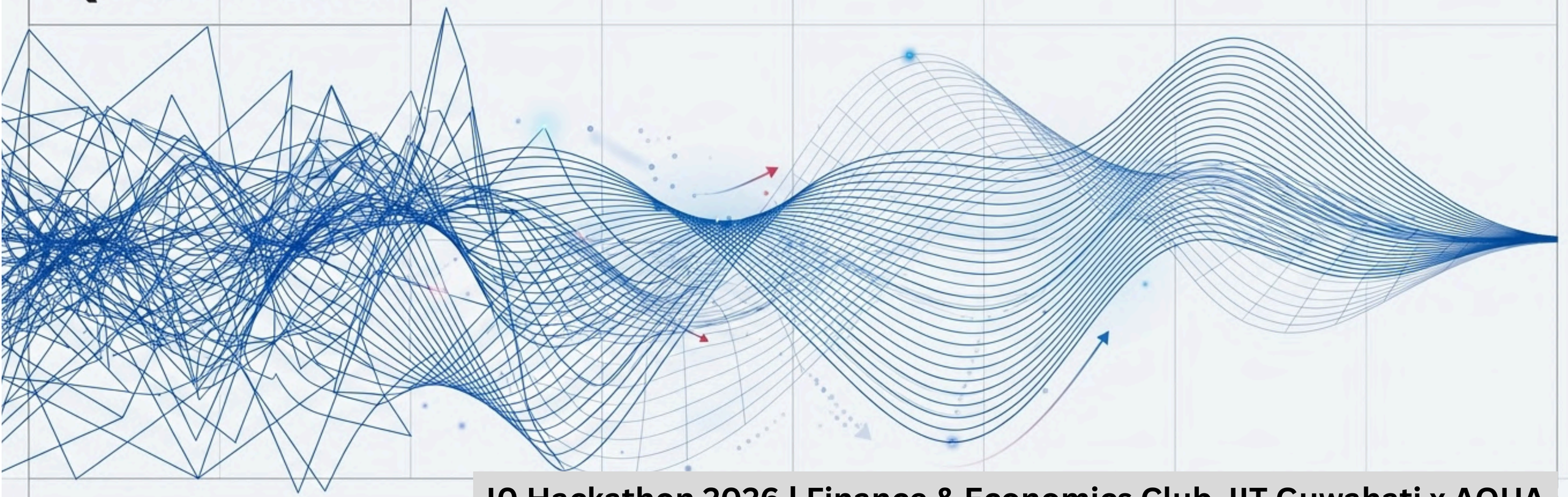
QuantDevs



IO Hackathon 2026 | Finance & Economics Club, IIT Guwahati x AQUA

Building a Hedge Fund's Strategic Edge

From Black-Scholes to Binomial: An American Options Pricing Engine & NVIDIA Case Study

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KEY INSIGHT:
We do not predict prices; we compare model value to market price to identify arbitrage opportunities.

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Problem Statement & Approach

The Objective : What the fund wants?

- To estimate a fair option price using a simple, transparent option pricing model.
- Compare the obtained model price with the live market price and explain any mispricing.
- Calculate and interpret greeks in clear, non-technical language and use them to identify the main risks in the option's position.
- Propose a basic hedging strategy to reduce potential losses by offsetting risk from adverse market movements.

What Is an Option? (Defining the Asset)

- An option is basically a 'token' you buy today (option price) that gives you the RIGHT (not obligation) to buy/sell a particular stock at a fixed strike price. But the twist is, this token expires after a time period.
- You can use your right to buy (call) or sell (put) a stock when market conditions are in your favor, so you can make a profit or avoid a bigger loss.
- Even if the stock price doesn't move, the option's value can still change due to time decay and volatility, which is why understanding and managing risk using Greeks is essential.

The QuantDevs Journey

Step 0 — Starting Point

Tech Background -> Intuition
From tech background, knew coding. not finance ., started with intuition.

Step 1 — BLack-Scholes (European)

Built **Black-Scholes** from scratch in C++ for European options to feel the formula, not‘ just use it.

Step 2 — Key Realisation

Realised we were using it wrong - trying to predict future prices instead of comparing model fair value vs actual market price to decide buy/ sell / hold.

Step 3 — European vs American Options

Understood difference between European vs American options → moved to Binomial CRR to handle early exercise and dividends.

Step 4 — Binomial CRR + q-Tool

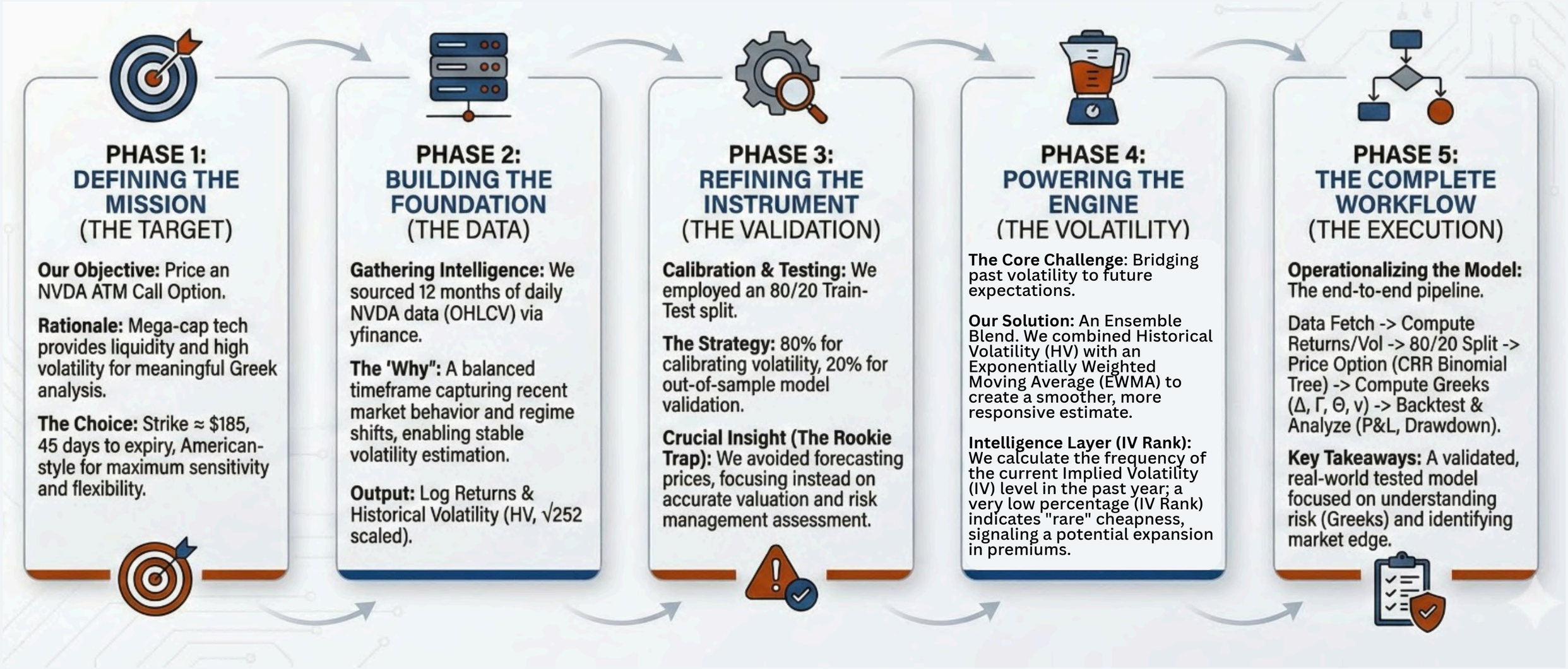
Wrapped everything into our q-tool that pulls NVDA data, prices the option, computes Greeks, and generates risk visualizations.

Step 5 — Decision Intelligence Layer

Ensemble Pricing: Blending 1Y HV and EWMA for robust fair value Contextual Signals: Using IV Rank to separate statistical risk from market sentiment Actionable Mandate: Automated Buy / Sell / Hold

Data & Methodology

From Market Data to Fair Value: How We Built the Model.



PHASE 1: DEFINING THE MISSION (THE TARGET)

Our Objective: Price an NVDA ATM Call Option.

Rationale: Mega-cap tech provides liquidity and high volatility for meaningful Greek analysis.

The Choice: Strike ≈ $185, 45 days to expiry, American-style for maximum sensitivity and flexibility.

PHASE 2: BUILDING THE FOUNDATION (THE DATA)

Gathering Intelligence: We sourced 12 months of daily NVDA data (OHLCV) via yfinance.

The 'Why': A balanced timeframe capturing recent market behavior and regime shifts, enabling stable volatility estimation.

Output: Log Returns & Historical Volatility (HV, √252 scaled).

PHASE 3: REFINING THE INSTRUMENT (THE VALIDATION)

Calibration & Testing: We employed an 80/20 Train-Test split.

The Strategy: 80% for calibrating volatility, 20% for out-of-sample model validation.

Crucial Insight (The Rookie Trap): We avoided forecasting prices, focusing instead on accurate valuation and risk management assessment.

PHASE 4: POWERING THE ENGINE (THE VOLATILITY)

The Core Challenge: Bridging past volatility to future expectations.

Our Solution: An Ensemble Blend. We combined Historical Volatility (HV) with an Exponentially Weighted Moving Average (EWMA) to create a smoother, more responsive estimate.

Intelligence Layer (IV Rank): We calculate the frequency of the current Implied Volatility (IV) level in the past year; a very low percentage (IV Rank) indicates "rare" cheapness, signaling a potential expansion in premiums.

PHASE 5: THE COMPLETE WORKFLOW (THE EXECUTION)

Operationalizing the Model: The end-to-end pipeline.

Data Fetch -> Compute Returns/Vol -> 80/20 Split -> Price Option (CRR Binomial Tree) -> Compute Greeks (Δ, Γ, Θ, ν) -> Backtest & Analyze (P&L, Drawdown).

Key Takeaways: A validated, real-world tested model focused on understanding risk (Greeks) and identifying market edge.

Option Pricing Framework

1. Market Calibration: Gathering the "Ingredients"

Before the math, the model needs live data. The script fetches:

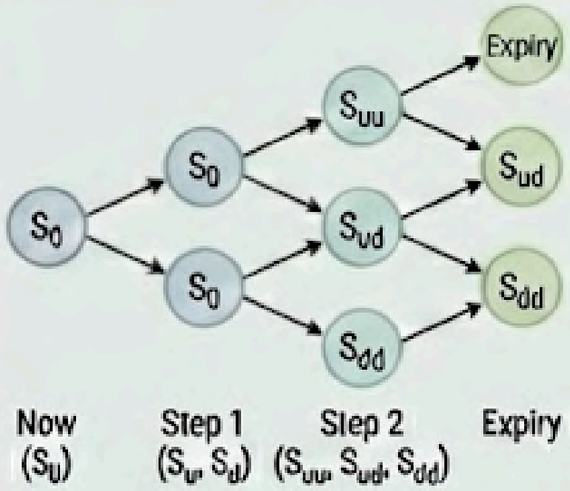
- **Spot Price (S):** Current market price.
- **Risk-Free Rate (r):** Safe investment yield (e.g., T-Bill).
- **Dividend Yield (q):** Crucial leak of value, affecting option price.
- **Volatility (σ):** The most important ingredient, calculated as an **Ensemble Volatility** (60% historical, 40% EWMA).

2. BSM Baseline & The Need for an American Model

Black-Scholes (BSM) is the baseline for European options (exercise only at expiry). However, most US single-stock options are American-style (exercise anytime).

We need a model like CRR to handle this early exercise flexibility, not to predict future prices but to compare with current market values.

3. Intuitively Understanding the CRR Binomial Model



Imagine the stock price moves in discrete steps, either up or down, over time. At each step, we know the possible future prices.

We start from expiry, calculate the option payoff for all final prices. Then, we **work backward**, step-by-step, to the present.

At each previous node, we calculate the option value by comparing

(a) the immediate exercise value (Intrinsic Value) and (b) the discounted expected future value from holding. This "**backward induction**" process with the **early exercise check** is the core of the American option pricing in the CRR model.

4. NVDA Insight: When American ≈ European

Rule: Early exercise of a call is optimal only when dividend yield (q) exceeds the risk-free rate (r).

NVDA case: q = 0.02%, while r = 4.35%.

Implication: The dividend benefit is too small to justify early exercise.

Result: American call price ≈ European call price for NVDA, so CRR converges to BSM.

Fair Valuation & Market Comparison

Before trading an option, we must check whether its market price is reasonable compared to a model-based fair value. This helps decide whether the option is cheap, expensive, or fairly priced.

Spot Price (S): 188.70 | Strike : 190 (near ATM) | Expiry (T): ~36 days | Option Type: Call | Style: American

Metric	Value
Model Fair Value (CRR)	$9.32
Market Option Price	$8.10
Absolute Mispricing	+$1.22
Relative Mispricing	+15.06%
Historical Vol (252d)	48.84%
EWMA Forecast	28.39%
Ensemble Vol (Model)	40.66%
Implied Volatility (IV)	36.41%
IV Rank (1Y)	21.1%

Interpretation

- If **Δ > 0**: Model value > Market price → option appears cheap → potential buy.
- If **Δ < 0**: Model value < Market price → option appears expensive → better to sell or avoid.

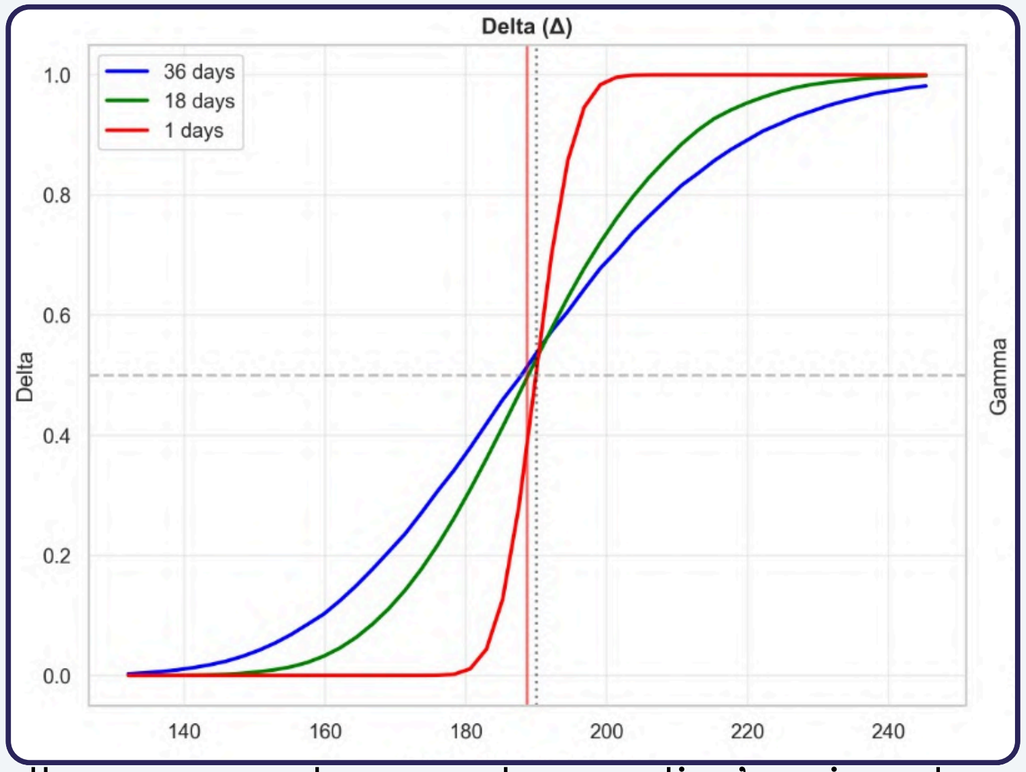
Decision Intelligence:

- High IV Rank **(IV >> Ensemble)**: Market is pricing in extreme future uncertainty , indicates premiums are inflated.
- Low IV Rank **(IV << Ensemble)**: Market is pricing in low uncertainty relative to our model indicates premiums may be underpriced insurance.

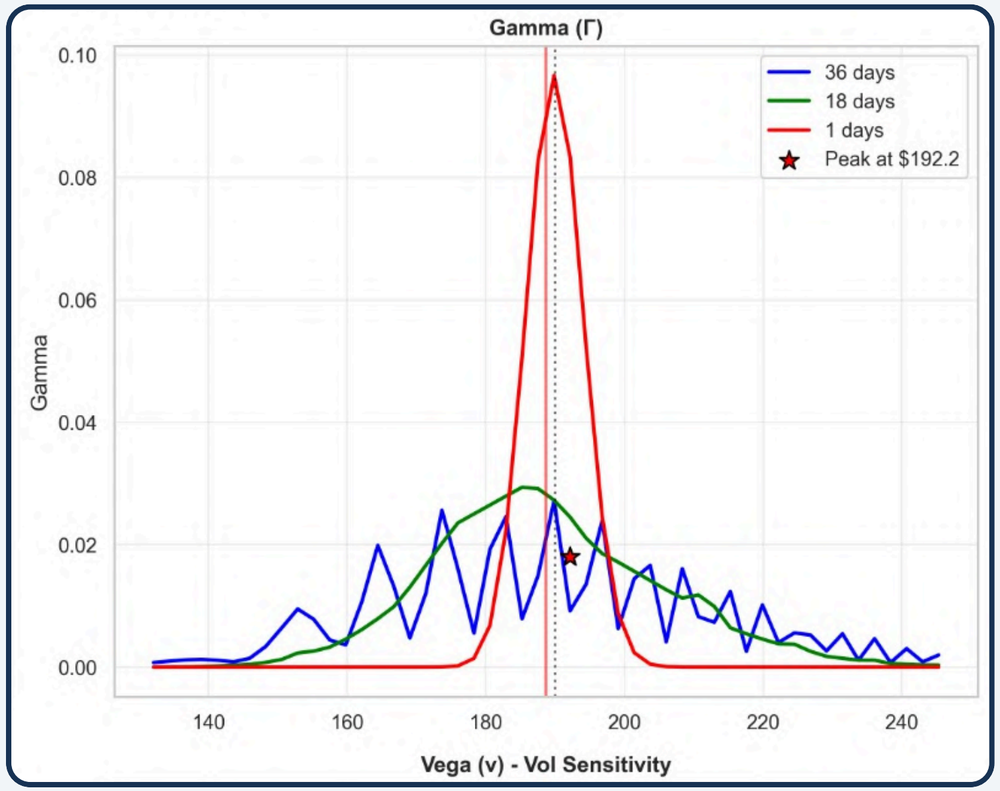
By comparing this to the market price and filtering through IV Rank, we move from mere calculation to a strategic decision: whether to buy, sell, hedge, or avoid the contract based on a statistical edge.

Greeks I: Managing Directional Risk & Instability

- Greeks are ***risk indicators*** that quantify your option's sensitivity => they show us how much money we make or lose when stock price moves (Delta, Δ), when time passes (Theta,Θ), when volatility changes (Vega,ν), when interest rates shift (Rho,ρ), or when our hedge gets unstable (Gamma,Γ)

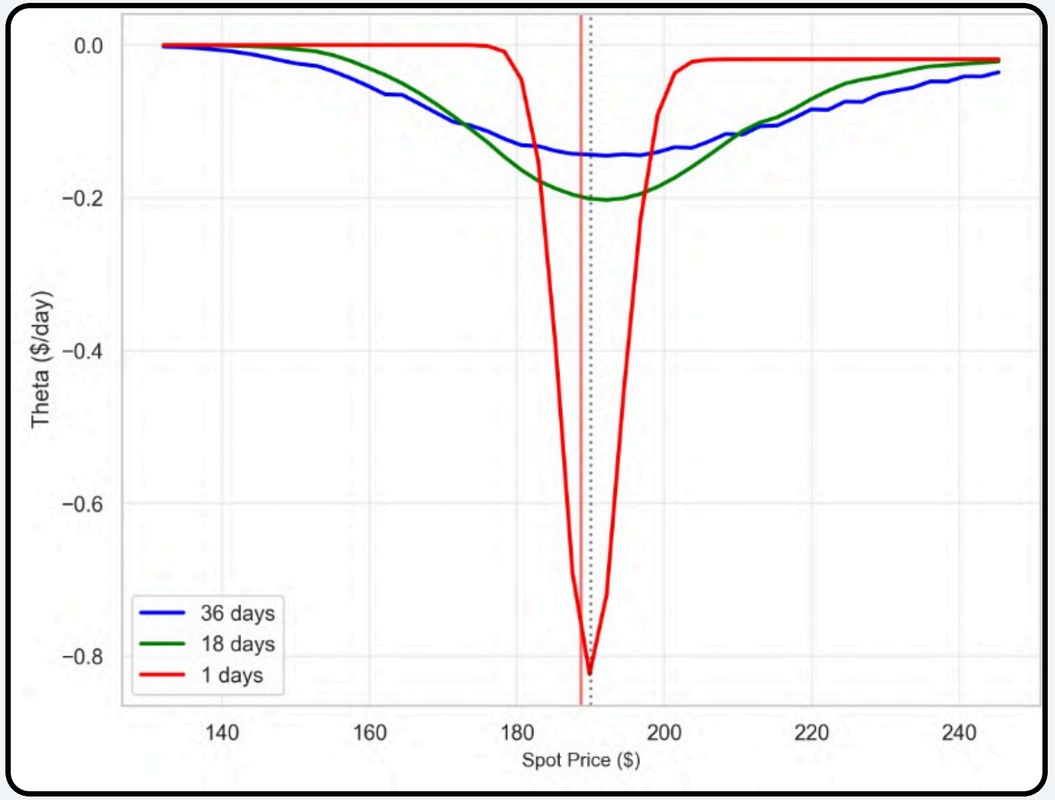


- Delta measures how much an option’s price changes for a $1 stock move.
- With 36 days remaining, Delta changes gradually due to time for price movement. With only 1 day remaining, time is nearly gone, so crossing the $190 strike causes a sudden jump in option value and Delta near $188.70.

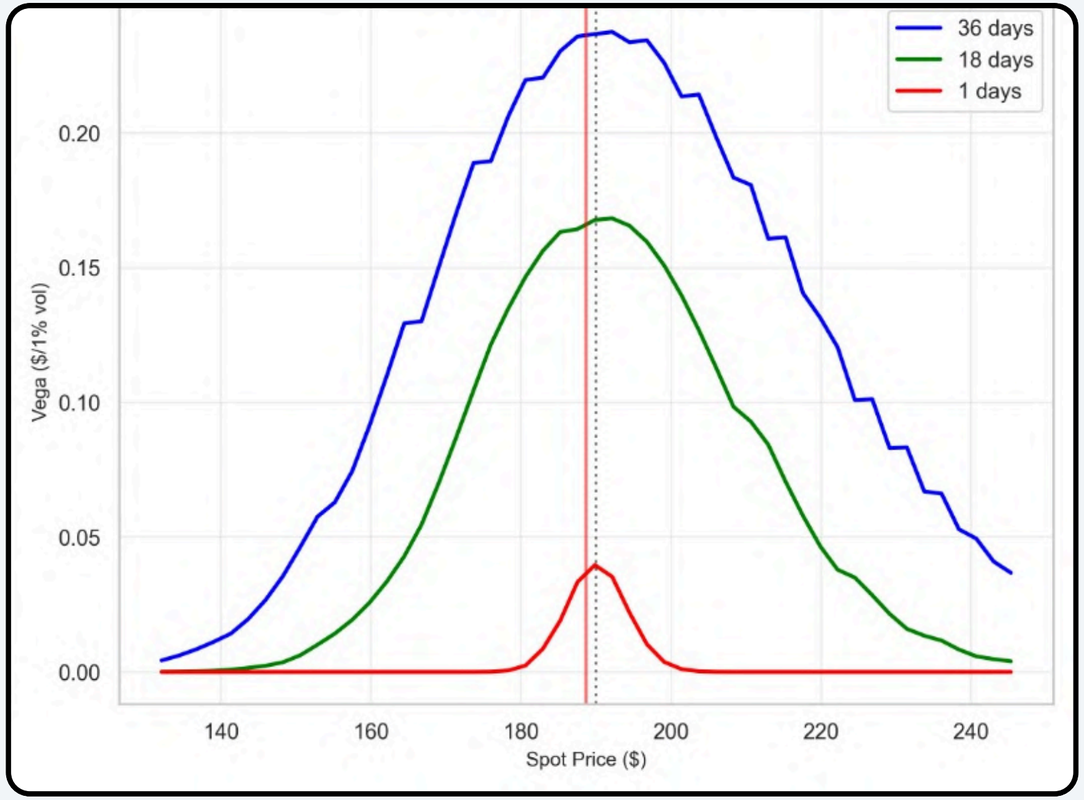


- Gamma measures how quickly Delta changes as the stock price moves.
- At the $190 strike (ATM), Gamma is highest because the option is most price-sensitive.
- As NVDA moves up, Delta increases rapidly, accelerating profits for each additional dollar gain.

Greeks II: The Cost of Time vs. The Reward of Panic



- Theta represents the loss in option value due to time decay.
- ATM options (like the $190 call) have the highest Theta because uncertainty and time value peak at the decision point.
- With 36 days remaining, time value decays slowly as there is room for price movement.
- With only 1 day remaining, time value collapses rapidly, reducing the option's premium if price does not move.



- Vega measures how much an option's price changes when market volatility changes.
- ATM options (like the $190 call) have the highest Vega because uncertainty is greatest at-the-money.
- With 36 days remaining, volatility has time to matter, so Vega is high and price reacts strongly.
- With 1 day remaining, uncertainty disappears, Vega drops sharply, and price depends mainly on the stock level.

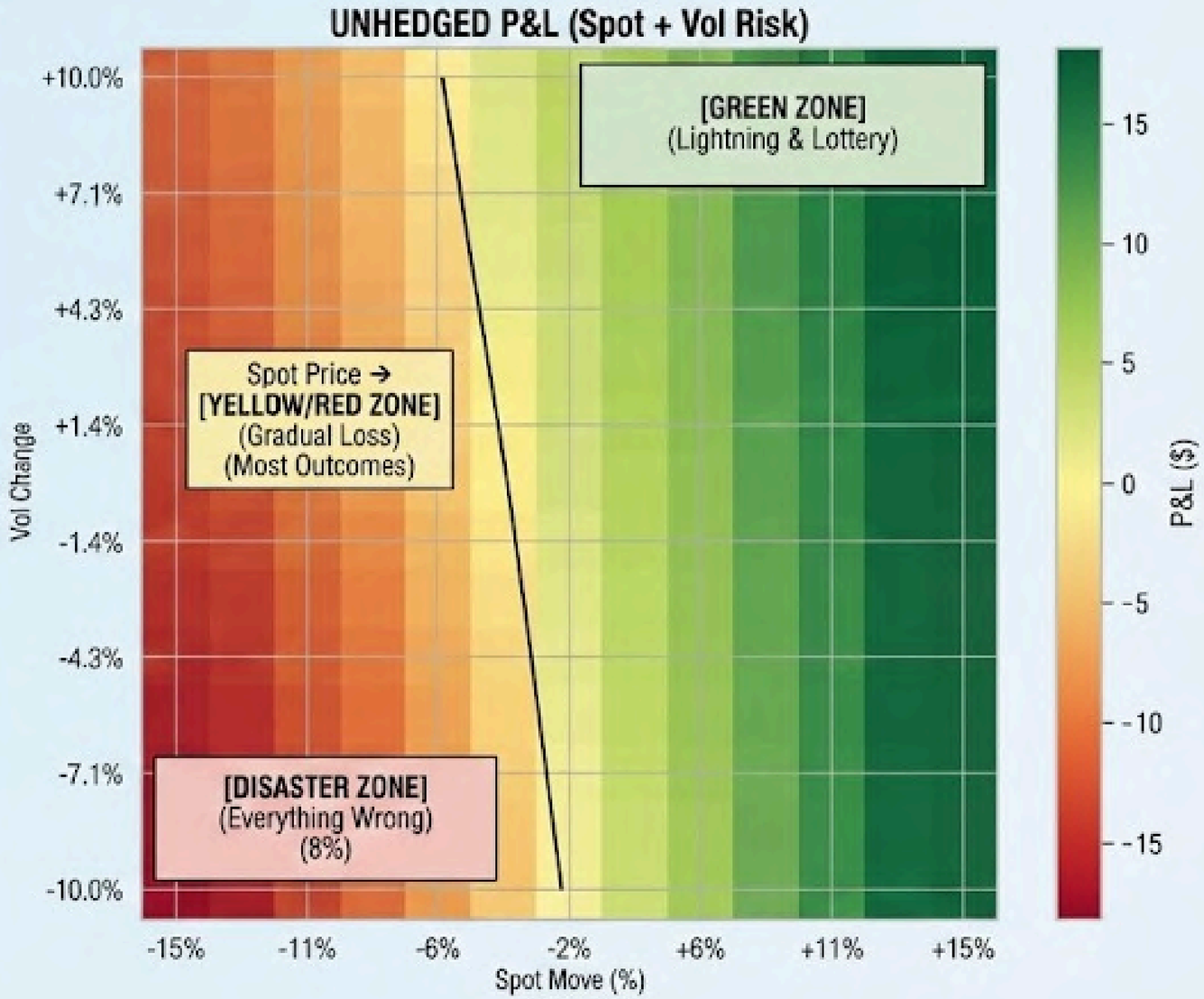
RISK ANALYSIS & SCENARIO TESTING (Unhedged Portfolios)

STRESS TESTING UNHEDGED POSITIONS

- **WHY STRESS TEST**: Understanding how the portfolio performs when market conditions deviate from the base case.
- **METHODOLOGY:** Tested 225 scenarios covering Stock Price changes, Volatility shifts, and Time decay.

- **THREE PRIMARY SCENARIOS:**
- Disaster Zone (8%): Stock drops, volatility decreases. Result: Significant Loss (S15).
- Struggle Zone (45%): Sideways market movement. Result: Gradual Loss due to time decay ($2-5/day).
- Jackpot Zone (3%): Stock rallies, volatility spikes. Result: Significant Gain ($17).

- **THE THETA BLEED** (Time Decay): Accelerating losses over time (9.9., Week 1: 44%, Week 3: -52%, Week 5: -92%).
- **KEY TAKEAWAY:** "Without hedging. the majority of outcomes result in losses. Time decay is a constant threat. making a sideways market destructive to the position."



Delta-Hedging Strategy (NVDA Case Study)

1. The Problem: You have "Delta Exposure"

Right now, you aren't just holding options; you are holding a directional bet. Your 100 calls have a Delta of 0.60.

- **The Meaning:** Your position acts exactly like owning 60 shares of NVDA.
- **The Risk:** If NVDA drops, those "60 shares" lose value fast. You are at the mercy of the market's direction.

2. The Fix: Reaching "Net Zero"

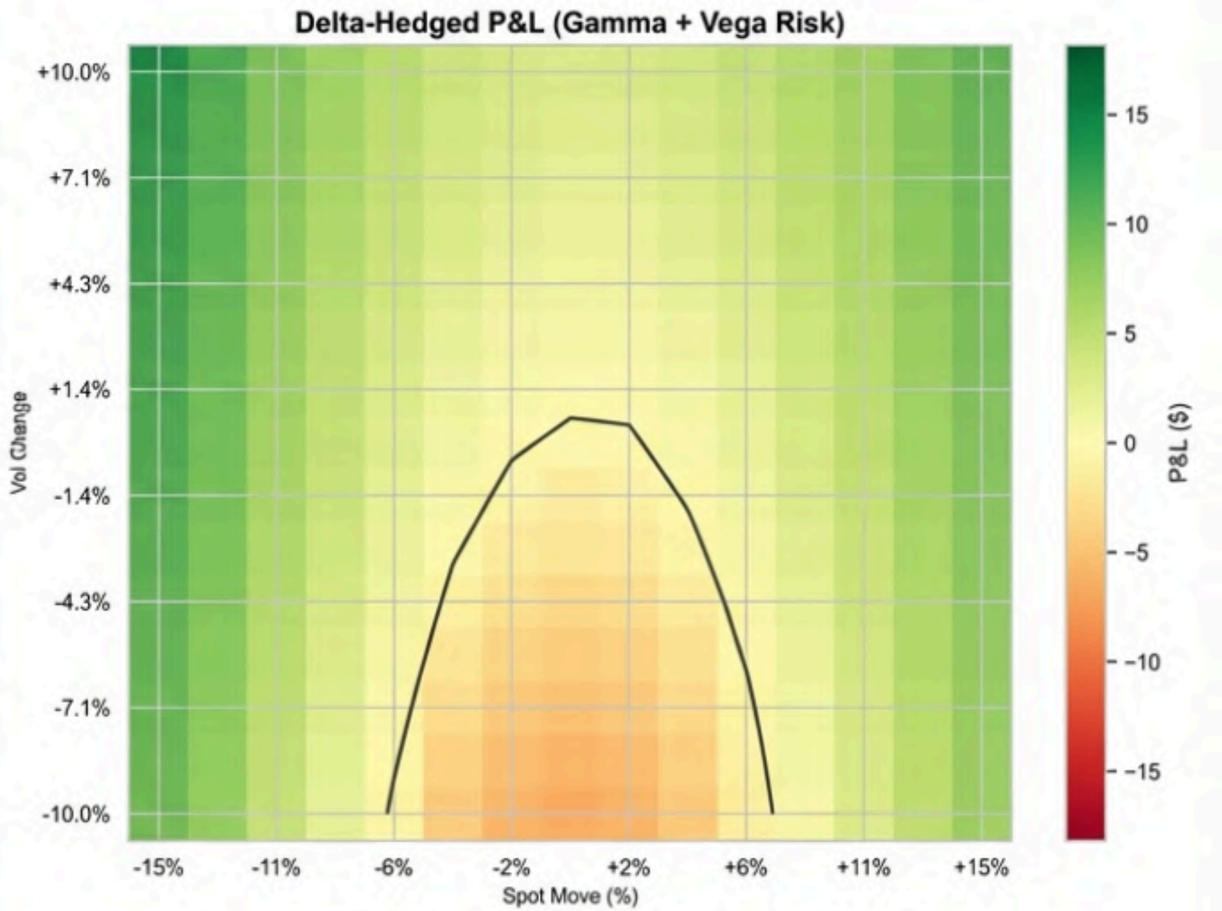
To stop being a victim of price swings, we neutralize your exposure.

- **The Math:** **+60(Options Delta) - 60(Short Stock) = 0**
- **The Result:** You are now **Delta Neutral.** You've created a "price-proof" shield where the stock's move in one direction is perfectly offset by the other side of your trade.

4. Visual Proof & The Daily Maintenance

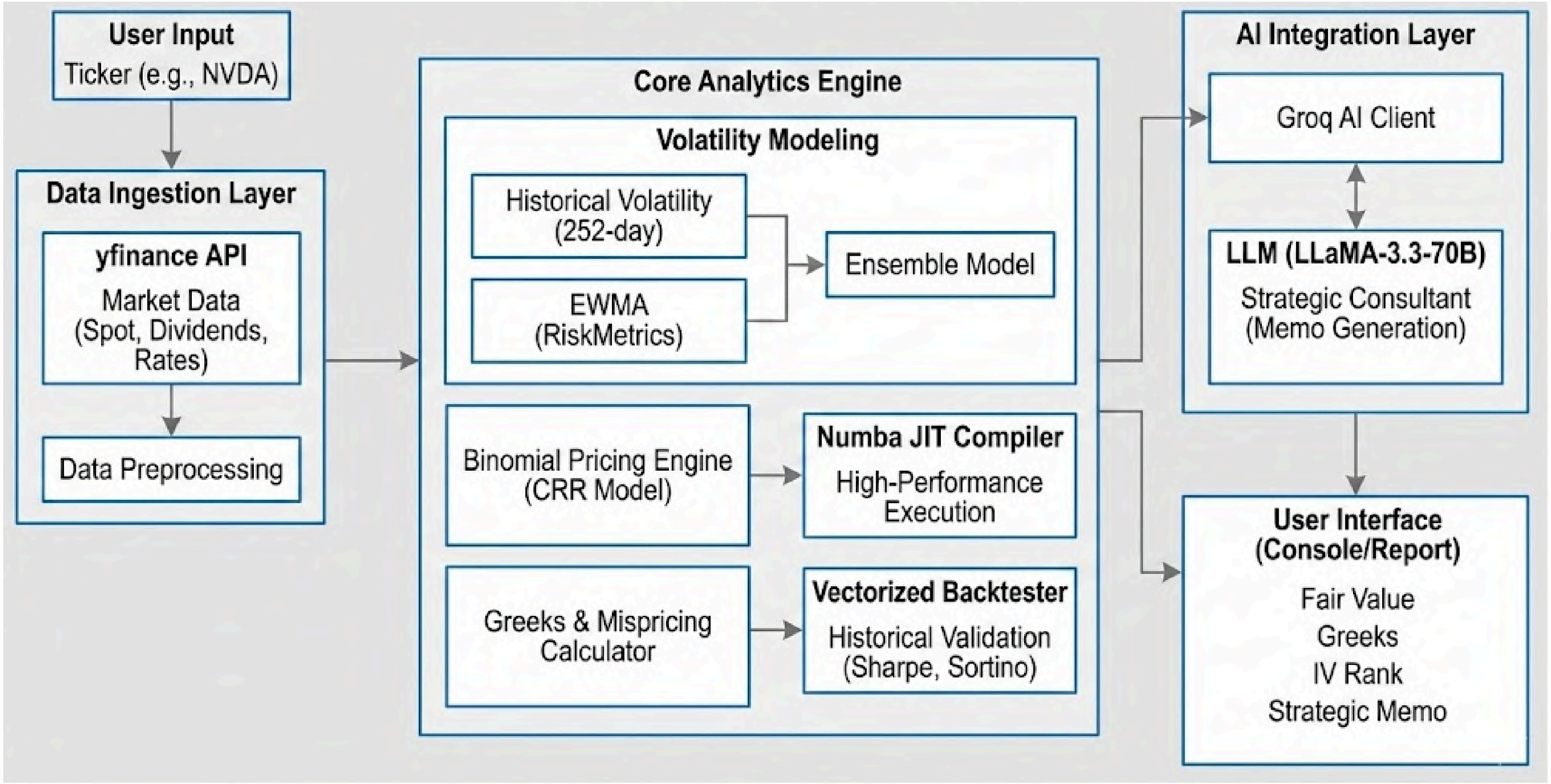
Look at the graph space below. This is how the "Profit Map" changes when you hedge.

- **The Symmetric Map:** Notice how the heatmap is now balanced. Whether NVDA moves left (down) or right (up), the colors are identical. You've killed "Directional Risk."
- **The Upkeep (Rebalancing):** Delta isn't static—it shifts as the stock moves. To keep this map symmetric, we rebalance. If NVDA rises and your Delta hits 0.70, you short 10 more shares. If it drops, you buy some back. This constant adjustment is the "heartbeat" of a Delta-Hedged trade.



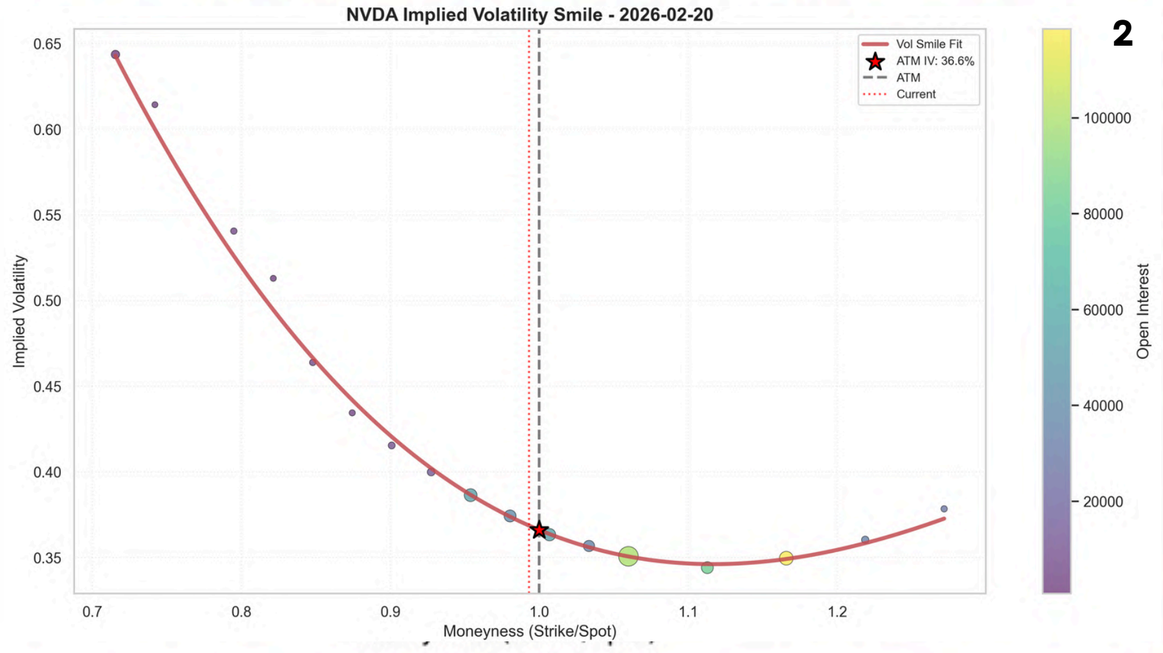
Use of Delta-Hedging replaces directional luck with a symmetric "Profit Map" that requires simple daily rebalancing to maintain professional-grade stability and shifts the focus from predicting NVDA's next move to managing a stable, symmetric profit engine through simple daily rebalancing.

Appendix A : Technical Architecture



Appendix B: Advanced Visualizations

NVDA Implied Volatility Smile - Feb 20, 2026



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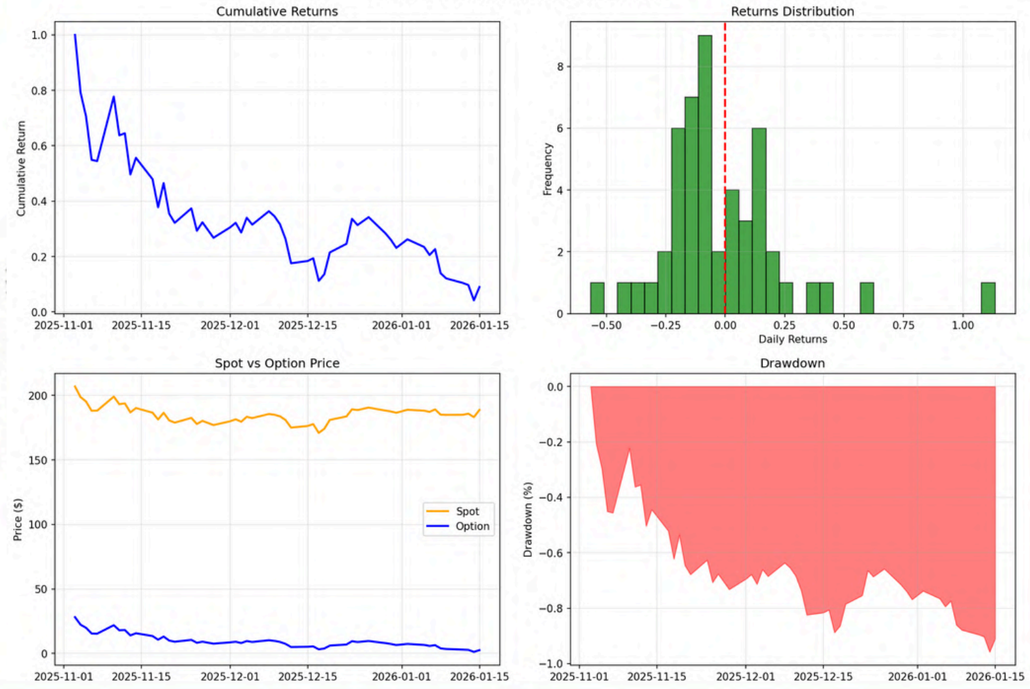
NVDA Portfolio Performance (Backtest)



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NVDA Value Surface (American Binomial)

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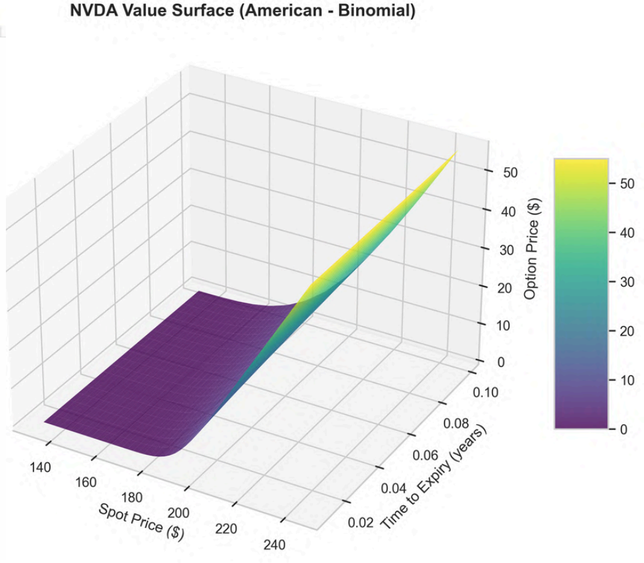

1. NVDA Portfolio Performance (Backtest):
=> Buy-and-hold ATM call over a 51-day period suffers a −95.78% drawdown as option value decays from ~$28 to near zero while NVDA remains flat around $190, demonstrating dominant theta decay and the necessity of active options management.

2. NVDA Implied Volatility Smile —> Feb 20, 2026
=> Implied volatility across strikes shows a classic smile, with elevated IV for deep OTM options (~65%), a minimum at ATM (~36.6%), and a slight increase for far ITM options (~38%), reflecting market-priced tail risk and a realistic volatility surface.

3. NVDA Option Value Surface (American Binomial)
=> 3D surface of American call value versus spot price ($140–$240) and time to expiry (0–0.1 years), showing increasing value with higher spot and longer time, and convergence to intrinsic value at expiration.

“We don’t predict the future. We price the probability.”

QuantDevs Analysis | IO Hackathon 2026

Sahil Rane & Vedant Patil

<=Click icon to check github

STRATEGIC INVESTMENT MEMORANDUM

TO: Senior Investment Committee **FROM:** Junior Quant, Team QuantDevs
DATE: Jan 15, 2026 **RE: NVDA $190 Call – Exploiting 13% Valuation Discontinuity**

I. EXECUTIVE SUMMARY: THE BOTTOM LINE

Our American Binomial pricing engine identifies a significant mispricing in the NVDA $190 Call (Feb 20, 36 DTE). We value the contract at **$9.32 vs market $8.10**. With an **IV Rank of 21.1%**, we are in a **LOW VOL regime** where premiums are historically cheap. However, unhedged exposure carries a **-95.78% max drawdown** risk due to Theta decay.

MANDATE: Execute a **Delta-Neutral Volatility Arbitrage**. BUY 100 contracts and SHORT 52 shares of NVDA. This transforms directional speculation into a pure volatility play, capturing the 13% model edge while mitigating directional risk.

II. VALUATION FRAMEWORK

Engine: American Binomial (CRR) JIT-Optimized
Calibration: Ensemble Vol (60% HV / 40% EWMA)

Volatility Matrix	Value
Historical Vol (252d)	48.84%
EWMA Forecast (λ=0.94)	28.39%
Ensemble (Fair Value)	**40.66%**
Market Implied Vol	36.41%
IV Rank (1Y)	**21.1%**

Price Comparison	Value	Edge
Model Fair Value	$9.32	
Market Quote	$8.10	**+13.1%**
Delta (Δ)	0.52	Exp: $52/$1
Gamma (Γ)	0.009	Acceleration
Vega (ν)	0.24	Uncertainty
Theta (Θ)	-0.14/d	Daily Rent

III. RISK DIAGNOSTICS

Backtest: 1Y Data, 80/20 Institutional Split

Metric	Value	Risk Level
Sharpe Ratio	-0.90	Negative
Sortino Ratio	-2.01	Severe
Max Drawdown	**-95.78%**	**Critical**

Root Cause: Options are wasting assets governed by:

$$dV \approx \Delta dS + \frac{1}{2}\Gamma(dS)^2 + \Theta dt + \nu d\sigma$$

Theta bleed ($-\$0.14 \times 36$ days) erodes **$5.04** of value per contract. Without a hedge, the asset must move aggressively just to break even.

QUANTS' INSIGHT: High Drawdown is not a model failure—it is a characteristic of unhedged Theta decay. Institutional returns require a Delta-Neutral approach.

IV. DELTA-HEDGING PROTOCOL

Problem: Unhedged exposure = +52 net deltas. A $10 drop in NVDA results in a **-$520 loss** plus time decay.
Solution: Short 52 shares of NVDA spot for every 100 calls purchased. This creates a **Gamma/Vega Play**.
Transformed P&L Profile:

$$dP\&L \approx \underbrace{\tfrac{1}{2}\Gamma(dS)^2}_{\text{Long Convexity}} + \underbrace{\Theta dt}_{\text{Time Cost}} + \underbrace{\nu d\sigma}_{\text{Vol Sensitivity}}$$

Investment Mandate: We profit if **Realized Volatility** (price swings) exceeds the market's **Implied Volatility**, or if uncertainty (IV) expands from its current 21% floor. Rebalance when $|\Delta| > 10$.

V. KEY RISKS

1. **Theta Bleed:** Fixed cost of $14/day per unit.
2. **IV Crush:** Risk of Vega loss if IV drops further.
3. **Gap Risk:** Significant overnight price jumps.
4. **Slippage:** Costs during daily Delta rebalancing.

Pre-Execution Checklist:

☐ Bid/Ask Spread ¡ 1% (Current: 0.6%)
☐ Secure stock borrow for short leg
☐ Set hard stop-loss at -30% model value

VI. STRATEGIC CONCLUSION

Opportunity: The 13.1% valuation edge provides a significant buffer. The Low-Vol regime suggests now is the time to "buy insurance" before a vol spike.

Action: Do not trade directionally. Execute the delta-neutral strategy to capitalize on mispriced convexity.

PORTFOLIO ACTION: Approve Buy-Write (Delta-Hedged) session open. This is a volatility arbitrage trade, not a directional bet.

Prepared: Team QuantDevs (Sahil Rane) — Model: American Binomial CRR v2.0 (JIT Accelerated)
Attachments: (1) Realized Vol Cone, (2) Backtest Eq Curve, (3) P&L Heatmap, (4) Greek Surfaces