# SPIKES® Volatility Index Methodology Guide

## Introduction

The SPIKES Volatility Index (SPIKES) is a measure of expected 30-day volatility in the SPDR® S&P 500® ETF (SPY), the largest exchange-traded fund in the world that tracks the most widely-followed stock index in the United States. With over $26 billion in daily notional value traded per day, SPY is the world's most actively traded ETF.[1]

A by-product of SPY's popularity is a highly liquid market for its associated options, accounting for an approximate daily notional trading value of $1 billion.[2]  SPIKES is calculated using live prices on options linked to SPY and represents the market's expectation of price movements in SPY over the next 30 days.

To best align to the way the trading community models risk and hedges exposure, SPIKES is constructed using the well-known variance swap methodology using live options prices to calculate volatility. SPIKES can be physically replicated with a strip of options, and can easily be incorporated into the existing ecosystem of volatility-based products, which include options, futures, and ETPs.

In addition, SPIKES incorporates material enhancements in its calculation to help improve index stability - namely its proprietary "price dragging" technique, which is designed to reduce erratic movements in the index during periods of high volatility and/or low liquidity in the broader market.  Options are often quoted in bulk by market makers, which in some cases cause a divergence from orthodox supply-demand dynamics as quotes are constantly updated across a series of strikes throughout the day. As a result, there can be more notable movements within the bid/ask spread that impact the calculation of an index based on mid-point prices. SPIKES proprietary price dragging technique has been designed to mitigate this effect, producing a more stable index value.

Moreover, to calculate the index, SPIKES uses highly-active, electronically-traded multi-listed SPY options over singly-listed S&P 500 index options. This better reflects the nature of today's high-velocity, and principally electronic, options market. The SPIKES Index is calculated by MIAX® during the times that SPY Options are open for trading, generally Monday – Friday, from 9:30am – 4:15pm ET.

[1] Source: Consolidated Tape Association (CTA). Represents the 180 day moving average, calculated as:
Daily Sum of (Trade Quantity x Trade Price) during regular trading hours.

[2] Source: Options Price Reporting Authority (OPRA). Represents the 180 day moving average, calculated as:
Daily Sum of (Trade Contracts * 100 * Trade price) where 100 is the option multiplier.

# The SPIKES Formula

Like most indexes, SPIKES has a defined rules-based approach to selecting components—a series of options on SPY—and weighting them to derive a single price for the index.

The formula for expected T-term variance is as follows:

$$\sigma^2 = \frac{1}{T}\left[2e^{RT}\Sigma i\ \frac{\Delta K_i p_i}{K_i^2} - \left(\frac{e^{RT}(p^c_{ATM} - p^p_{ATM})}{K_{ATM}}\right)^2\right]$$

**T**    Time to options expiration (in years, with 1-second precision)

$K_i, p_i$    A list of unique SPY options strikes, ordered from lowest to highest, and corresponding SPY options prices; of a call if $K_i > K_{ATM}$; and of a put if $K_i < K_{ATM}$; if $K_i = K_{ATM}$ then an average between the ATM SPY put and call prices

$\Delta K_i$    Half the difference between the strikes on either side of $K_i$;

$$\Delta K_i = \frac{(K_{i+1} - K_{i-1})}{2}$$

$p^c_{ATM}$    Price of the at-the-money (ATM) SPY call option

$p^p_{ATM}$    Price of the ATM SPY put option

$K_{ATM}$    Strike closest to the point where linearly interpolated SPY call and put prices intersect

For the last (highest and lowest) selected strikes, $\Delta K_i$ is simply the absolute difference between $K_i$ and the nearest selected option's strike

**R**    Risk-free interest rate to option's expiration

# Calculation Methodology

SPIKES is calculated using only standard options on SPY that expire on the third Friday of each calendar month. Although weekly options on SPY are available, these are **not** used in the calculation of the SPIKES Index.

The calculation linearly interpolates between the variances of two monthly expirations—near-term (the closest expiration more than two full days into the future) and next-term (the monthly expiration following the near-term). This expiration selection method is used to avoid using highly irregular option prices close to the options settlement date.

The 30-day point is typically in between these two expirations and the index value is interpolated between the volatilities of these two terms. When the closest expiration is too close to expiry (less than two full days), rolling to the third-closest expiration occurs. This rolling rule serves to reduce spurious variability in the index by means of minimizing the period of "extrapolation" between the two expirations. The switch from closest to third-closest expiry rarely has any noticeable impact on the index value, as the weight of the switched term is close to zero.

After the SPY options expirations used in the calculation have been selected, the calculation proceeds as follows:

**1. Determine Option Prices**

SPIKES uses a proprietary "price dragging" technique to capture live options prices as inputs for the index calculation. The option price inputs that result from price dragging are called Cash Reference Prices (CRPs), and determined as follows:

- Set all CRPs to 0 at SPY options market opening;
- For trades, only consider standard simple trades (conditions "space", I, or J.)
- For quotes, only consider NBBO eligible bids and offers from all eligible exchanges (quote conditions A, B, C, O, or "space")
- Block trades, out of sequence prints, as well as trades resulting from complex transactions and stopped orders are ignored.
- On the opening quote, the opening **bid** is used as the CRP;
- When there is a trade, the CRP is set to trade price;
- For newly-placed ask (bid) quotes, if the ask (bid) is lower (higher) than current CRP, the CRP is set to ask (bid).

This method should materially reduce erratic movements of the index value as quotations on out-of-the-money (OTM) options are rapidly altered during times of low liquidity and or high volatility.

## 2. Select the Options Used in the Calculation

For each of the expirations, the options to be used in the calculation are then selected by removing in-the-money (ITM) and far OTM options:

- To determine the at-the-money (ATM) strike, only use strikes for which both the call and put prices are available.  For each strike, find the absolute value of the call CRP minus the put CRP, and select the strike where that value is closest to zero. In the case of a tie, select the lower strike.

- Stepping away from the ATM, (for puts going to the next lower strike, and for calls the next higher strike) when two consecutive options with CRPs of 5 cents or less are reached exclude all options further away from the money.

## 3. Weight the Options and Estimate Volatility

For each term, the volatility is estimated using the variance swap formula, with the selected options' CRPs weighted according to the SPIKES formula:

$$\sigma^2 = \frac{1}{T}\left[ 2e^{RT}\Sigma i\ \frac{\Delta K_i p_i}{K_i^2} - \left( \frac{e^{RT}(p^c_{ATM} - p^p_{ATM})}{K_{ATM}} \right)^2 \right]$$

The risk-free interest rate is the yield (mid-point of bid-ask) for the United States Treasury Bill which matures on the date closest to the monthly SPY expiration--generally the day prior to the monthly expiration date. In the event of two T-Bills maturing equidistant from the monthly options expiration, use the shortest dated maturity.

## 4. Calculate the Index

Compute the 30-day weighted average of the near- and next-term variances, take the square root, and multiply by 100, as follows:

$$\text{SPIKES} = 100 \times \sqrt{\left( \frac{t_1}{t_M}\frac{t_2 - t_M}{t_2 - t_1}\sigma_1^2 + \frac{t_2}{t_M}\frac{t_M - t_1}{t_2 - t_1}\sigma_2^2 \right)}$$

| | |
|---|---|
| $t_1$ | Time (in seconds) to near-term expiration |
| $\sigma_1$ | Estimated volatility computed by variance swap formula, near-term |
| $t_2$ | Time (in seconds) to next-term expiration |
| $\sigma_2$ | Estimated volatility computed by variance swap formula, next-term |
| $t_M$ | Number of seconds in 30 days (30 x 86,400 = 2,592,000) |

## Sample Calculation

Some examples of "price dragging" and options selection using real prices are included on the following page to help illustrate how SPIKES is calculated.  Since the full calculation is very repetitive, only a select sample of the full calculation method is included.

A fully worked up example of the full calculation with formulas in Excel is available upon request.
Email products@miaxglobal.com.

## SPIKES Overview: Index Methodology

## Price Dragging

Here "price dragging" is used for one option to determine the Cash Reference Price.

| Time | Update | Cash Reference Price Update | Comment |
|---|---|---|---|
| 9:30:00 | Market Open | 0 | Initially set at zero |
| 9:31:12 | 2.35 bid | Set to 2.35 | Opening CRP is the bid |
| 9:33:01 | 2.31 bid | Unchanged | Bid updates but is not above current CRP |
| 9:33:48 | 2.37 ask | Unchanged | Ask is not below the last eligible CRP of 2.35 |
| 9:36:41 | Trade at 2.37 | Set to 2.37 | Trade triggers CRP update to 2.37 |
| 9:38:34 | 2.38 ask | Unchanged | Ask is updated but is not below the last CRP |
| 9:39:00 | 2.36 ask | Set to 2.36 | Ask moves below the latest CRP, becomes the new CRP |

## Options Selection

The following calculations use historical SPY option prices (determined by using the price dragging technique) sampled on February 13th, 2015. Based on the SPIKES rules, the two closest eligible expirations are February 20th, 2015 and March 20th, 2015. Both are more than two days away from the current date of February 13th so are selected as near- and next-term.

The intersections of put and call prices are observed in between the yellow highlighted strikes. For the near-term, the absolute difference between the 209.50 strike call and put price is 28 cents, whereas for 210 it is 20 cents. Since the intersection of the price curves is closer to 210, the ATM strike is 210. Using the same logic, the next-term ATM strike would be 209.

Once the ATM strike is determined, the series is truncated after two consecutive CRPs are 5 cents or less. For the near-term, all strikes at 199 and below and 217 and above are removed as the puts encounter two consecutive CRPs below or equal to 5 cents at 200 and 199.50 and the calls at 215 and 216. Similarly, for the next-term expiration, strikes at 148 and below and 240 and above are truncated.

### Near-Term (February 20th)

| Strike | Call Price | Put Price |
|---|---|---|
| 197 | 12.82 | 0.04 |
| 197.5 | 12.32 | 0.03 |
| 198 | 11.83 | 0.04 |
| 198.5 | 10.62 | 0.03 |
| 199 | 10.86 | 0.05 |
| 199.5 | 10.35 | 0.04 |
| 200 | 9.87 | 0.05 |
| 200.5 | 9.36 | 0.06 |
| 201 | 8.85 | 0.06 |
| 201.5 | 8.36 | 0.07 |
| 202 | 7.86 | 0.08 |
| 202.5 | 7.42 | 0.09 |
| 203 | 6.91 | 0.10 |
| 203.5 | 6.44 | 0.11 |
| 204 | 5.96 | 0.13 |
| 204.5 | 5.48 | 0.15 |
| 205 | 5.01 | 0.19 |
| 205.5 | 4.54 | 0.23 |
| 206 | 4.11 | 0.28 |
| 206.5 | 3.64 | 0.33 |

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| Strike | Call Price | Put Price |
|---|---|---|
| 207 | 3.22 | 0.41 |
| 207.5 | 2.80 | 0.50 |
| 208 | 2.41 | 0.60 |
| 208.5 | 2.04 | 0.71 |
| 209 | 1.68 | 0.88 |
| 209.5 | 1.35 | 1.07 |
| **210** | **1.09** | **1.29** |
| 210.5 | 0.82 | 1.53 |
| 211 | 0.60 | 1.80 |
| 212 | 0.30 | 2.51 |
| 212.5 | 0.21 | 2.92 |
| 213 | 0.15 | 3.32 |
| 214 | 0.07 | 4.24 |
| 215 | 0.04 | 5.82 |
| 216 | 0.03 | 6.21 |
| 217 | 0.02 | 6.74 |
| 217.5 | 0.02 | 6.90 |
| 218 | 0.01 | 8.22 |
| 219 | 0.01 | 8.76 |
| 220 | 0.01 | 10.19 |
| 221 | 0.01 | 11.20 |

## Next-Term (March 20th)

| Strike | Call CRP | Put CRP |
|---|---|---|
| 144 | 65.85 | 0.03 |
| 145 | 64.87 | 0.04 |
| 146 | 63.85 | 0.03 |
| 147 | 62.87 | 0.04 |
| 148 | 61.87 | 0.04 |
| 149 | 60.57 | 0.04 |
| 150 | 59.84 | 0.04 |
| 151 | 58.88 | 0.06 |
| 152 | 57.88 | 0.06 |
| 153 | 56.58 | 0.06 |
| 154 | 55.86 | 0.06 |
| 155 | 54.70 | 0.07 |
| 156 | 53.59 | 0.06 |
| 157 | 52.90 | 0.07 |
| 158 | 51.87 | 0.06 |
| 159 | 50.86 | 0.06 |
| 160 | 49.60 | 0.07 |
| 161 | 48.93 | 0.07 |
| 162 | 47.92 | 0.08 |
| 163 | 46.92 | 0.08 |
| 164 | 45.62 | 0.08 |
| 165 | 44.95 | 0.09 |
| 166 | 43.94 | 0.09 |
| 167 | 42.63 | 0.10 |
| 168 | 41.64 | 0.11 |
| 169 | 40.95 | 0.11 |
| 170 | 39.65 | 0.12 |
| 171 | 38.98 | 0.12 |

| Strike | Call Price | Put Price |
|---|---|---|
| 172 | 37.83 | 0.13 |
| 173 | 36.66 | 0.13 |
| 174 | 35.97 | 0.14 |
| 175 | 34.68 | 0.16 |
| 176 | 33.69 | 0.17 |
| 177 | 32.70 | 0.18 |
| 178 | 31.72 | 0.19 |
| 179 | 31.18 | 0.20 |
| 180 | 30.07 | 0.22 |
| 181 | 29.47 | 0.23 |
| 182 | 28.04 | 0.26 |
| 183 | 27.08 | 0.27 |
| 184 | 26.04 | 0.30 |
| 185 | 24.97 | 0.32 |
| 186 | 24.12 | 0.33 |
| 187 | 23.02 | 0.36 |
| 188 | 22.61 | 0.39 |
| 189 | 21.20 | 0.43 |
| 190 | 20.22 | 0.46 |
| 191 | 19.26 | 0.51 |
| 192 | 18.29 | 0.55 |
| 193 | 16.59 | 0.60 |
| 194 | 15.76 | 0.67 |
| 195 | 15.44 | 0.73 |
| 196 | 14.51 | 0.82 |
| 197 | 13.56 | 0.90 |
| 198 | 12.67 | 1.00 |
| 199 | 11.76 | 1.11 |
| 200 | 10.83 | 1.25 |
| 201 | 9.99 | 1.38 |
| 202 | 9.11 | 1.54 |
| 203 | 8.27 | 1.71 |
| 204 | 7.42 | 1.92 |
| 205 | 6.67 | 2.14 |
| 206 | 5.82 | 2.39 |
| 207 | 5.09 | 2.68 |
| 208 | 4.38 | 3.00 |
| **209** | **3.70** | **3.37** |
| 210 | 3.09 | 3.80 |
| 211 | 2.53 | 4.26 |
| 212 | 1.98 | 4.79 |
| 213 | 1.53 | 5.38 |
| 214 | 1.18 | 6.03 |
| 215 | 0.88 | 6.77 |
| 216 | 0.60 | 7.56 |
| 217 | 0.42 | 8.41 |
| 218 | 0.30 | 9.32 |
| 219 | 0.22 | 10.27 |
| 220 | 0.17 | 11.21 |
| 221 | 0.13 | 12.34 |
| 222 | 0.10 | 13.16 |

| Strike | Call Price | Put Price |
|---|---|---|
| 223 | 0.09 | 13.85 |
| 224 | 0.08 | 15.15 |
| 225 | 0.06 | 16.14 |
| 230 | 0.04 | 21.12 |
| 235 | 0.03 | 25.81 |
| 240 | 0.02 | 31.11 |
| 245 | 0.01 | 36.09 |
| 250 | 0.01 | 41.08 |
| 255 | 0.01 | 46.08 |
| 260 | 0.01 | 51.08 |

## Index Dissemination

SPIKES is calculated by MIAX® and disseminated every 100 milliseconds via OPRA and the MIAX Product Feed (MPF).

A sample of data vendors and the symbol for SPIKES from each data vendor are below:

| Data Vendor | Symbol |
|---|---|
| Bloomberg | SPIKE |
| Thomson Reuters | .SPIKE |
| LiveVol | ^SPIKE |
| Yahoo Finance | ^SPIKE |

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