Title: Value-at-Risk and Scenario-Based Stress Testing for Crude Oil Futures Portfolio

1. Objective and Rationale

This model aims to quantify the market risk of a sample crude oil futures portfolio using multiple Value-at-Risk (VaR) approaches and scenario stress testing. The rationale is to demonstrate a scalable framework that supports:

- Daily risk monitoring using 1-day and 10-day VaR estimates

- Stress scenario analysis for sudden price movements

- Portfolio sensitivity to crude oil volatility, aligned with the operational demands of trading desks

2. Data and Assumptions

- Instruments: WTI (CL=F) and Brent (BZ=F) daily front-month settlement prices

- Source: Yahoo Finance via yfinance API

- Time Horizon: 3 years (1 July 2022 – 1 July 2025)

- Positions Assumed:
    - Long 100 contracts of Brent
    - Short 50 contracts of WTI

- Contract Specs:
    - 1 contract = 1,000 barrels
    - USD-denominated notional exposure

Returns computed using log differences. No basis risk hedging assumed. FX risk ignored.

3. Methodology

3.1 Value-at-Risk (VaR) Models

- **Parametric (Variance-Covariance)**
    - Assumes normal distribution of returns
    - $VaR = z \times \sigma \times \sqrt{h} \times$ Position value
    - Calculated for 1-day and 10-day horizons at 95% and 99% confidence levels

- **Historical Simulation VaR**
    - Empirical quantile of historical P&L
    - Does not assume normality or linearity

- **Monte Carlo Simulation**
    - Simulates thousands of return paths
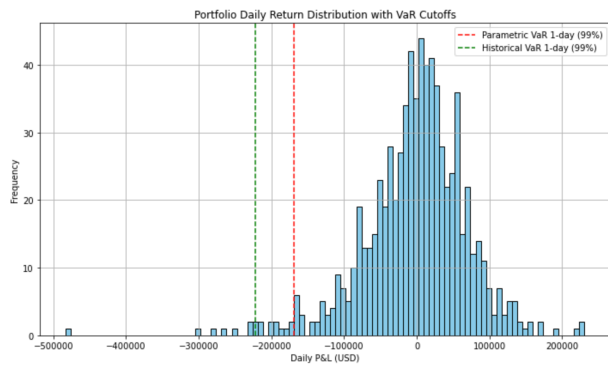   - Assesses tail risk under stochastic return assumptions

3.2 Scenario-Based Stress Testing

- **Event-Based**:
    - March 2020 (COVID crash)
    - Feb–Mar 2022 (Russia-Ukraine oil price spike)

- **Hypothetical**:
    - Crude oil price drops by 10%, 15%, and 20%
    - Impact on combined P&L of both positions

3.3 Tools Used

- Python 3.11
- Libraries: pandas, numpy, matplotlib, yfinance, scipy.stats

4. Key Results and Interpretation

Portfolio Daily Return Distribution with VaR Cutoffs

Metric	Result (USD)
1-day Parametric VaR (99%)	–$169,453.25
10-day Parametric VaR (99%)	–$535,858.24
1-day Parametric VaR (95%)	–$120,469.41
10-day Parametric VaR (95%)	–$380,957.71
1-day Historical VaR (99%)	–$222,749.65
10-day Historical VaR (99%)	–$704,396.26
1-day Historical VaR (95%)	–$124,663.92
10-day Historical VaR (95%)	–$394,221.92
1-day Monte Carlo VaR (99%)	–$175,110.7
10-day Monte Carlo VaR (99%)	–$552,711.25
1-day Monte Carlo VaR (95%)	–$121,357.97
10-day Monte Carlo VaR (95%)	–$389,177.38

	Brent P&L (USD)	WTI P&L (USD)	Total Portfolio P&L (USD)
Stress Test: –10% Oil Price Shock	-676100.01	325550.00	-350550.00
Stress Test: –15% Oil Price Shock	-1014150.01	488325.00	-525825.00
Stress Test: –20% Oil Price Shock	-1352200.01	651100.01	-701100.01

- Parametric VaR slightly underestimates tail risk compared to historical approach
- Stress test validates significant downside exposure under price shock scenarios
- P&L distribution shows slight negative skew; non-normality handled better by historical VaR

5. Takeaways

- Daily VaR monitoring provides robust, real-time exposure management for the trading desk
- Scenario-based insights are critical for stress reporting and capital planning
- Historical simulation provides better tail-risk capture than Gaussian assumptions
- This model can be extended to multi-asset books (e.g., LNG, FX, cross-commodity) and integrated into Wisewood's existing analytics pipeline
- Position-level granularity and reconciliation with physical trades will further enhance control

6. Future Enhancements

- Integrate rolling volatility estimation (EWMA/GARCH) for time-varying risk
- Add cross-asset correlation shocks (oil-USD, oil-equities)
- Automate report generation and alerts for breaches in VaR limits
- Incorporate inventory and physical position reconciliation