Good constraint set. Below is a **much more concrete, testable mapping** from **Chapter 2 onward**, with **only equity-relevant chapters**, and **every exercise explicitly using Alpaca data** for **hypothesis testing, estimation, or live paper strategies**. I'll be blunt about *what is real vs academic* and *what each test is meant to falsify*.

Assumption throughout:

- Asset class: **US equities / ETFs only**
- Data source: **Alpaca bars / trades / quotes**
- Mode: **offline analysis + paper trading where appropriate**

Chapter 2 — Returns & Random Walks

Goal: Prove (or falsify) weak-form efficiency using Alpaca data, not theory.

Exercise 2.1 — Return Definition Sensitivity Test

Alpaca use: Daily bars (get_bars)
Steps

1. Pull 10+ years of daily bars for SPY, AAPL, NVDA.
2. Compute:
    - Simple returns
    - Log returns
    - Overnight vs intraday returns
3. Hypothesis test:
    - H_0: Mean return = 0
    - Test: one-sample t-test (with Newey–West correction)

What you're testing

- Whether any return definition produces statistically meaningful drift.
- You'll likely reject significance except for long samples → supports random walk.

Why it matters

- Prevents you from building strategies on fragile return definitions.

Exercise 2.2 — Autocorrelation & Variance Ratio Test

Alpaca use: Same bars
Steps

1. Compute autocorrelation at lags 1–20.
2. Perform variance ratio test (k = 2, 5, 10).
3. Repeat for:
    - Daily close-to-close
    - Overnight returns only

Expected outcome

- Close-to-close ≈ random
- Overnight returns often show weak structure

Trading implication

- If anything is exploitable, it's overnight risk premia, not intraday noise.

Exercise 2.3 — Microstructure Reality Check

Alpaca use: Trades + Quotes (if available)
Steps

1. Compute naive momentum signal (past 5-day return).
2. Backtest twice:
    - Ignoring spreads/slippage
    - Using bid-ask midpoint + ½ spread penalty
3. Compare Sharpe degradation.

Lesson
Most "Chapter 2 alpha" dies the moment you price execution.

Chapter 4 — Exploratory Data Analysis (EDA)

Goal: Identify where strategies fail before you code them.

Exercise 4.1 — Regime Labeling via Rolling Volatility

Alpaca use: Daily bars
Steps

1. Compute 20-day rolling volatility.
2. Label days as:
    - Low vol (bottom 30%)
    - Medium
    - High vol (top 30%)
3. Compare mean/variance of returns across regimes.

Hypothesis

- H_0: Mean returns identical across regimes.

Outcome

- Often rejected → regimes exist.

Exercise 4.2 — Regime-Conditioned Strategy

Alpaca use: Same data + paper trading

Strategy

- Momentum only in low-vol regime
- Mean-reversion only in high-vol regime

Rules

- Momentum: top decile past 10-day returns
- Mean-reversion: z-score < −2
- Flat otherwise

Evaluation

- Compare vs unconditional strategy
- Key metric: max drawdown reduction

Chapter 5 — Univariate Distributions & Tail Risk

Goal: Stop assuming Gaussian returns.

Exercise 5.1 — Distribution Fit & Model Selection

Alpaca use: Daily returns

Steps

1. Fit:
    - Normal
    - Student-t
2. Compare via AIC/BIC.
3. Repeat per asset.

Expected

- Student-t almost always wins.

Exercise 5.2 — Tail-Aware Position Sizing

Alpaca use: Same returns + paper trading

Strategy

- Position size $\propto$ 1 / Expected Shortfall (ES)
- ES computed from fitted distribution

Compare

- Equal weight
- Vol-targeting
- ES-targeting

Key metric

- Worst 5% PnL outcomes

Reality check

This won't boost returns. It protects capital.

Chapter 6 — Resampling & Bootstrap

Goal: Detect backtest overfitting.

Exercise 6.1 — Sharpe Confidence Intervals

Alpaca use: Any strategy returns
Steps

1. Bootstrap daily returns (block bootstrap).
2. Build 95% CI for Sharpe.
3. Test:
    - Is Sharpe > 0 with confidence?

Decision rule

- If CI crosses 0 → strategy is noise.

Exercise 6.2 — Strategy Selection Under Uncertainty

Alpaca use: Two competing strategies
Steps

1. Bootstrap difference in Sharpe.
2. Only deploy strategy A if:
    - CI(Sharpe_A − Sharpe_B) > 0

This is institutional-grade discipline.

Chapter 7 — Multivariate Models

Goal: Understand correlation instability.

Exercise 7.1 — Rolling Correlation Breakdown

Alpaca use: ETF baskets (SPY, QQQ, IWM, XLK)
Steps

1. Compute 60-day rolling correlations.
2. Visualize correlation spikes during drawdowns.

Lesson
Diversification fails when you need it most.

Exercise 7.2 — Minimum Variance Overlay

Alpaca use: Same ETF universe + paper trading
Strategy

- Base portfolio: equal weight ETFs
- Overlay: rebalance monthly to min-variance weights

Compare

- Volatility
- Drawdown
- Turnover cost

Chapter 8 — Copulas (Risk-Only, No Trading Alpha)

Goal: Stress-test diversification assumptions.

Exercise 8.1 — Gaussian vs Tail Dependence

Alpaca use: Joint returns
Steps

1. Transform returns to pseudo-observations.
2. Estimate Gaussian correlation.
3. Compare joint crash probabilities empirically.

Output

- Probability of joint −3σ events vs Gaussian assumption.

Use case

- Portfolio risk committee justification, not trading signals.

Chapter 12–13 — Time Series Models

Goal: Prove return forecasting is weak; volatility forecasting isn't.

Exercise 12.1 — ARIMA Return Forecast Falsification

Alpaca use: Daily returns
Steps

1. Fit ARIMA(1,0,1) rolling.
2. Trade only when forecast > threshold + costs.
3. Walk-forward only.

Expected

- Flat or negative alpha.

This is a good result.

Exercise 12.2 — Volatility Forecasting Comparison

Alpaca use: Same returns
Models

- Rolling σ
- EWMA
- GARCH(1,1)

Metric

- MSE of realized vs forecast volatility.

Chapter 14 — GARCH & Volatility Timing

Goal: Risk control, not prediction.

Exercise 14.1 — Volatility-Targeted Momentum

Alpaca use: Daily bars + paper trading
Strategy

- Momentum signal fixed
- Exposure scaled so predicted vol = 10% annualized

Compare

- Fixed exposure
- EWMA scaling
- GARCH scaling

Outcome

- Vol targeting improves drawdowns, not raw returns.

Chapter 15 — Cointegration & Pairs Trading

Goal: One of the few statistically defensible equity strategies.

Exercise 15.1 — Pair Discovery Pipeline

Alpaca use: Sector stocks
Steps

1. Pre-filter by correlation.
2. Test cointegration (Engle-Granger).
3. Estimate spread & half-life.

Exercise 15.2 — Live Paper Pairs Strategy

Alpaca use: Real-time paper orders
Rules

- Enter $|z| > 2$
- Exit $|z| < 0.5$
- Dollar-neutral
- Kill switch if cointegration breaks

Metrics

- Hit rate
- Mean reversion speed
- Capital usage

Chapter 16 — Portfolio Selection

Goal: Translate theory into operational reality.

Exercise 16.1 — Efficient Frontier vs Reality

Alpaca use: ETF universe
Steps

1. Estimate mean/cov monthly.
2. Compute:
    - Min-variance
    - Tangency portfolio
3. Paper trade with monthly rebalance.

Reality check

- Mean estimates unstable
- Covariance dominates performance

Exercise 16.2 — Turnover-Penalized Optimization

Alpaca use: Same
Add constraint

- Penalize turnover explicitly in optimizer.

Compare

- Net returns after transaction costs.