VCF Pilot Test Suite – Mathematical Validation Framework

Overview

A **Pilot** in VCF Research is now defined as a *mathematically isolated test module* used to validate every foundational component of our system.

This scientific test layer ensures that:

- Each formula is correctly implemented
- Inputs behave as expected
- Outputs match theoretical behavior
- Edge-case behavior is numerically stable
- Interpretation aligns with the VCF paradigm

This document defines the official **Pilot Test Suite** for all phases.

Phase I — Regime_Engine

Economic Regime Engine

Tests confirm the correctness of macro + liquidity geometry.

Math Tests

1. **Z-score correctness**
2. **Pillar averaging stability**
3. **Angle identity tests**
   - atan2 symmetry
   - θ quadrant correctness
4. **Coherence positivity**
5. **Economic cycle validation** using known historical macro cycles
6. **Leading / lagging correlation checks**
7. **Synthetic macro signal tests** (sinusoid $\rightarrow$ expected angle path)

Expected Outputs

- Correct θ transitions across synthetic and historical data
- Verified leading indicators
- Verified confirming and lagging indicators

Phase II — Sector_Regime_Engine

Sector Interaction & Sector Regime Engine

A novel engine to measure sector leadership, lagging, synchrony, divergence, and harmonic structure.

Math Tests

1. **Sector normalization stability**
2. **Sector dispersion monotonicity**
3. **Sector breadth correctness**
4. **FFT / wavelet harmonic power conservation**
5. **Dominant cycle detection on synthetic datasets**
6. **Sector synchrony tests**
7. **Cross-sector harmonic resonance tests**
8. **ϕ angle tests** with controlled sector-risk inputs

Expected Outputs

- Consistent sector leadership maps
- Detectable cycles and harmonic structure
- Clear sector regimes (defensive, cyclical, mixed, dislocated)

Phase III — Unified_Engine

Unified State Space Engine

Combines macro + sectors + harmonics into a single 3D VCF geometry.

Math Tests

1. **Unified feature vector consistency**
2. **PCA orthogonality validation**

3. **Eigenvalue ordering**
4. **Variance explained threshold (>80%)**
5. **Noise sensitivity tests**
6. **Rotation invariance tests**
7. **Geometry reconstruction tests**

Expected Outputs

- Stable Θ_VCF, Φ_VCF, R_VCF
- Unified geometry reflecting macro + sector interactions
- Reproducible state vectors

Phase IV — Wavelit_Engine

Wavelet + Resonance Regime Engine

Time–frequency cycle analysis and macro–market resonance.

Math Tests

1. **CWT admissibility**
2. **Wavelet power conservation**
3. **Scale-to-frequency mapping correctness**
4. **Short/long cycle wavelet ratio consistency**
5. **Dominant cycle detection**
6. **Phase-shift tests** (0°, 90°, 180°)
7. **Resonance correctness** on synthetic sinusoidal data
8. **Wavelet-feature integration into unified state space**

Expected Outputs

- Accurate wavelet decomposition
- Correct resonance detection
- Time-frequency cycle atlas
- Final VCF regime classification

Pilot Directory Structure

```
vcf/
pilots/
Phase_I_Regime_MathTests/
Phase_II_Sector_MathTests/
Phase_III_Unified_MathTests/
Phase_IV_Wavelit_MathTests/
```

Each folder will contain:

- Synthetic datasets
- Expected outputs
- Identity and invariance tests
- Stability tests
- Visual validation plots

Scientific Goal

This Pilot Test Suite moves VCF from a model into a **fully scientific framework**, where each mathematical building block is validated independently before integration.

This is how new paradigms are built.