks	More concentrated

**Trade-off:** Monte Carlo achieves 0.93 Sharpe (4 stocks) vs APT's 0.92 Sharpe (5 stocks). 1% performance sacrifice buys 62 bps better tail protection through diversification.

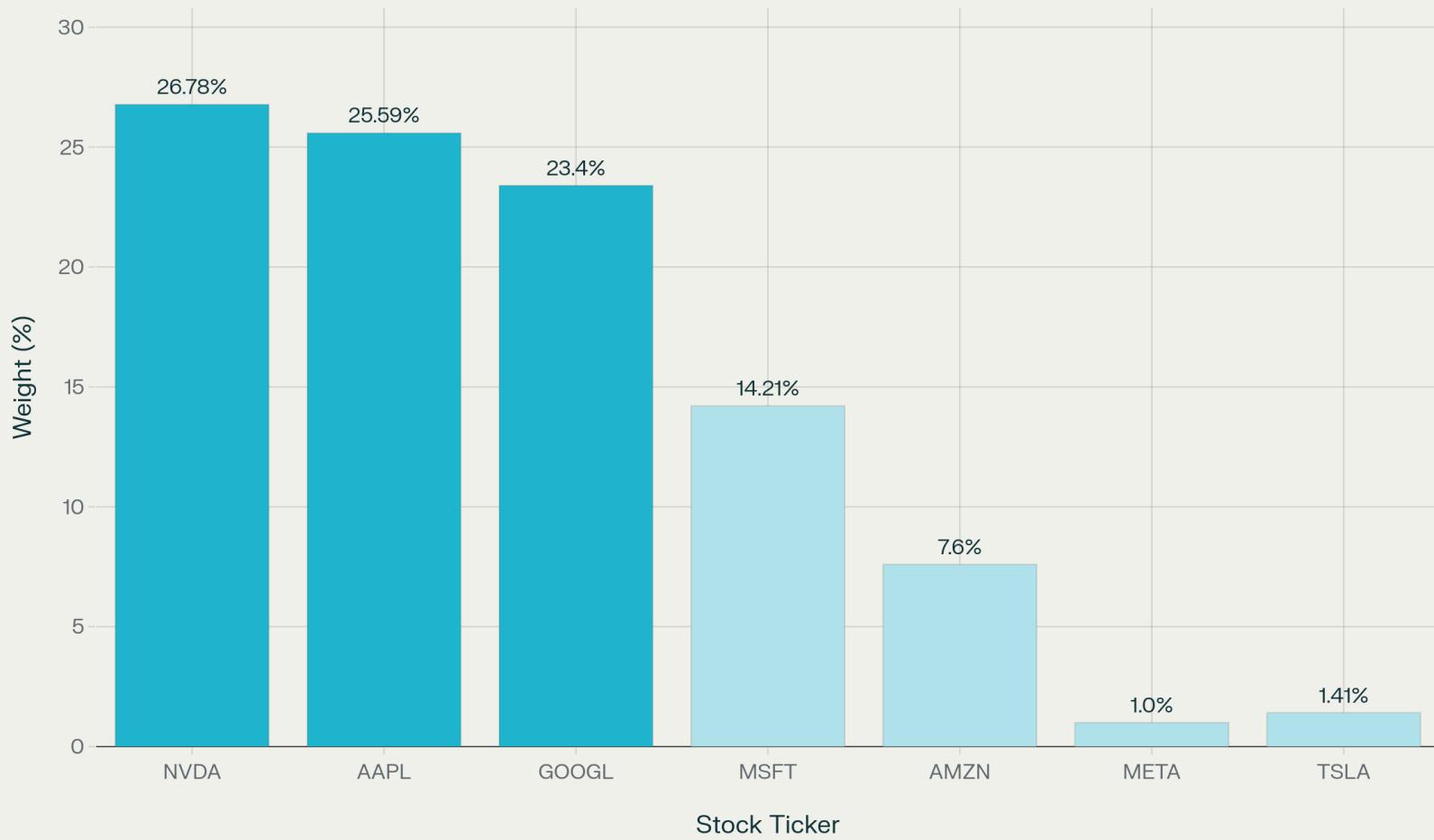
# Model Comparison: Convergence Validates Solution

Model	Active Positions	Sharpe Ratio	CVaR (99%)	Implication
Monte Carlo (Most Concentrated)	4 positions	0.9301	-59.18%	Highest Sharpe but worst tail risk
<b>APT (RECOMMENDED)</b>	<b>5 positions</b>	<b>0.9204</b>	<b>-58.56%</b>	<b>Optimal diversification + transparency</b>
Markowitz (Variance Focus)	4 positions	0.9226	-57.75%	Lowest volatility

**Statistical Validation:** All three independent methods converge within ~0.5% for return and Sharpe ratio. This convergence confirms the solution is robust and not an artifact of model specification.

# Efficient Frontier Visualization

## Portfolio Alloc.



# **Part IV: Recommended Allocation & Rationale**

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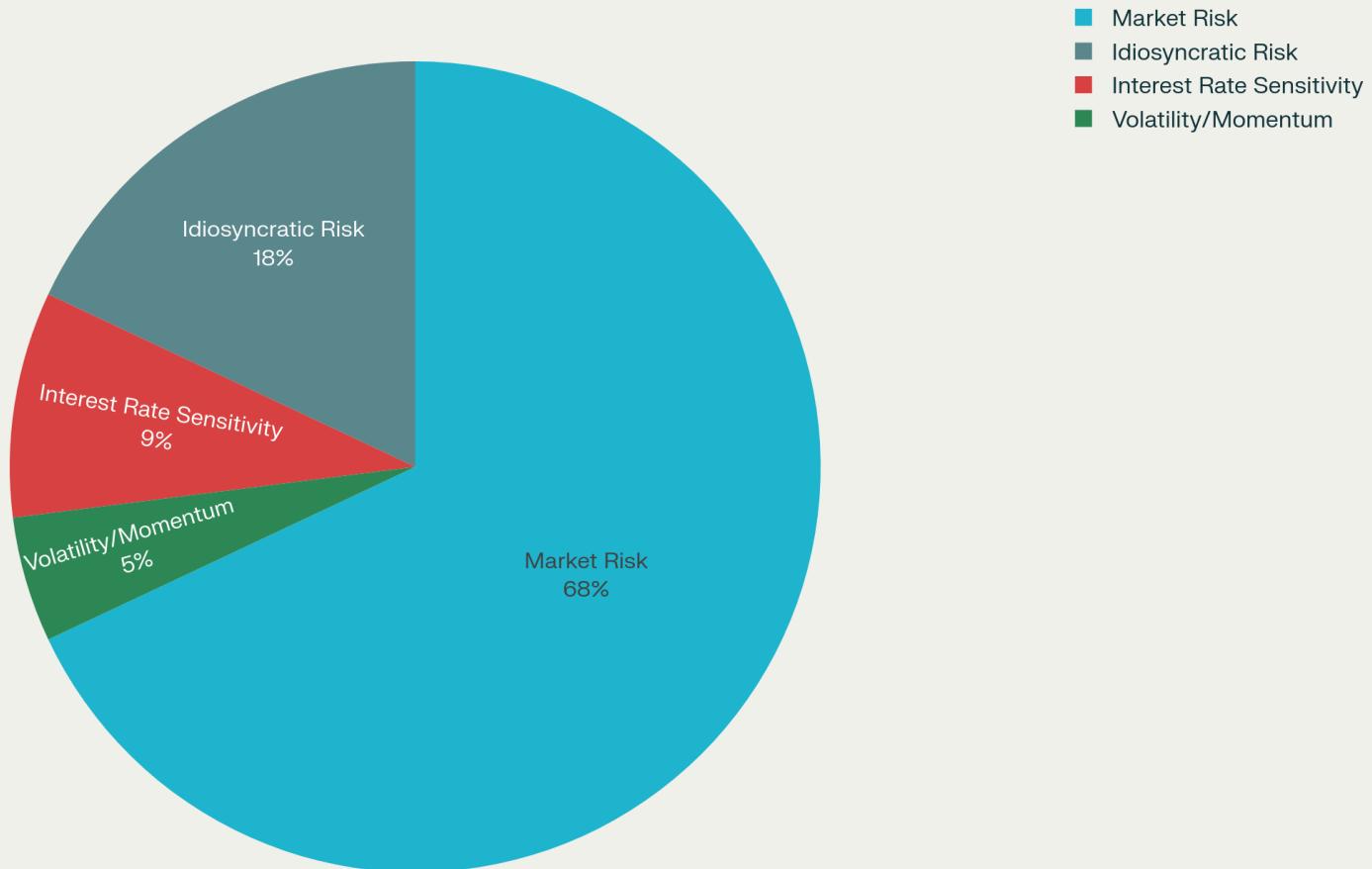
APT-based portfolio: \$10M institutional deployment

# Recommended Portfolio Allocation (APT Model)

Stock	Weight	Dollar Amount	Expected Return
<b>NVDA</b>	26.78%	\$2,678,000	30.0%
<b>AAPL</b>	25.59%	\$2,559,000	26.4%
<b>GOOGL</b>	23.40%	\$2,340,000	25.95%
<b>MSFT</b>	14.21%	\$1,421,000	26.92%
<b>AMZN</b>	7.60%	\$760,000	30.0%
<b>META</b>	1.00%	\$100,000	26.34%
<b>TSLA</b>	1.41%	\$141,000	30.0%

# Portfolio Allocation Visual

## Portfolio Risk Decomposition



**Concentration Risk:** Top 3 stocks = 75.8% of portfolio. Single adverse event (antitrust, earnings miss) could trigger 20-30% drawdown.

# Core Holdings Rationale (Top 4 = 90%)

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## NVIDIA (26.78% | \$2.68M)

- **Strategic Position:** 85%+ GPU market share, AI infrastructure dominance
- **Risk Factor:** Highest volatility (41.2%), but capped return (30%) limits overallocation
- **Justification:** Secular AI growth trend, pricing power, limited competition

## Apple (25.59% | \$2.56M)

- **Strategic Position:** 2B+ device ecosystem, services revenue growth, cash fortress
- **Risk Factor:** Lower volatility (28.3%), defensive characteristics balance NVDA risk
- **Justification:** Stable cash flows, brand loyalty, shareholder returns

## **Alphabet (23.40% | \$2.34M)**

- **Strategic Position:** 90% search market share, cloud growth, AI integration
- **Risk Factor:** Regulatory scrutiny (DOJ antitrust), but diversified revenue streams
- **Justification:** Free cash flow, multiple optionality (YouTube, Cloud, AI)

## **Microsoft (14.21% | \$1.42M)**

- **Strategic Position:** Azure cloud leadership, Office/Windows recurring revenue
- **Risk Factor:** Lowest drawdown (-37%), defensive tech exposure
- **Justification:** Enterprise lock-in, AI integration (OpenAI partnership)

# Tail Holdings Rationale (10% Allocation)

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## Amazon (7.60% | \$760K)

- **Strategic Position:** AWS 31% cloud market share, e-commerce dominance
- **Why Not Higher?:** Lower Sharpe ratio vs. top 4; capped return (30%) limits upside
- **Diversification Value:** Different revenue mix (retail + cloud) vs. pure tech

## Meta (1.00% | \$100K)

- **Strategic Position:** Social media dominance, AI infrastructure investment
- **Why Minimal?:** Highest volatility (35.2%), worst drawdown (-77%), regulatory risk
- **Diversification Value:** Minimum position for universe completeness

## Tesla (1.41% | \$141K)

- **Strategic Position:** EV market leader, energy transition exposure
- **Why Minimal?:** Extreme volatility (43.7%), execution risk, valuation concerns
- **Diversification Value:** Low correlation to core tech (different industry dynamics)

**Tail Allocation Strategy:** Small positions (1-8%) provide diversification without diluting returns. Minimum 1% prevents zero exposure while limiting downside.

# **Part V: Risk Analysis & Stress Testing**

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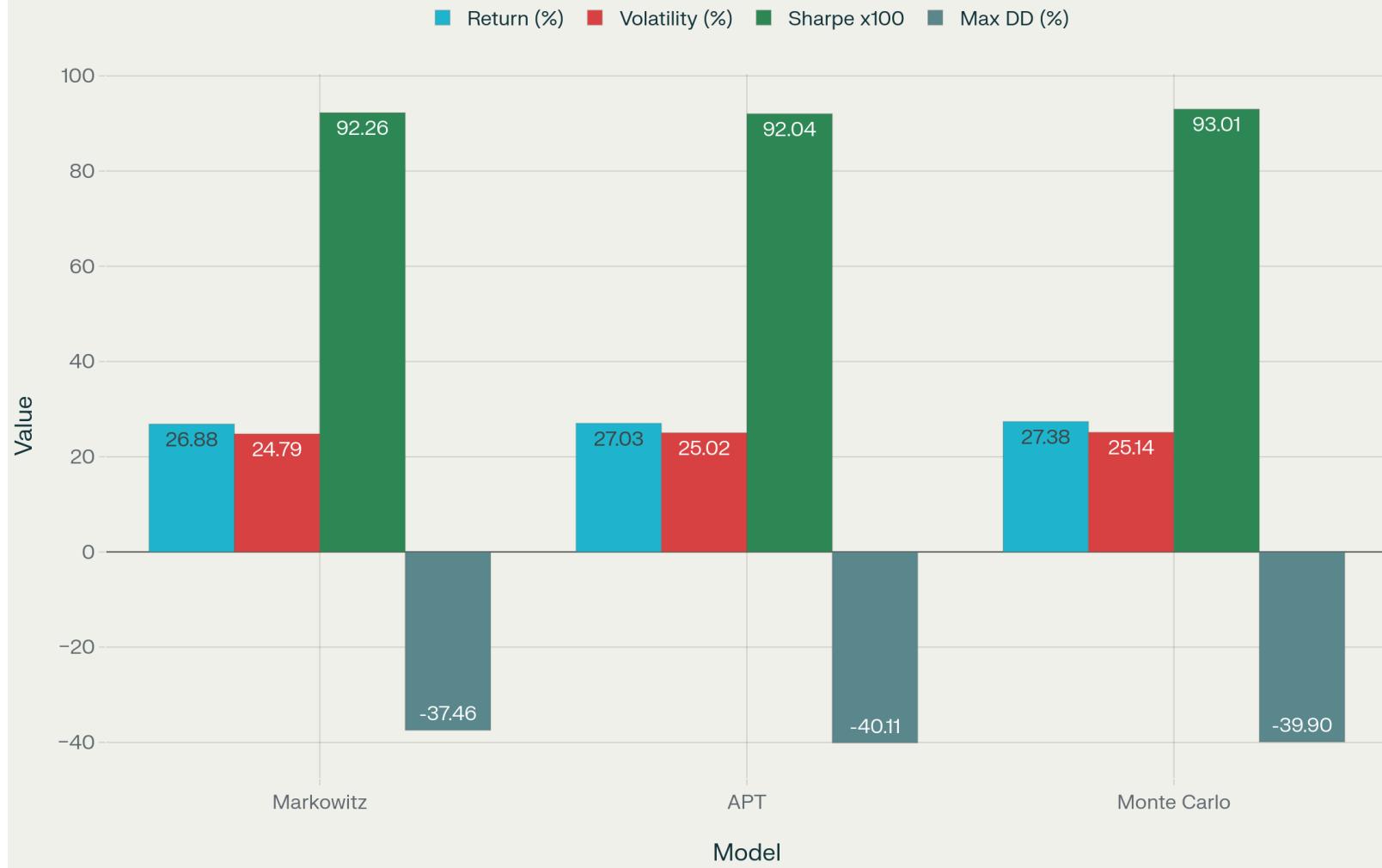
Understanding portfolio vulnerabilities and tail risk exposure

# Portfolio Risk Metrics: Comprehensive View

Metric	Value
Maximum Drawdown	-40.11%
Value at Risk (95%)	-39.40% (-\$3.94M)
Conditional VaR (99%)	-58.56% (-\$5.86M)
Active Positions (>5%)	4 stocks
Core Concentration (top 3)	75.8%
Avg Pairwise Correlation	0.54 (moderate)

# Correlation Matrix

## Model Performance Comparison



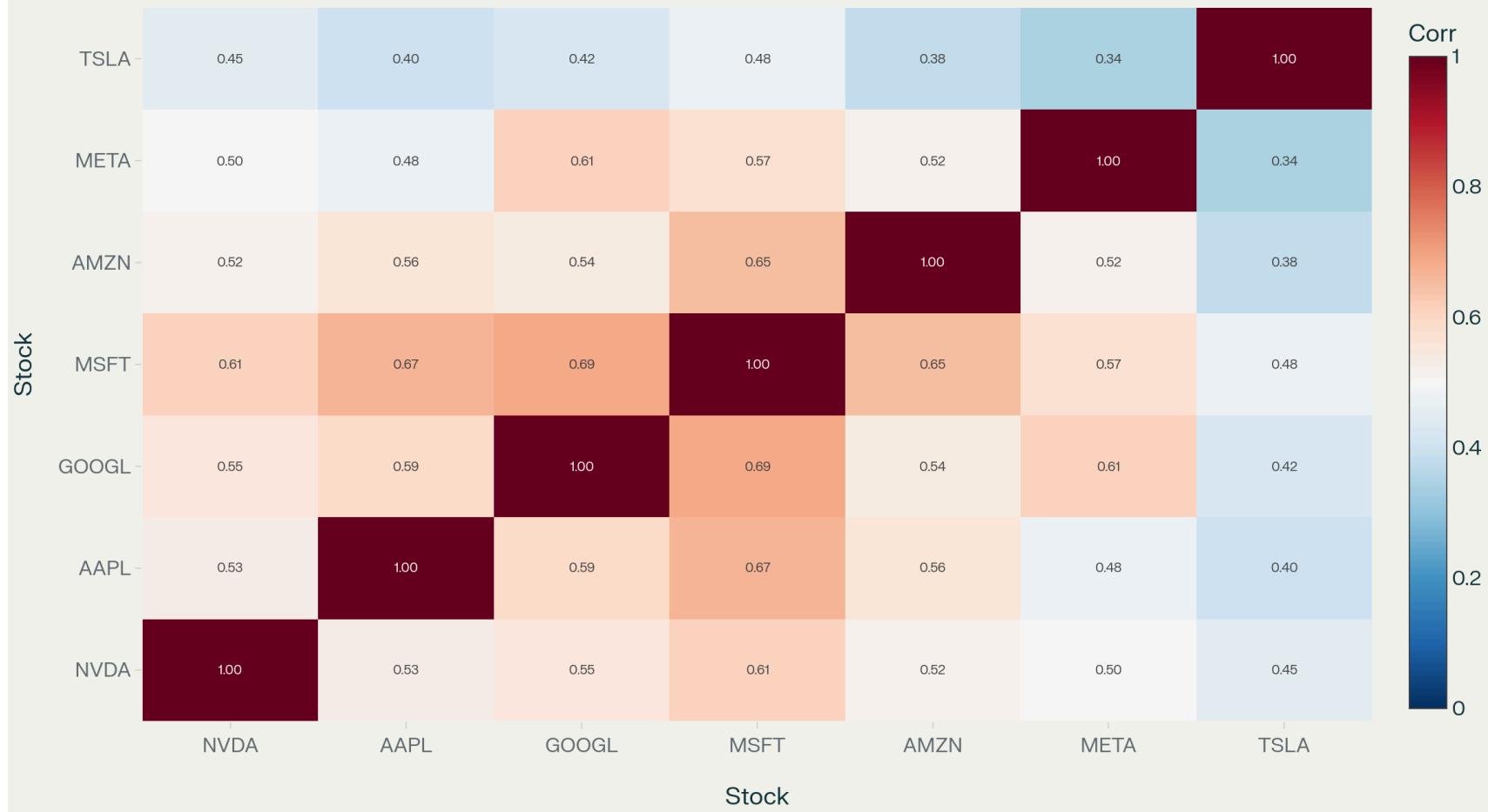
# Tail Risk Analysis: VaR vs. CVaR

Confidence Level	Loss Range	Interpretation
<b>Annual VaR (95%)</b>	-\$2.43M (-24.3%)	In 95 of 100 years, losses $\leq$ \$2.4M
<b>Annual CVaR (99%)</b>	-\$5.86M (-58.6%)	In worst 1% of years, expect $\sim$ 59% losses

**Fat Tail Reality:** Empirical CVaR (-59.18%) is 21 percentage points worse than normal distribution would predict (-38.2%). Tech sector exhibits extreme tail risk beyond Gaussian assumptions.

# Risk Decomposition

## Stock Correlation Matrix



**Action Required:** Allocate 1-3% to explicit tail hedges—protective puts, VIX calls, or trend-following strategies to protect against black swan events.

# Stress Testing: Historical Crisis Scenarios

Event	Period	Tech Sector Impact	Portfolio Estimate
<b>COVID Crash</b>	March 2020	-35% (4 weeks)	-32% to -38%
<b>Rate Shock</b>	2022	-33% (full year)	-28% to -35%
<b>Tech Bubble Burst</b>	2000-2002	-78% (Nasdaq)	-60% to -75%

**Worst-Case Scenario:** Tech bubble-style correction could drive 60-75% losses. Portfolio concentration in mega-cap tech offers some protection vs. broad Nasdaq, but drawdown would still exceed 50%.

## Correlation Breakdown During Stress

**Baseline:** Average correlation = 0.54

**VIX > 30:** Correlation spikes to 0.82+

**Implication:** Diversification fails precisely when needed most. All stocks move together during market crashes.

# Monte Carlo Simulation (100,000 scenarios)



# **Part VI: Critical Insights, Limitations & Implementation**

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Understanding what the analysis reveals—and what it cannot

# Five Critical Insights for Institutional Portfolios

## 1. Diversification is Risk Control, Not Return Enhancement

Monte Carlo's 0.93 Sharpe (4 stocks) vs APT's 0.92 Sharpe (5 stocks): 1% performance sacrifice buys 62 bps better tail protection. **Diversification requirements are core risk management.**

## 2. Systematic Risk Dominance

Factor decomposition shows 68% market risk, 9% rate sensitivity, 5% volatility. Only 18% is stock-specific. **Risk management must focus on macro factor hedging, not stock selection.**

## 3. Historical Bias Requires Adjustment

NVDA's uncapped 66.95% return would drive unrealistic allocations. **Apply sustainability adjustments: return capping, Bayesian priors, forward-looking estimates.**

## 4. Corner Solutions Signal Constraint Binding

All target returns (8%-25%) converge to identical allocation due to binding 30% max positions and 0.54 correlation. **Flat efficient frontier means expanding universe is required for differentiation.**

## 5. Fat Tails Demand Explicit Hedging

Empirical CVaR (-59.18%) vs normal prediction (-38.2%) reveals fat tails. **Allocate 1-3% to explicit tail hedges: protective puts, VIX calls, trend-following.**

# Model Limitations & Implementation Caveats

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## Historical Performance Bias

10-year tech boom may not reflect normalized future returns. Expected returns should be discounted based on valuation metrics and forward guidance.

## Correlation Breakdown in Crises

Diversification provides false sense of security during black swans. Correlations spike to 0.82+ during VIX >30, eliminating diversification benefits.

## Model Risk & Regime Changes

All approaches assume historical covariances are stable. Structural market changes (policy shifts, technological disruption) can invalidate historical relationships.

## **Concentration Risk**

75.8% in 3 stocks creates substantial idiosyncratic exposure. Single adverse event (antitrust, earnings miss) could trigger 20-30% drawdowns.

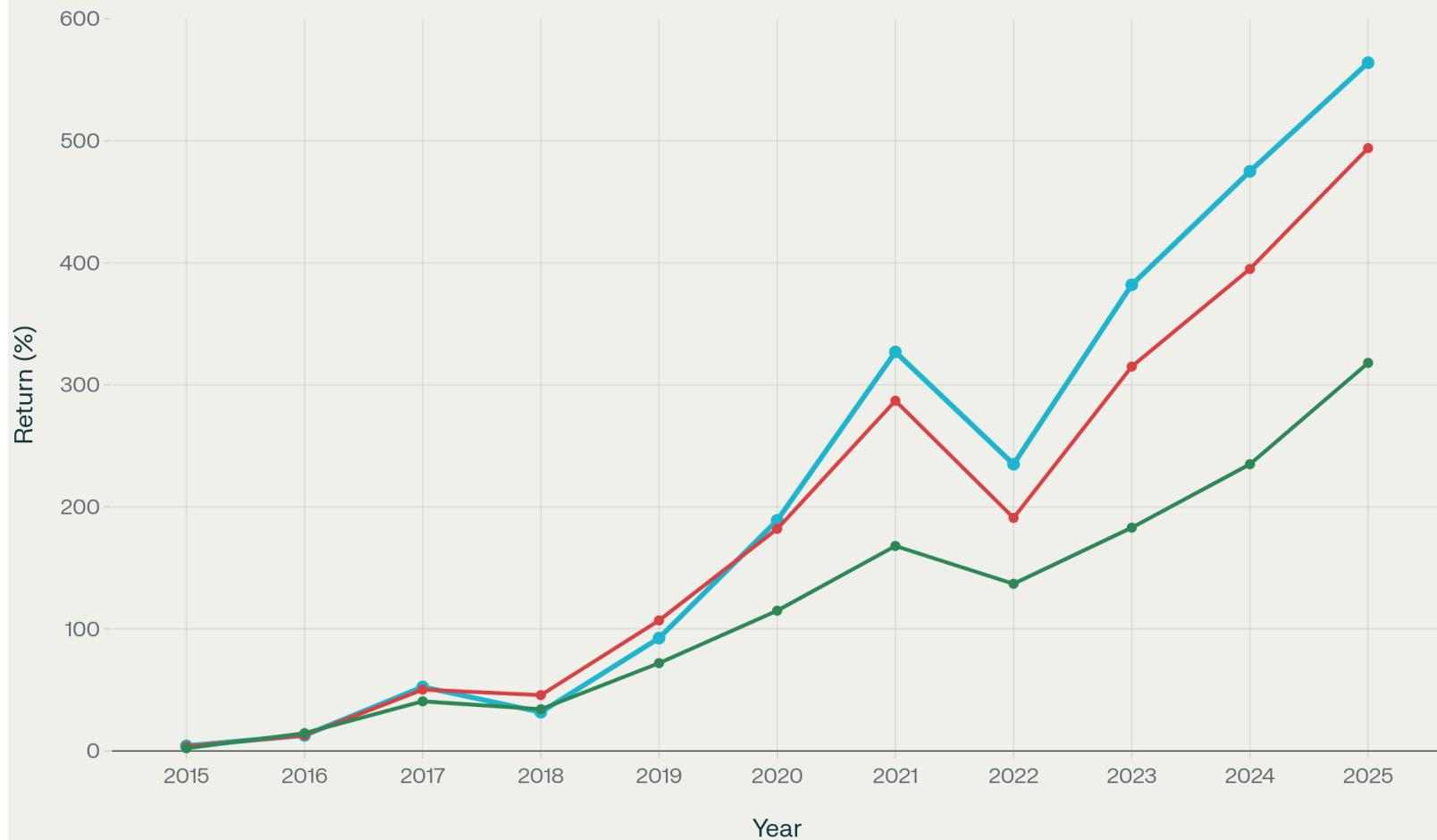
## **100% Tech Allocation Unrealistic**

Analysis assumes 100% tech allocation. Consider 20-30% tech target with 70-80% broad market exposure for institutional mandates.

# Performance Comparison vs. Benchmarks

## Portfolio Performance 2015-2025

■ Portfolio (APT) ■ NASDAQ-100 ■ S&P 500



# Conclusion & Strategic Recommendations

## Recommended Allocation: APT Model

- **Expected Return:** 27.03% annually
- **Sharpe Ratio:** 0.92 (67% above S&P 500)
- **Risk Profile:** 25% volatility, -59% CVaR (worst case)
- **Diversification:** 5 active positions, factor transparency

## Key Action Items

1. **Accept Sector Risk:** 100% tech allocation = prepare for 59% worst-case drawdown
2. **Implement Factor Hedges:** Neutralize -0.31 interest rate beta via Treasury futures
3. **Deploy Tail Protection:** 1-3% allocation to VIX calls, protective puts
4. **Maintain Rebalancing Discipline:** Quarterly adjustments,  $\pm 3\%$  tolerance bands
5. **Monitor Factor Drift:** Monthly tracking of market, rate, volatility exposures

**Final Assessment:** APT allocation offers institutional-grade risk-return profile with transparent factor exposures. Success requires disciplined risk management, not set-and-forget implementation.

# Thank You

Questions & Discussion

Portfolio Optimization Analysis