

Application of Signal Processing in Investing

Often Referred to as Algorithmic Trading in Investing Communities

Presented to IEEE Dallas CVT

By

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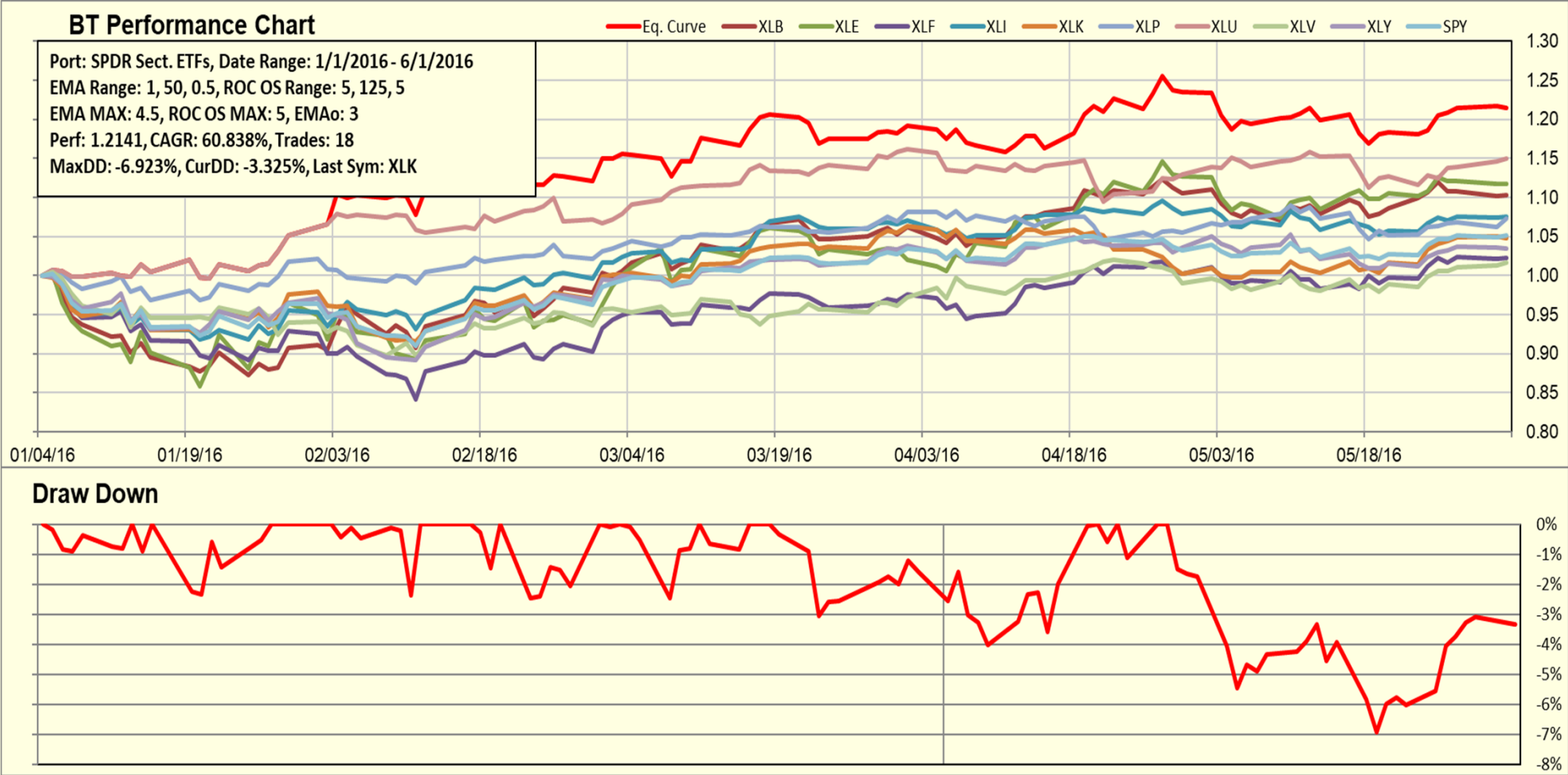
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Presentation Outline

- I. Signal Processing(SP) Background and Investing Applications
 - A. Algorithmic Investing – Algorithms make and/or guide decisions
 - B. Stationarity
 - C. Covariance and Correlation
 - D. Optimization
- II. Generic Investing Strategies – Invest in what and when?:
 - A. Fundamental – Symbols with best financials: e.g., Price, Earnings, Profits/loss, Sales, PE, etc.
 - B. Technical – Symbols with best chart, price, indicators, etc. parameters and characteristics.
- III. Popular Investing strategies
 - A. **Modern Portfolio Theory (MPT)**: Diversification -Percent (%) Allocation
 - B. **Momentum Investing: EMAROC**: Rotate to Best Performing Symbol(s)
 - 1. **EMA** – Exponential Moving Average -days
 - 2. **ROC** – % Rate of Change – days
- IV. Excel/VBA, C++, and C# code and Charts
 - A. Backtest (BT)
 - B. Walk Forward (WF)
 - C. Demonstrations

2016 SPDR SP500 Sector ETFs



Significant Signal Processing Applications¹

- Speech & Audio Processing/Recognition/Compression
- Video and Image Processing/Recognition/Compression
- Hearing Aids
- Wearables (e.g., Medical, Location, Fitness, etc.)
- Autonomous Vehicles
- Communication in Systems and Networks
- Brain Waves
- Transmission/Modulation
- Language Translation
- Investing (1950s Origins)(not on SPS List)

1. IEEE Signal Processing Society (SPS) Web Site (www.signalprocessingsociety.org)

Key Signal Processing (SP) Terminology

- I. Frequency Domain/Time Domain
 - 1. Laplace Transform
 - 2. Fast Fourier Transform
- II. Time Series
 - 1. Stochastic Processes (Probabilistic Time Series)
 - 2. Analog/Digital
 - 3. Quantization
 - 4. Stationarity
 - 5. Covariance, Correlation
 - 6. Optimization

Investing Activities

- I. Create/Obtain Screens/Ranks from Universe, Symbols deemed best for best future performance
 - A. Populate Portfolio(s) with Symbols with desirable future investing Characteristics
 - B. Fundamental Screening and Ranking
 - C. Technical Screens and Ranks
 - D. Buy and Sell
- II. Portfolios
 - A. Personal Investing Goals can vary over time
 - B. Buy or Sell symbols based on Screen/Rank
 - C. Can long or short
 - D. Can be longer term investor or Day Trader
 - E. Some hire Professional Financial Advisors to manage their investments
- III. Tools and Data Sources
 - A. Charting
 - B. Data Sources
 - C. Analysis and Ranking Tools

SP500 Index And Sectors

- Portfolio of ~500 Largest Companies listed on US Stock Exchanges
- Currently Maintained by S&P Dow Jones Indices
- Currently has 503 Symbols, 3 companies have 2 share classes of stock
- Free float weighted by **Market Capitalization**
- Comprises 80% of US equity market capitalization
- Each Symbol assigned to one of 12 Subordinate Sectors (e.g., Technology, etc.)
- Updated regularly using published Rules
- Shares of Indexes can't be purchased
- Various Finance Companies offer ETFs or mutual funds for purchase that mimic Indexes and their sectors

SPDR SP500 Sector ETFs

SPDR ETFs are offered by State Street
SP500 Index currently has 503 Symbols
% Weighting based on each Symbol's Market Cap

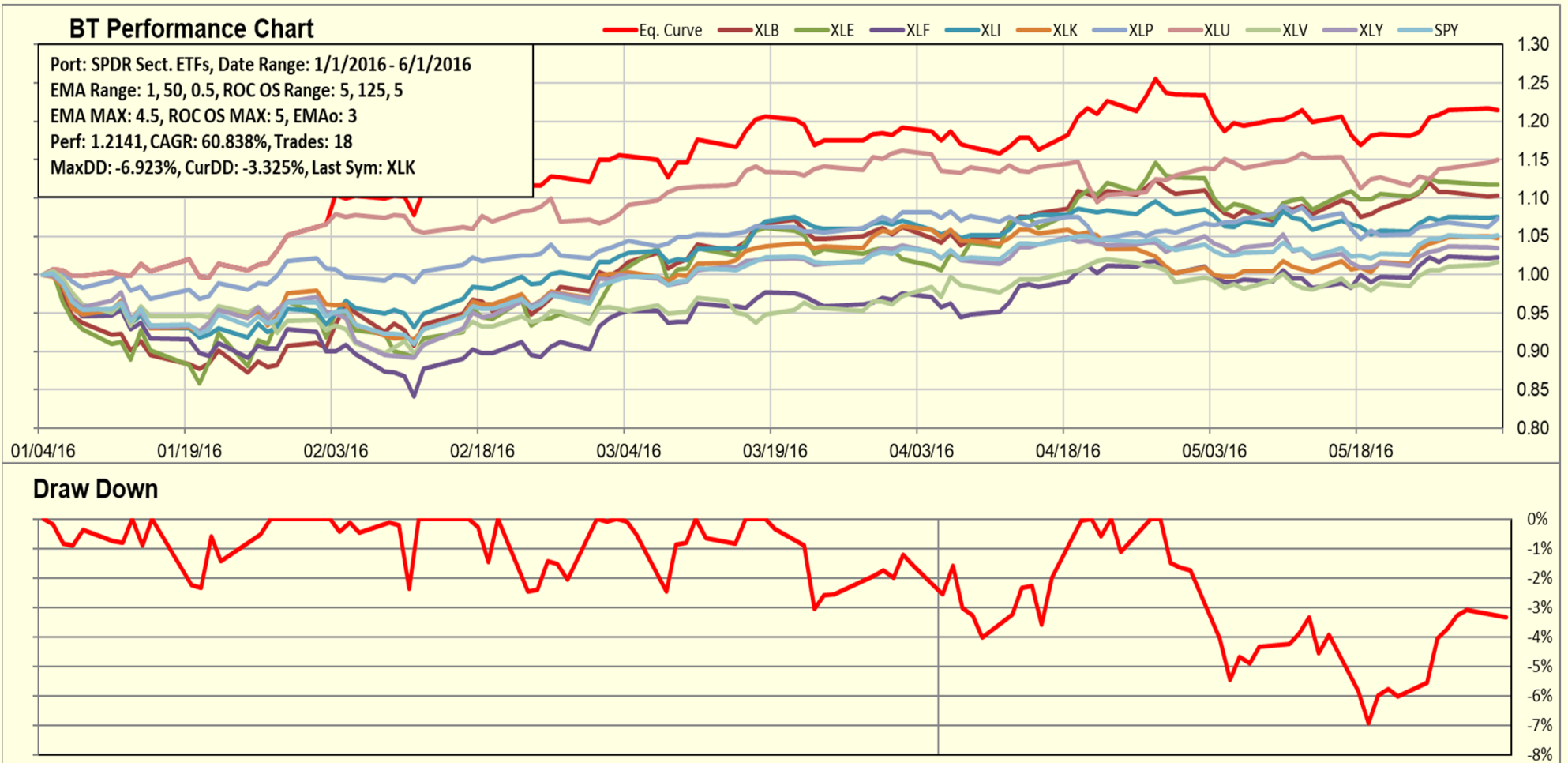
Symbol	Sector	Percent
SPY	SP500	100.00%
XLB	Materials	2.53%
XLC*	Communication Services	8.56%
XLE	Energy	4.25%
XLF	Finance	10.83%
XLI	Industrials	7.91%
XLK	Technology	28.04%
XLP	Consumer Staples	6.50%
XLRE*	Real Estate	2.87%
XLU	Utilities	2.99%
XLV	Healthcare	14.00%
XLY	Consumer Discretionary	11.52%

* Not used in Presentation Analyzes

Typical SP500 Index Chart



2016 SPDR SP500 Sector ETFs



Stationarity

- I. Dictionary Generically Defines Stationarity as “unchanging in condition”
- II. Signal Processing defines Stationarity as unchanging Probability Distribution(s), i.e.: Unchanging Moments:
 - 1) 1st Moment: Mean
 - 2) 2nd Moment: (Co-) Variance, Correlation, Standard Deviation(stdDev)
 - 3) 3rd Moment: Skewness,
 - 4) 4th Moment: Kurtosis, and Higher Moments
- III. A Gaussian Normal Distribution has only 2 moments:
 - 1) Mean
 - 2) Stand Deviation (StDev)
- IV. Best to Invest in Portfolio with Symbols with Stationary Price Data

Non-Stationarity

- I. Most Sources indicate that no Time Series are fully Stationarity
- II. Many Knowledgeable sources indicate that non-stationarity time series can't be analyzed as calculated parameters are inaccurate (no meaning).
 - A. Means, StdDevs, etc. can't be reliability estimated.
 - B. Author's Opinion is that Stationarity is inadequately addressed in academia and application(s).
 - C. Time Series Degrees of Stationarity should be addressed over various time frames.
- III. This presentation will present generic application(s) of stationarity in investing
- IV. Often **Best to not invest in Non-Stationary Portfolios**

Convert Non-stationary Time Series to Stationary

- I. Stock Price Data is not Stationary
 - A. Mean and StDev change
 - B. Thus, portfolio optimization algorithms typically don't work well with price data
- II. Community Solution
 - A. Calculate with (more) stationary daily price change (or % price change)**
 - B. Price change is a good proxy for price
 - C. Covariance, Correlation, etc. herein are calculated using % price change

Covariance & Correlation Formulas (2 Symbols)

Portfolios generate matrices of Covariance and Correlations

Excel Matrix multiplication tools efficiently do these calculations over symbols & date ranges

Formulas Below (x, y are symbol prices (e.g. adj. close))

Use Daily Price Change (not price) : Better Stationarity

Means

1st moments

$$\hat{x} = \frac{1}{n} \sum_{i=0}^{n-1} (x_i)$$

$$\hat{y} = \frac{1}{n} \sum_{i=0}^{n-1} (y_i)$$

Covariance(cov)

2nd moments

$$cov(x, y) = \frac{1}{n-1} \sum_{i=0}^{n-1} (x_i - \hat{x}) * (y_i - \hat{y})$$

Correlation(cor)

$$stddev(x) = \sqrt{cov(x, x)}$$

Normalize cov

$$cor(x, y) = cov(x, y) / (stddev(x) * stddev(y))$$

Portfolio Covariance & Correlation using Excel Matrix Calculations

$$\begin{aligned} \mathbf{covPort} &= \mathbf{PPort}^T * \mathbf{PPort} / \#Dates \\ \mathbf{corPort} &= \mathbf{covPort} / (\mathbf{stdev} * \mathbf{stdev}^T) \end{aligned}$$

Where:

PPort is Excel matrix with Portfolio prices

- dates descending (rows)
- Symbols (Columns)

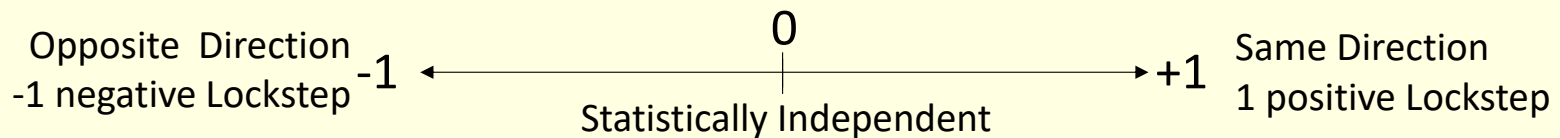
covPort is Portfolio Covariance Matrix (# Syms by # Syms)

corPort is Portfolio Correlation Matrix (# Syms by # Syms)

Stdev is column vector of stdev of each Symbol

Correlation: According to Investopedia

“Correlation is a statistical measure that determines how assets move in relation to each other. It can be used for individual securities, like stocks, or it can measure general market correlation, such as how asset classes or broad markets move in relation to each other. It is measured on a scale of -1 to +1. A perfect positive correlation between two assets has a reading of +1. A perfect negative correlation has a reading of -1. Perfect positive or negative correlations are rare.”¹
(Except correlation of a symbol with itself is always 1)

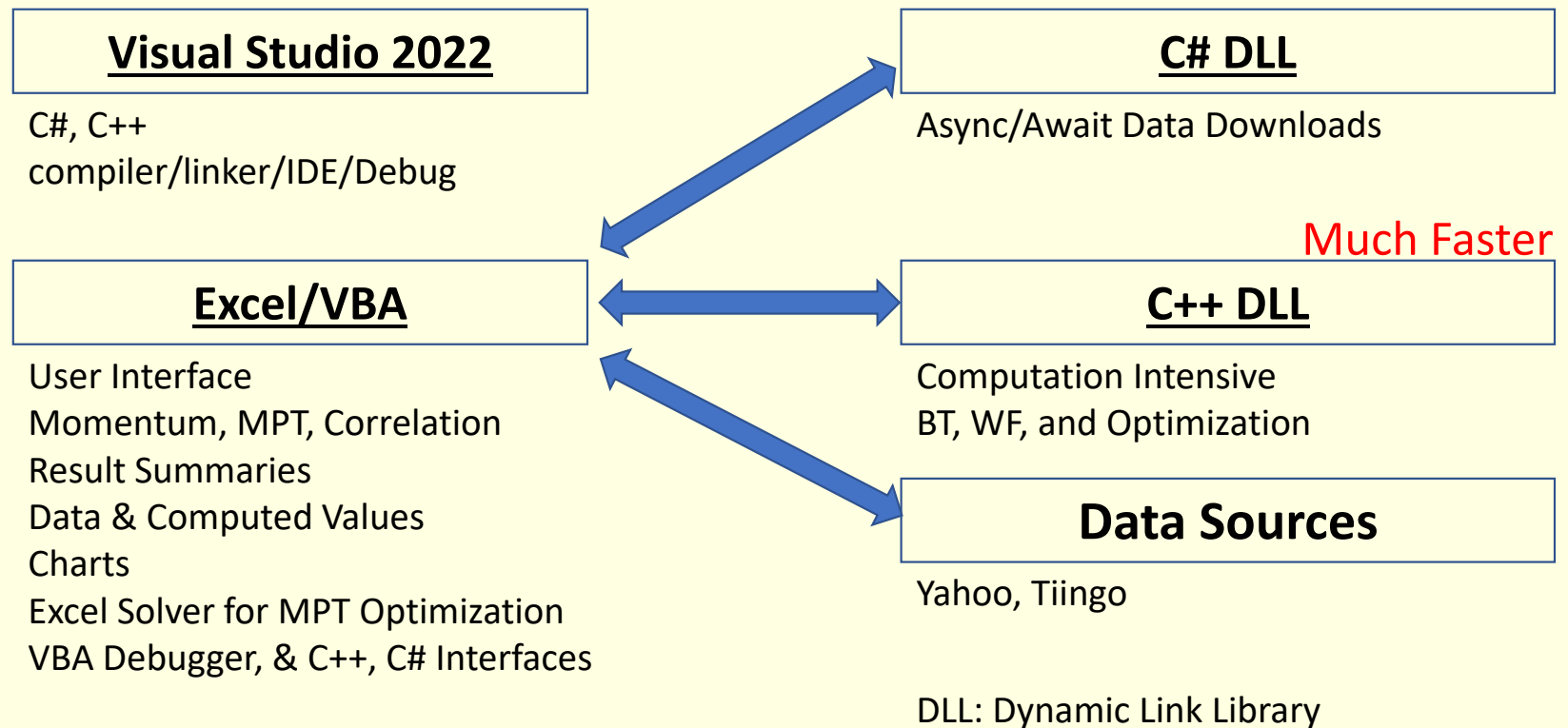


Correlation:

- 2 Asset Symbols (e.g., x, y; or AAPL, AMD adj. close)
- Same Time Frames
- Different Time Frames (Predictive, +1 or -1 most Predictive)
- Auto often used for correlation of symbol with itself

¹ <https://www.investopedia.com/articles/financial-advisors/022516/4-reasons-why-market-correlation-matters.asp>

PortAll Tool: Excel, C#, C++ Tool Block Diagram



Modern Portfolio Theory (MPT)

- I. Introduced in 1952 “Portfolio Selection” Article in Journal of Finance, By Harry Markowitz, Noble Prize-Winning American Economist
- II. Introduced mathematical framework for developing portfolios
- III. Applies mathematics, probability, and statistical methods
- IV. Formalizes methods for **Diversification: Optimized % Allocation(s)** to portfolio symbols based on objective(s)
- V. Objectives: Maximize Expected Return at Acceptable Expected Risk (Loss):
 - A. **Maximum Return:** Always 100% in best performing Symbol
 - B. **Equal Weight:** Equal % \$ amount in each Portfolio Symbol
 - C. **Minimum Risk:** % for Minimum Volatility, or Portfolio StDev
 - D. **Maximize Sharp Ratio:** % for Average Return/StDev)
- VI. Widely used in Investing Community for years – Often without Optimization
- VII. Many Financial Advisors appear to Diversify based on Experiences

SPDR SP500 and Sector ETFs

MPT % Allocations and Optimized Yearly Returns

Date Range: 1/1/2021 – 9/15/2022

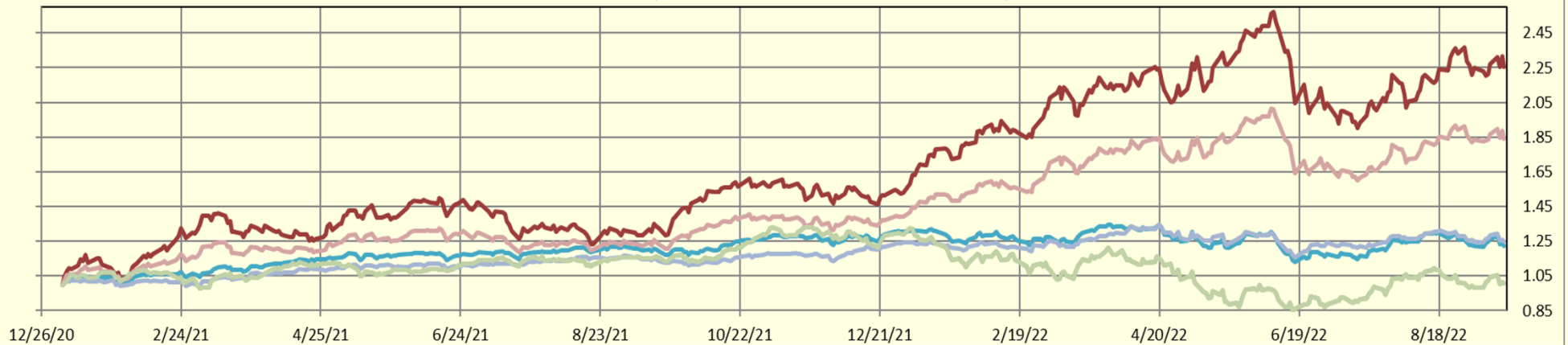
MPT % Allocations					
Port. Weights	Eq. Wt.	Max Ret	Min StDev	Max Sharpe	Custom
XLB	10.00%	0.00%	0.00%	0.00%	0.00%
XLE	10.00%	100.00%	8.53%	57.44%	0.00%
XLF	10.00%	0.00%	0.00%	0.00%	0.00%
XLI	10.00%	0.00%	0.00%	0.00%	0.00%
XLK	10.00%	0.00%	0.00%	0.00%	0.00%
XLP	10.00%	0.00%	45.44%	0.00%	0.00%
XLU	10.00%	0.00%	15.77%	42.56%	0.00%
XLV	10.00%	0.00%	30.27%	0.00%	0.00%
XLY	10.00%	0.00%	0.00%	0.00%	100.00%
SPY	10.00%	0.00%	0.00%	0.00%	0.00%
Total	100.00%	100.00%	100.00%	100.00%	100.00%

Portfolio Optimization, Yearly					
Portfolio	Eq. Wt.	Max Ret	Min StDev	Max Sharpe	Custom
Mean	11.784%	53.552%	12.659%	36.942%	3.646%
Std Dev	16.427%	32.322%	13.169%	20.975%	26.890%
SharpeR	71.734%	165.681%	96.129%	176.124%	13.558%

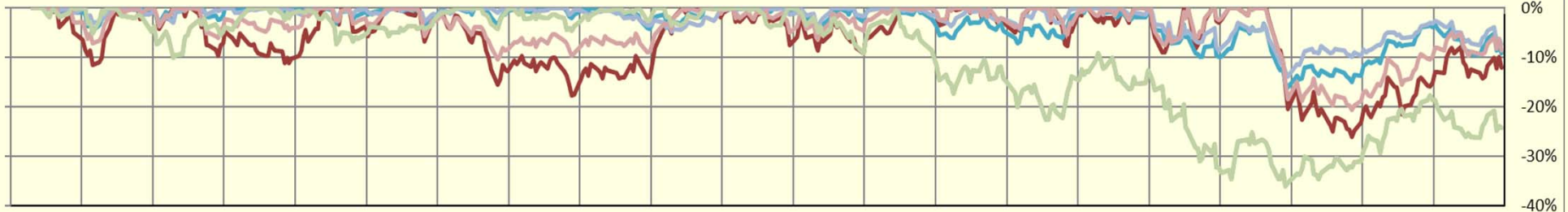
SPDR SP500 and Sector ETF Performance Chart

MPT Optimization Performance Chart

— XLE — XLY — Eq. Wt. — Min StDev — Max Sharpe — Custom



MPT DrawDown



Momentum Investing Strategies

- I. Investing Community observes Recent Best Performing Symbols, have significantly better probability for best future Performance.
- II. Momentum strategies Invest best in performing symbols, rotating and re-allocating at appropriate times.
- III. Recent Performance Determination
 - A. Investing Community typically uses % Rate of Change (ROC)
 - B. Enhanced Momentum Strategy (EMAROC)
 - 1) Applying EMA Indicator(Low pass IIR Filter) prior to ROC improves performance
 - 2) Populating Portfolio with Symbols having less than 50% Correlations can substantially improve performance. (note can! - not will!)
 - 3) Rotate to Maximum EMAROC ranked Portfolio Symbol daily, if rank changes
 - 4) Sell on 8% DrawDown (DD) from peak price in recent date range.

BackTest(BT) and Walk Forward(WF) Analyses

I. BackTest(BT) Analyzes & Charts

- A. Optimizes and Invests in same Historical Time Period
- B. Illustrates Historical Performance
- C. Not Algorithmically Investable

II. Walk Forward(WF) Analyzes & Charts

- A. InSample Optimization (**Historical**) Period
- B. Followed by OutSample (**Future**) Investing Period
- C. Algorithmically Investable

In-Sample & Out-Sample Investing Analysis

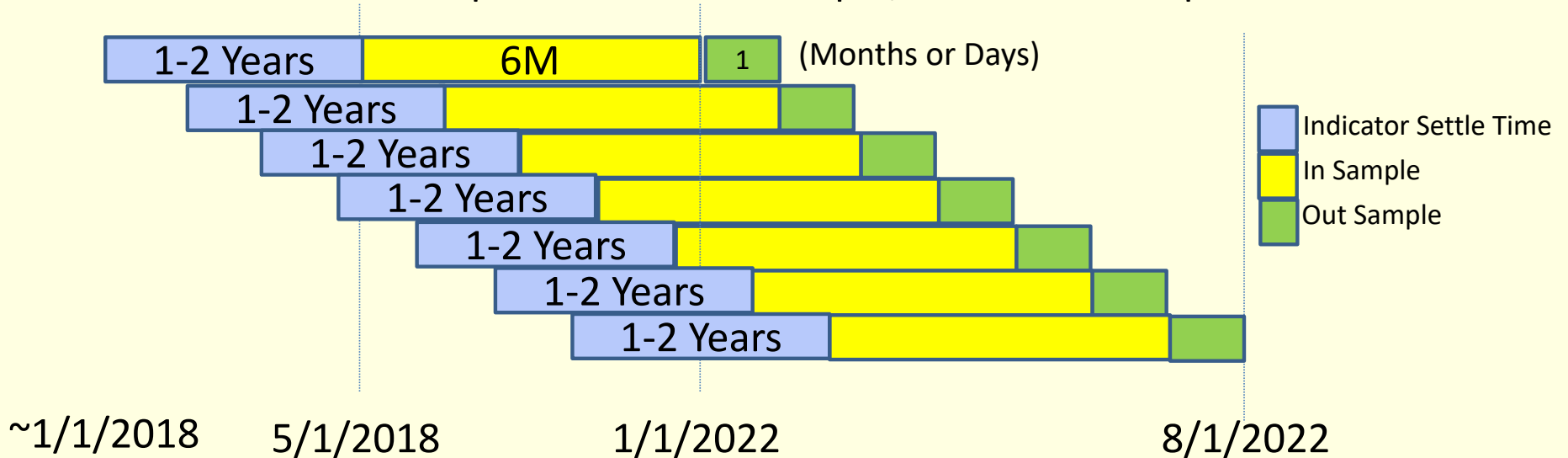
In-Sample (Backtest) Analysis

- Calculate Equity Curve over In-Sample Historical Date Range
- Optimization uses InSample range of Indicator Values



Out-Sample Analysis – Walk Forward

- Calculate Optimum ROC In-Sample, Invest Out Sample



In-Sample & Out-Sample Analysis (Freeze Start Date)

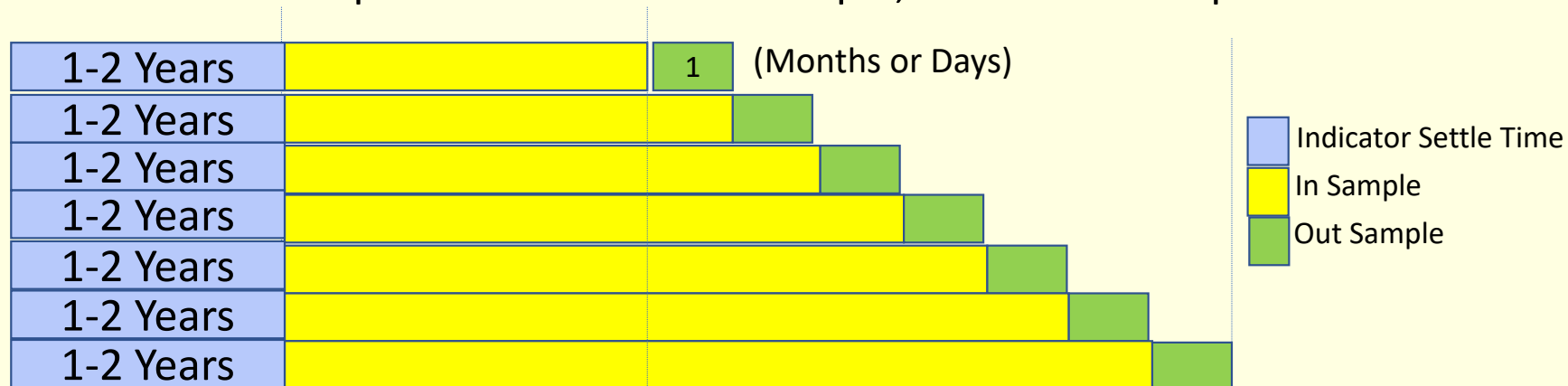
In-Sample (Backtest) Analysis

- Calculate and Optimize Equity Curve over In-Sample Historical Date Range
- Optimization uses same range of Indicator Values



Out-Sample Analysis – Walk Forward

- Calculate Optimum EMAROC In-Sample, Invest Out Sample



Freeze Date – Often Improves Stationarity

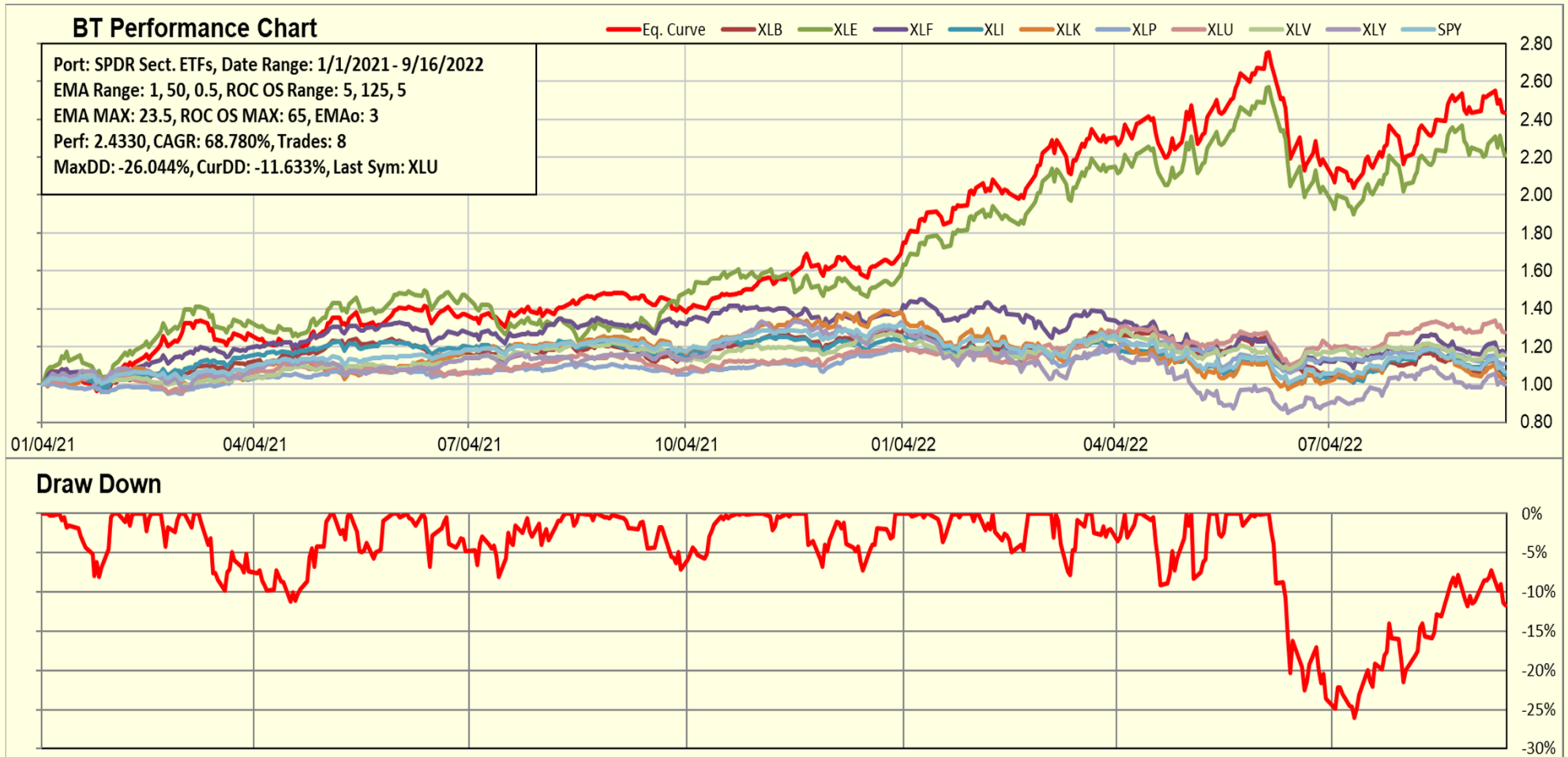
~1-5/1/2018

1/1/2000

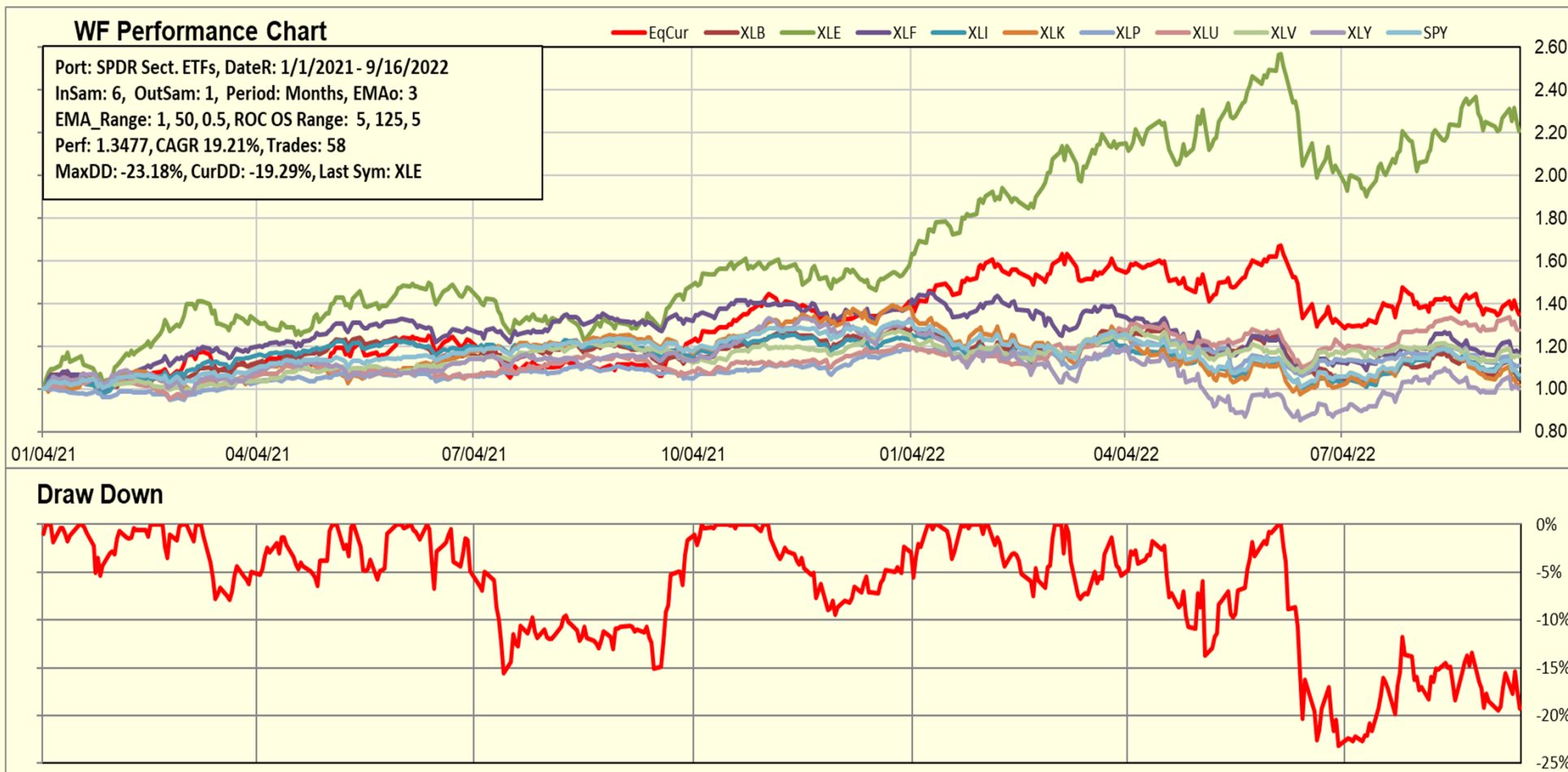
1/1/2022

9/1/2022

SPRD Sect. ETFs BT Performance Chart



SPDR Sect. ETFs WF Performance Chart



SPDR Sect. ETFs WF Performance Table

InSample BT Performance: 143.4% Profit (Previous Slide)
 Outsample WF Performance: 34.7% Profit

		In Sample			Out Sample	
Start Date	End Date	EMA	ROC_OS	Perf In	End Date	Perf Out
20180101	20201231	44.0	90	2.1319	20210201	1.0252
20180101	20210131	43.5	95	2.1462	20210301	1.0551
20180101	20210228	3.0	5	2.3127	20210401	1.0172
20180101	20210331	3.0	5	2.4254	20210501	0.9979
20180101	20210430	36.0	120	2.5338	20210601	1.0684
20180101	20210531	36.0	120	2.6785	20210701	1.0212
20180101	20210630	36.0	120	2.7919	20210801	0.9011
20180101	20210731	3.0	5	2.6242	20210901	0.9862
20180101	20210831	3.0	5	2.5946	20211001	1.1135
20180101	20210930	3.0	5	2.7542	20211101	1.1571
20180101	20211031	3.0	5	3.2345	20211201	0.9407
20180101	20211130	3.0	5	3.0928	20220101	1.0413
20180101	20211231	3.0	5	3.2265	20220201	1.1155
20180101	20220131	3.0	5	3.5749	20220301	0.9542
20180101	20220228	3.0	5	3.5637	20220401	1.0375
20180101	20220331	3.0	5	3.6760	20220501	0.9487
20180101	20220430	3.0	5	3.4773	20220601	1.1003
20180101	20220531	14.5	70	3.7571	20220701	0.8282
20180101	20220630	3.0	5	3.2416	20220801	1.0864
20180101	20220731	3.0	5	3.6364	20220901	0.9350
20180101	20220831	49.5	55	3.4711	20221001	0.9990

SPDR Sect. ETFs
 EMA Order 3

Eq Cur Ret 1.3477
 # Trades 58
 CAGR 19.21%
 Max DD -23.18%
 Date 07/05/2022

Stationary Price Data Often Improves Performance

Portfolio: IBD50 10/7/2021 Top 12 Symbols
Optimize EMA & ROC

WF: Freeze, 1/1/2018, Date: Stationary

In Sample					Out Sample	
Start Date	End Date	EMA	ROC_OS	Perf In	End Date	Perf Out
20180101	20201231	12.5	40	72.1063	20210201	1.1284
20180101	20210131	12.5	40	76.5350	20210301	1.0832
20180101	20210228	12.5	40	85.3208	20210401	1.0933
20180101	20210331	12.5	40	95.8518	20210501	1.1648
20180101	20210430	12.5	40	110.5095	20210601	0.9839
20180101	20210531	12.5	40	108.4256	20210701	1.2347
20180101	20210630	12.5	40	144.5939	20210801	0.9429
20180101	20210731	12.5	40	130.3159	20210901	1.2320
20180101	20210831	12.5	40	165.9713	20211001	0.8863
20180101	20210930	12.5	40	163.8391	20211101	1.2209
20180101	20211031	12.5	40	170.3211	20211201	0.9242
20180101	20211130	12.5	40	167.9342	20220101	1.1808
20180101	20211231	12.5	40	191.3716	20220201	0.8396
20180101	20220131	12.5	40	151.8067	20220301	1.0997
20180101	20220228	12.5	40	173.7225	20220401	1.0162
20180101	20220331	12.5	40	173.1998	20220501	0.9118
20180101	20220430	12.5	40	159.4909	20220601	1.0658
20180101	20220531	12.5	40	170.0803	20220701	0.9187
20180101	20220630	12.5	40	154.6439	20220801	0.9793
20180101	20220731	12.5	40	158.2079	20220901	1.2161
20180101	20220831	12.5	40	195.9833	20221001	1.0152

IBD50-211007
EMA Order 3

Eq Cur Ret 2.6858
Trades 18
CAGR 78.90%
Max DD -28.47%
Date 09/14/2021

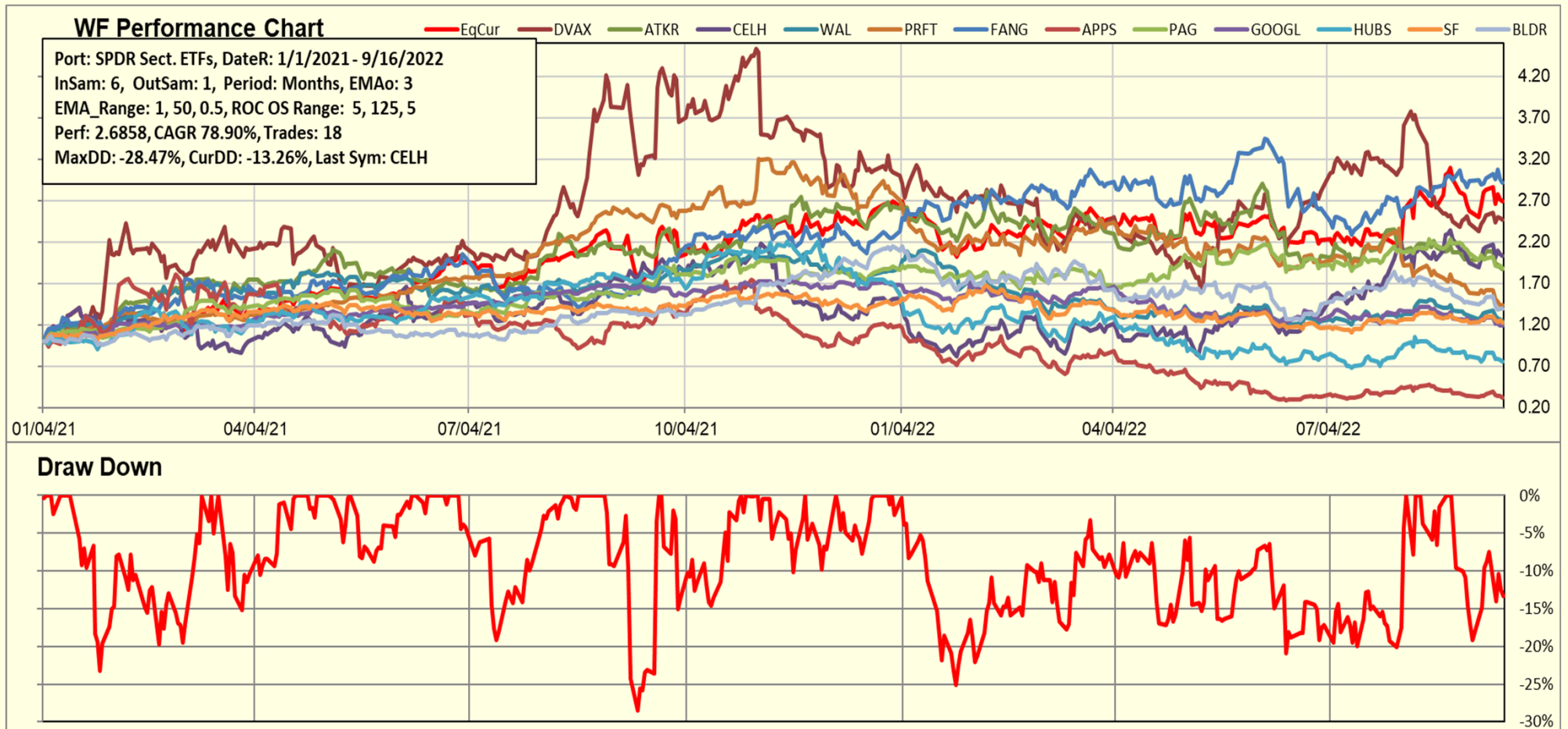
WF: No Freeze Date: not Stationary

In Sample					Out Sample	
Start Date	End Date	EMA	ROC_OS	Perf In	End Date	Perf Out
20200701	20201231	28.5	25	7.5492	20210201	1.1284
20200801	20210131	29.0	30	5.3201	20210301	1.1705
20200901	20210228	16.5	110	3.7529	20210401	1.0094
20201001	20210331	50.0	125	3.4094	20210501	0.9169
20201101	20210430	28.5	105	3.9482	20210601	0.9536
20201201	20210531	47.5	90	2.6823	20210701	0.9023
20210101	20210630	1.0	10	2.3776	20210801	0.8039
20210201	20210731	10.0	50	2.1053	20210901	1.3461
20210301	20210831	9.5	50	2.3016	20211001	0.8863
20210401	20210930	3.5	5	2.5657	20211101	1.2223
20210501	20211031	3.5	5	2.2900	20211201	0.7126
20210601	20211130	49.0	120	1.8784	20220101	0.9997
20210701	20211231	14.0	5	1.9800	20220201	0.9011
20210801	20220131	1.0	10	1.8128	20220301	0.9135
20210901	20220228	3.0	25	1.4770	20220401	0.6122
20211001	20220331	12.5	15	1.5192	20220501	0.9121
20211101	20220430	7.0	30	1.2876	20220601	0.8290
20211201	20220531	2.0	95	1.4307	20220701	1.0014
20220101	20220630	8.5	65	1.3618	20220801	1.4989
20220201	20220731	8.5	65	2.2109	20220901	1.0032
20220301	20220831	8.5	65	2.4036	20221001	1.0152

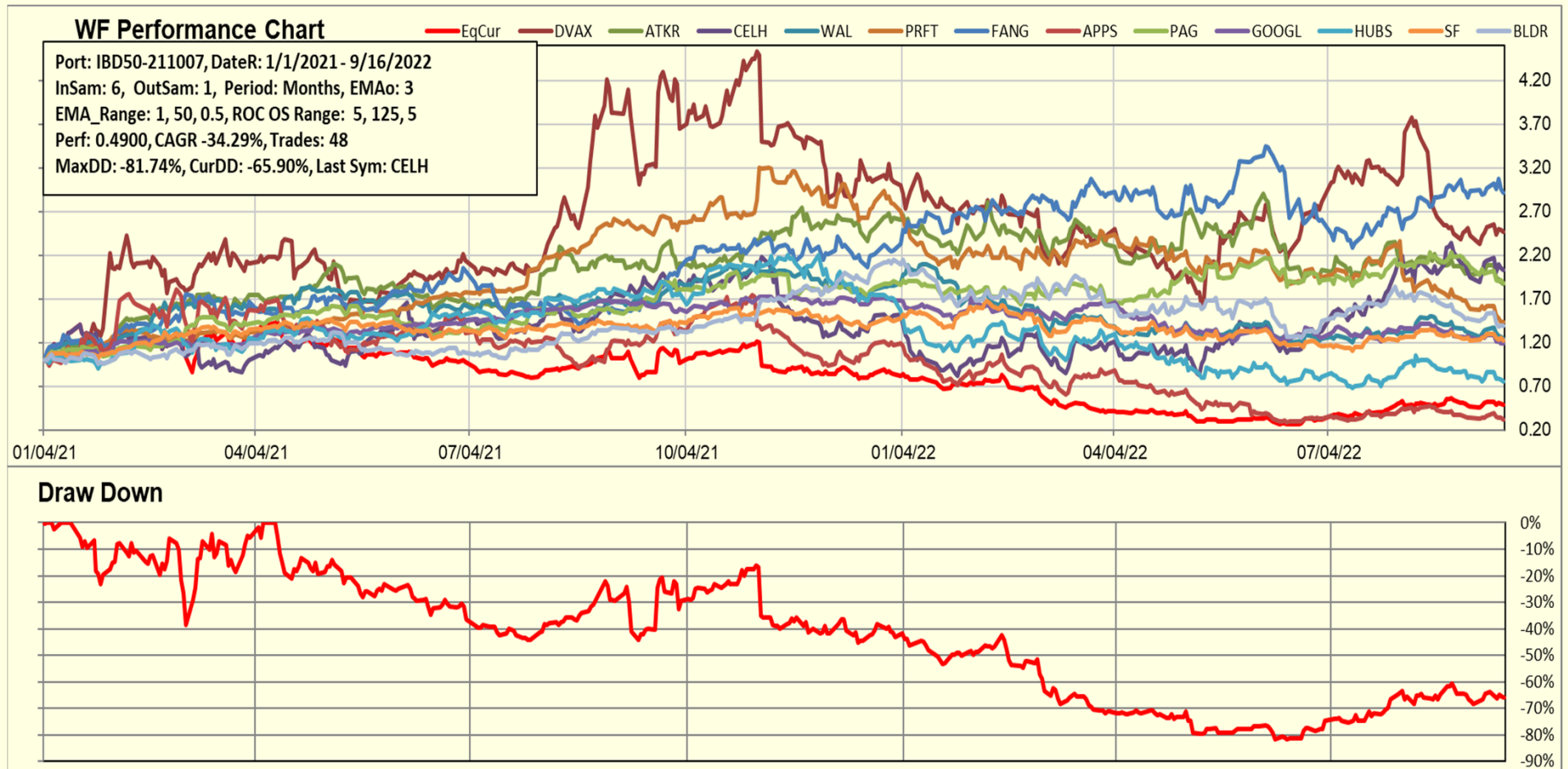
IBD50-211007
EMA Order 3

Eq Cur Ret 0.4900
Trades 48
CAGR -34.29%
Max DD -81.74%
Date 06/16/2022

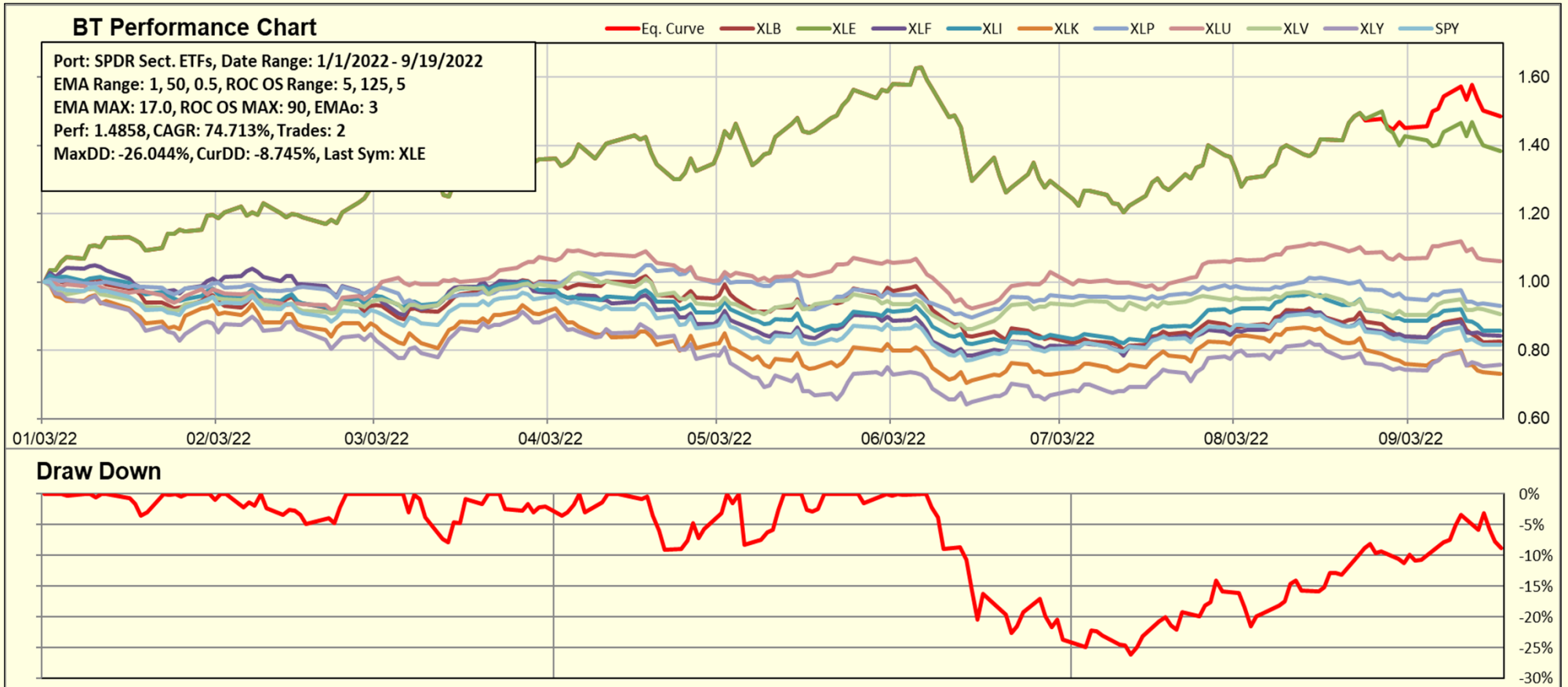
WF Performance: Stationary Portfolio (Freeze Date)



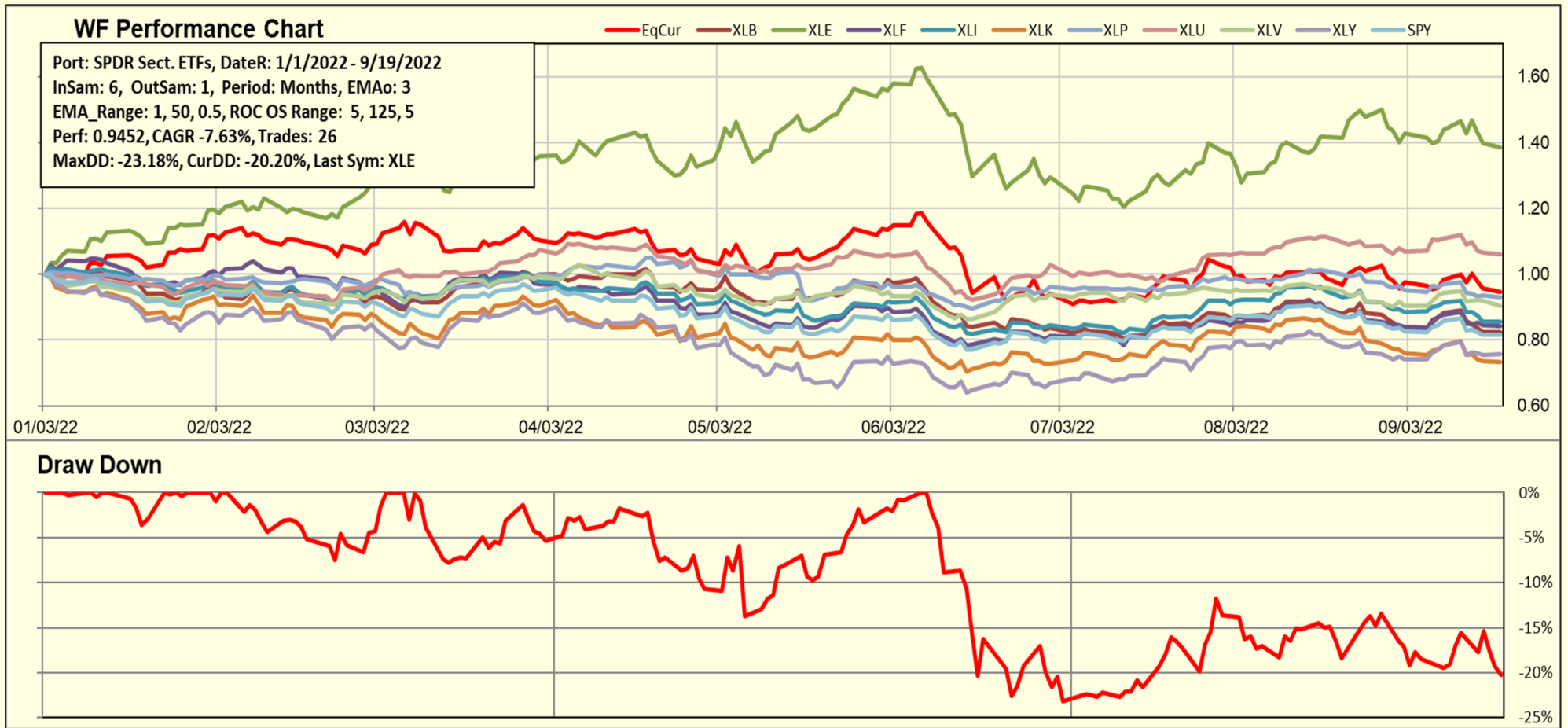
WF Performance: non-Stationary Portfolio (No Freeze Date)



2022 YTD BT Chart: SPDR ETFs



2022 YTD WF Chart: SPDR ETFs



Summary and Conclusions

- I. Algorithmic Investing Considerations
 1. Fundamental Indicators are often useful in Populating Portfolios
 2. Technical Indicators usually provide 2nd level Screening (downsizing)
 3. Technical Indicators best Buy/Sell timing indicators
 4. Appropriately use % Price Change (Not Price)
 5. Best to invest in Stationary Portfolios, especially when optimizing
 6. Get-Out Strategy: 8% Draw Down, avoid excessive losses
- II. MPT
 1. MPT is essentially diversification, i.e., % Allocation
 2. Effectively applies mathematics to optimize various objective goals
- III. Momentum: Rotate to best historically performing symbols
 1. Less than ~50% Symbol Correlations usually improves performance
 2. EMAROC improves widely used ROC-only rotation strategies
- IV. 2022 has not been a good year for investing