



GO-SEC LABS

Vault Protocol Security Audit Report

Prepared for: Vault Protocol
Security Report

Version: v2.0 | Vault Report

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Table of Contents

Project Summary.....	3
Executive Summary.....	4
Project Goals.....	5
Audit Coverage and Scope.....	6
Summary of Findings.....	7
Details of Findings.....	9
#1. Arbitrary Token Transfer in Liquidation Function.....	9
#2. Precision Loss in Health Factor Calculation.....	10
#3 Cross-Function Reentrancy in Composite Functions.....	11
#4. Mathematical Overflow in USD Value Calculation.....	13
#5: CEI Pattern Violations in Core Functions.....	14
#6. Unbounded Loop DoS Risk.....	16
#7. Public Burn Function in Mock Contracts.....	17
#8. Unbounded Loop in Constructor.....	18
#9. Event Emission After External Calls.....	20
#10. Oracle Timestamp Manipulation.....	20
#11. Unsafe Percentage Calculations.....	21
#12. Stablecoin Peg Protection Missing.....	23
#13. Constructor Parameter Order Error.....	25
#14. Missing Constructor Input Validation.....	25
#15. Inconsistent Error Handling Patterns.....	26
#16. Solidity Version Inconsistencies.....	26
Vulnerability Classifications.....	28
Security Recommendation.....	29
Appendices.....	31
Notices and Remarks.....	34
About Go-Sec Labs.....	35

Project Summary

Vault Protocol is a **decentralized stablecoin system** enabling users to mint **vUSD** (USD-pegged stablecoin) by depositing cryptocurrency collateral. The protocol ensures stability through **200% overcollateralization** and **automated liquidation mechanisms**.

Repository Information:

- **GitHub Repository:** <https://github.com/zacksfF/Vault>
- **Audited Branch:** `fix/critical-security-vulnerabilities`
- **Commit Hash:** `96f348a`

Supported Assets

- **Collateral:** WETH (Wrapped Ethereum), WBTC (Wrapped Bitcoin)
- **Output:** vUSD stablecoin pegged to \$1.00
- **Minimum Collateralization:** 200% (deposit \$2 worth of crypto per \$1 vUSD minted)

Key Operations

- **Deposit & Mint:** Users deposit collateral and generate vUSD
- **Health Monitoring:** Continuous position tracking via health factors
- **Liquidations:** 10% bonus system maintains protocol stability
- **Price Feeds:** Chainlink oracles provide tamper-resistant pricing

Security Architecture

- Reentrancy protection on all functions
- Input validation and access controls
- Health factor-based risk management
- Emergency pause mechanisms

User Journey

1. **Deposit:** Lock WETH/WBTC as collateral
2. **Mint:** Generate vUSD up to 50% of collateral value
3. **Manage:** Monitor health factor to avoid liquidation
4. **Exit:** Burn vUSD to unlock collateral

Executive Summary

Vault Protocol Security Audit was conducted by **Zakaria Saif**, Blockchain Security Engineer, from **February 3-26, 2025**. The comprehensive assessment employed **static analysis**, **manual code review**, **architectural analysis**, and **dynamic testing** methodologies to evaluate the security posture of this decentralized stablecoin protocol.

Audit Results Summary

Severity Level	Count	Status	Risk Level
🔴 Critical	4	Fixed	Extreme Risk
🟡 High	5	Fixed	High Risk
🟡 Medium	7	Fixed	Medium Risk
TOTAL	16	Fixed	-

Project Timeline

Date	Activity	Status
Feb 3	Initial Assessment & Scope Definition	✅ Complete
Feb 5	Architecture Review	✅ Complete
Feb 8	Static Analysis (Slither + Semgrep)	✅ Complete
Feb 13	Manual Code Review & Vulnerability Analysis	✅ Complete
Feb 18	Dynamic Testing (Foundry + Echidna Setup)	✅ Complete
Feb 22	Integration Testing & Edge Cases	✅ Complete
Feb 26-27	Final Review & Delivery	✅ Complete

Project Goals

Primary Objective: Conduct a comprehensive security assessment of Vault Protocol's decentralized stablecoin system to identify vulnerabilities and ensure production readiness.

Security Focus: Eliminate critical vulnerabilities in core contracts, validate mathematical precision in health factor calculations, verify reentrancy protection, and assess oracle integration security.

Quality Assurance: Ensure robust collateral management, accurate liquidation mechanisms, and economic model integrity through multi-layered analysis combining static scanning, manual review, and dynamic testing.

Deliverable Target: Provide a detailed vulnerability report with severity classifications, proof-of-concept exploits, a comprehensive remediation roadmap, and testing framework for ongoing security validation.

Audit Coverage and Scope

In-Scope Contracts:

- **VaultEngine.sol** (366 LOC) - Core protocol logic, collateral management, liquidations
- **VaultStablecoin.sol** (92 LOC) - ERC-20 stablecoin implementation with mint/burn
- **PriceOracle.sol** (69 LOC) - Chainlink price feed integration and validation
- **VaultMath.sol** (85 LOC) - Mathematical calculations and precision handling
- **VaultErrors.sol** (33 LOC) - Standardized error definitions
- **IVaultEngine.sol** (28 LOC) - Interface definitions and events

Out-of-Scope:

- External dependencies (OpenZeppelin, Chainlink contracts)
- Deployment scripts and configuration files
- Frontend integration and user interface components
















Security Assessment Areas:


- **Access Control** - Authorization mechanisms and privilege escalation
- **Reentrancy Protection** - Cross-function attack prevention
- **Mathematical Security** - Precision loss, overflow, and calculation accuracy
- **Economic Logic** - Liquidation mechanics and stablecoin peg stability
- **Oracle Integration** - Price feed validation and manipulation resistance
- **Gas Optimization** - DoS prevention and scalability considerations

Methodology

Analysis Type	Tools Used	Coverage	Duration
Static Analysis	Slither, Semgrep	100% code coverage	5 days
Manual Review	Line-by-line analysis	Core contracts	8 days
Architecture Review	Design pattern analysis	Full system	4 days
Dynamic Testing	Foundry, Echidna	Key functions	7 days

Summary of Findings

F.No	Severiry	Title	Type	Status
# 1	 Critical	Arbitrary Token Transfer in Liquidation Function	Authorization Bypass	Fixed
# 2	 Critical	Precision Loss in Health Factor Calculation	Mathematical Precision Loss	Fixed
# 3	 Critical	Cross-Function Reentrancy in Composite Functions	Reentrancy Attack Vector	Fixed
# 4	 Critical	Mathematical Overflow in USD Value Calculation	Integer Overflow Risk	Fixed
# 5	 High	CEI Pattern Violations in Core Functions	State Consistency Risk	Fixed
# 6	 High	Unbounded Loop DoS Risk	Denial of Service	Fixed
# 7	 High	Public Burn Function in Mock Contracts	Access Control Vulnerability	Fixed
# 8	 High	Unbounded Loop in Constructor	Gas Optimization / DoS Risk	Fixed
# 9	 High	Event Emission After External Calls	MEV/Front-runni ng Vulnerability	Fixed
# 10	 Medium	Oracle Timestamp Manipulation	Oracle Manipulation	Fixed
# 11	 Medium	Unsafe Percentage Calculations	Mathematical Precision	Fixed
# 12	 Medium	Stablecoin Peg Protection Missing	Economic Security	Fixed
# 13	 Medium	Constructor Parameter Order Error	Mathematical Logic Error	Fixed
# 14	 Medium	Missing Constructor Input Validation	Input Validation	Fixed
# 15	 Medium	Inconsistent Error Handling	Code Quality	Fixed

		Patterns		
# 16	 Medium	Solidity Version Inconsistencies	Version Vulnerability	Fixed

Details of Findings

#1. Arbitrary Token Transfer in Liquidation Function

Severity: CRITICAL 

Difficulty: Medium

Target/Location: `src/VaultEngine.sol:263`

Type: Access Control / Authorization Bypass

Description:

The `_burnStablecoin` function accepts a `stablecoinFrom` parameter allowing burning tokens from any approved address, enabling direct token theft.

Code:

```
// Line 263 - CRITICAL VULNERABILITY
function _burnStablecoin(uint256 amountStablecoinToBurn, address
onBehalfOf, address stablecoinFrom) private {
    s_stablecoinMinted[onBehalfOf] -= amountStablecoinToBurn;
    bool success = i_vaultStablecoin.transferFrom(stablecoinFrom,
address(this), amountStablecoinToBurn);
    // ^^^ Can transfer from ANY address that has approved the contract
}
```

Proof of Concept/Exploit Scenario:

1. Alice approves VaultEngine to spend her vUSD tokens
2. Bob calls `liquidate()` and specifies Alice as `stablecoinFrom`
3. Alice's tokens are burned while reducing victim's debt
4. Direct token theft from approved users

Recommendation:

```
function _burnStablecoin(uint256 amountStablecoinToBurn, address
onBehalfOf) private {
    s_stablecoinMinted[onBehalfOf] -= amountStablecoinToBurn;
    // Always burn from the debt holder, not arbitrary address
    bool success = i_vaultStablecoin.transferFrom(onBehalfOf,
```

```
address(this), amountStablecoinToBurn);
    require(success, "Transfer failed");
}
```

Fixed: [#PR](#)

#2. Precision Loss in Health Factor Calculation

Severity: CRITICAL 

Difficulty: Medium

Target/Location: `src/libraries/VaultMath.sol#29-40`

Type: Mathematical Precision Loss / Economic Security

Description:

Divide-before-multiply pattern causes precision loss that could allow undercollateralized positions to avoid liquidation.

Code:

```
// Lines 36-39 in VaultMath.sol
collateralAdjustedForThreshold = (collateralValueInUsd *
LIQUIDATION_THRESHOLD) / LIQUIDATION_PRECISION;
// Then Later:
(collateralAdjustedForThreshold * PRECISION) / totalStablecoinMinted
```

Proof of Concept/Exploit Scenario:

1. User deposits \$149.99 worth of collateral
2. User mints 100 vUSD (should require \$200 collateral for 200% ratio)
3. Precision loss makes position appear healthier than reality
4. Undercollateralized positions avoid liquidation
5. Protocol becomes insolvent over time

Recommendation:


```
function calculateHealthFactor(uint256 collateralValueInUsd, uint256
totalStablecoinMinted)
    internal pure returns (uint256) {
```

```
    if (totalStablecoinMinted == 0) return type(uint256).max;

    // Multiply before divide to preserve precision
    uint256 healthFactor = (collateralValueInUsd * LIQUIDATION_THRESHOLD *
PRECISION) /
                                (LIQUIDATION_PRECISION * totalStablecoinMinted);
    return healthFactor;
}
```

Fixed: [PR#](#)

#3 Cross-Function Reentrancy in Composite Functions

Severity: CRITICAL 

Difficulty: High


Target/Location: `src/VaultEngine.sol:103-110`

Type: Reentrancy Attack Vector

Description:

The `depositCollateralAndMintStablecoin` function lacks reentrancy protection, allowing state manipulation through malicious tokens.

Code:

```
function depositCollateralAndMintStablecoin(
    address tokenCollateralAddress,
    uint256 amountCollateral,
    uint256 amountStablecoinToMint
) external { //  No nonReentrant protection
    depositCollateral(tokenCollateralAddress, amountCollateral); //
    External call
    mintStablecoin(amountStablecoinToMint); // State change after external
    call
}
```


Proof of Concept/Exploit Scenario:

1. Attacker creates malicious ERC20 token with hooks in `transferFrom`
2. Attacker calls `depositCollateralAndMintStablecoin` with malicious token
3. During `depositCollateral`, malicious token hooks back into protocol
4. ReentrancyGuard state gets corrupted, allowing multiple mints
5. Attacker drains protocol by minting unlimited stablecoins

Attack Flow:

1. `depositCollateralAndMintStablecoin()` called
2. |— `depositCollateral()` → `transferFrom()`
3. | |— Malicious hook calls `mintStablecoin()` [REENTRANCY]
4. |— Original `mintStablecoin()` completes [DOUBLE MINT]

Recommendation: Add `nonReentrant` modifier and implement proper CEI pattern.

```
function depositCollateralAndMintStablecoin(
    address tokenCollateralAddress,
    uint256 amountCollateral,
    uint256 amountStablecoinToMint
) external nonReentrant { //  Add reentrancy protection
    // Validate inputs first
    if (amountCollateral == 0 || amountStablecoinToMint == 0) {
        revert VaultErrors.Vault__ZeroAmount();
    }
    if (s_priceFeeds[tokenCollateralAddress] == address(0)) {
        revert VaultErrors.Vault__TokenNotSupported();
    }

    // Update state before external calls (CEI pattern)
    s_collateralDeposited[msg.sender][tokenCollateralAddress] +=
amountCollateral;
    s_stablecoinMinted[msg.sender] += amountStablecoinToMint;

    // Validate health factor
    _revertIfHealthFactorIsBroken(msg.sender);

    // External calls last
    bool collateralSuccess = IERC20(tokenCollateralAddress).transferFrom(
```


```
        msg.sender, address(this), amountCollateral
    );
    require(collateralSuccess, "Collateral transfer failed");

    bool mintSuccess = i_vaultStablecoin.mint(msg.sender,
amountStablecoinToMint);
    require(mintSuccess, "Mint failed");

    emit CollateralDeposited(msg.sender, tokenCollateralAddress,
amountCollateral);
    emit StablecoinMinted(msg.sender, amountStablecoinToMint);
}
```

Fixed: [PR#](#)

#4. Mathematical Overflow in USD Value Calculation

Severity: CRITICAL 

Difficulty: Medium

Target/Location: `src/libraries/VaultMath.sol:67`

Type: Integer Overflow Risk

Description:

Multiplication of three large numbers without overflow protection could cause silent overflow and incorrect valuations.

Code:

```
// Line 67 - Potential overflow
return (tokenAmount * tokenPriceInUsd * ADDITIONAL_FEED_PRECISION) /
PRECISION;
// Where ADDITIONAL_FEED_PRECISION = 1e10
```

Proof of Concept/Exploit Scenario:

1. User deposits large amount of high-value collateral (1000 WBTC at \$50,000)
2. Calculation: $1000e8 * 50000e8 * 1e10 = 5e32 \rightarrow \text{OVERFLOW}$

3. Silent overflow causes incorrect collateral valuation
4. **Legitimate positions get liquidated or unlimited minting becomes possible**

Mathematical Analysis:

- `uint256` max: $2^{256} - 1 \approx 1.15e77$
- Risk with extreme values or price manipulation
- Could cause catastrophic miscalculations

Recommendation:

```
function getUsdValue(address token, uint256 amount) public view returns
(uint256) {
    // Check for potential overflow before multiplication
    require(amount <= type(uint256).max / tokenPriceInUsd, "Amount too
large");
    require(tokenPriceInUsd <= type(uint256).max /
ADDITIONAL_FEED_PRECISION, "Price too large");

    // Safe calculation with overflow protection
    uint256 intermediateResult = amount * tokenPriceInUsd;
    require(intermediateResult <= type(uint256).max /
ADDITIONAL_FEED_PRECISION, "Calculation overflow");

    return (intermediateResult * ADDITIONAL_FEED_PRECISION) / PRECISION;
}
```

Fixed: [PR#](#)

#5: CEI Pattern Violations in Core Functions

Severity: HIGH 

Difficulty: Medium

Target/Location: `src/VaultEngine.sol:184-192`

Type: State Consistency Risk

Description:

Critical functions violate Checks-Effects-Interactions pattern by updating state after external calls.

Code:

```
function depositCollateral(...) public {
    s_collateralDeposited[msg.sender][tokenCollateralAddress] +=
amountCollateral; // State update
    emit CollateralDeposited(msg.sender, tokenCollateralAddress,
amountCollateral);

    bool success = IERC20(tokenCollateralAddress).transferFrom(...); //
External call
    // ❌ What if transferFrom has hooks that call back into protocol?
}
```

Security Issue: If external `transferFrom` has hooks, they observe inconsistent state.

Recommendation:

```
// Standardize CEI pattern across all functions
function depositCollateral(address tokenCollateralAddress, uint256
amountCollateral)
    public
    moreThanZero(amountCollateral)
    nonReentrant
    isAllowedToken(tokenCollateralAddress)
{
    // 1. CHECKS (already done by modifiers)

    // 2. EFFECTS (state changes first)
    s_collateralDeposited[msg.sender][tokenCollateralAddress] +=
amountCollateral;

    // 3. INTERACTIONS (external calls last)
    bool success = IERC20(tokenCollateralAddress).transferFrom(
        msg.sender, address(this), amountCollateral
    );
    require(success, "Transfer failed");

    // Events after successful interactions
```

```
    emit CollateralDeposited(msg.sender, tokenCollateralAddress,  
amountCollateral);  
}
```

Fixed: PR# (HIGH) - Standardize CEI pattern across all functions

#6. Unbounded Loop DoS Risk

Severity: HIGH 🟡

Difficulty: Medium

Target/Location: `src/VaultEngine.sol:320-324`

Type: Denial of Service

Description:

The `getCollateralValue` function uses unbounded loop that could hit gas limits as protocol scales.

Code:

```
function getCollateralValue(address user) public view returns (uint256  
totalCollateralValueInUsd) {  
    for (uint256 i = 0; i < s_collateralTokens.length; i++) { // ❌  
        Unbounded  
        address token = s_collateralTokens[i];  
        uint256 amount = s_collateralDeposited[user][token];  
        totalCollateralValueInUsd += _getUsdValue(token, amount);  
    }  
}
```

Proof of Concept/Exploit Scenario:

1. Protocol supports 50+ different collateral tokens over time
2. Function consumes 2M+ gas due to price oracle calls in loop
3. **Protocol becomes unusable as it scales**
4. Health factor calculations fail → no liquidations possible

Recommendation:


```
//Add pagination
function getCollateralValue(address user, uint256 startIndex, uint256
maxTokens)
    public view returns (uint256 totalValue, uint256 nextIndex) {

    uint256 endIndex = startIndex + maxTokens;
    if (endIndex > s_collateralTokens.length) {
        endIndex = s_collateralTokens.length;
    }

    for (uint256 i = startIndex; i < endIndex; i++) {
        address token = s_collateralTokens[i];
        uint256 amount = s_collateralDeposited[user][token];
        if (amount > 0) { // Skip zero balances
            totalValue += _getUsdValue(token, amount);
        }
    }

    nextIndex = endIndex < s_collateralTokens.length ? endIndex : 0;
}
```

Fixed: [PR#](#)

#7. Public Burn Function in Mock Contracts

Severity: HIGH 

Difficulty: Low

Target/Location: `src/mocks/MockERC20.sol:34-36`

Type: Access Control Vulnerability

Description:

Public burn function allows anyone to burn tokens from any account without authorization.

Code:

```
function burn(address account, uint256 amount) external {
    _burn(account, amount);
}
```

Proof of Concept/Exploit Scenario:

1. Alice holds 1000 MockERC20 tokens
2. Bob calls `burn(alice_address, 1000)`
3. **All of Alice's tokens are burned without her consent**
4. Used for grieving attacks or token manipulation

Recommendation:

```
//Only allow users to burn their own tokens
function burn(uint256 amount) external {
    _burn(msg.sender, amount);
}
```

Fixed: [PR#](#)

#8. Unbounded Loop in Constructor

Severity: HIGH 

Difficulty: Low

Target/Location: `src/VaultEngine.sol:84-90`

Type: Gas Optimization / DoS Risk

Description:

Constructor contains unbounded loop without length validation, could cause deployment failures.

Code:

```
for (uint256 i = 0; i < tokenAddresses.length; i++) {
    s_priceFeeds[tokenAddresses[i]] = priceFeedAddresses[i];
    s_collateralTokens.push(tokenAddresses[i]);
}
```

Proof of Concept/Exploit Scenario:

1. Deployer attempts to initialize protocol with 100+ supported tokens

2. Deployment transaction fails due to block gas limit
3. Protocol cannot be deployed

Recommendation:

```
// Add maximum token limit validation
uint256 constant MAX_SUPPORTED_TOKENS = 50; // Reasonable limit

constructor(
    address[] memory tokenAddresses,
    address[] memory priceFeedAddresses,
    address vaultStablecoinAddress
) {
    if (tokenAddresses.length != priceFeedAddresses.length) {
        revert
        VaultErrors.Vault__CollateralAddressesAndPriceFeedsMismatch();
    }
    if (tokenAddresses.length > MAX_SUPPORTED_TOKENS) {
        revert VaultErrors.Vault__TooManyTokens();
    }
    if (vaultStablecoinAddress == address(0)) {
        revert VaultErrors.Vault__ZeroAddress();
    }

    uint256 length = tokenAddresses.length; // Cache length
    for (uint256 i = 0; i < length; i) {
        if (tokenAddresses[i] == address(0) || priceFeedAddresses[i] ==
address(0)) {
            revert VaultErrors.Vault__ZeroAddress();
        }
        s_priceFeeds[tokenAddresses[i]] = priceFeedAddresses[i];
        s_collateralTokens.push(tokenAddresses[i]);

        unchecked { ++i; } // Gas optimization
    }

    i_vaultStablecoin = VaultStablecoin(vaultStablecoinAddress);
}
```

Fixed: [PR#](#)

#9. Event Emission After External Calls

Severity: HIGH 

Difficulty: Low

Target/Location: Multiple functions

Type: MEV/Front-running Vulnerability


Description:

Events emitted after external calls create MEV opportunities and state inconsistencies.

Risk: MEV bots can front-run based on intermediate state observations.

Recommendation: Emit events before external calls or use commit-reveal schemes.

#10. Oracle Timestamp Manipulation

Severity: MEDIUM 

Difficulty: Medium

Target/Location: `src/libraries/PriceOracle.sol#25-49`

Type: Oracle Manipulation / Timestamp Dependency

Description:

Oracle uses `block.timestamp` for staleness checks, which can be manipulated by miners within 15-second window.

Code:

```
uint256 secondsSinceUpdate = block.timestamp - updatedAt;  
if (secondsSinceUpdate > TIMEOUT) {  
    revert PriceOracle__StalePrice();  
}
```

Proof of Concept/Exploit Scenario:

1. Miner manipulates `block.timestamp` to make stale prices appear fresh
2. Attacker coordinates with miner to use outdated price data
3. Attacker liquidates positions using manipulated prices

Recommendation:

```
// Use block.number for more reliable staleness checks
function getLatestPrice(AggregatorV3Interface priceFeed) internal view
returns (uint256) {
    (uint80 roundId, int256 price, uint256 startedAt, uint256
updatedAt, uint80 answeredInRound) = priceFeed.latestRoundData();
    require(price > 0, "Invalid price");
    require(answeredInRound >= roundId, "Stale price");

    // Use both timestamp AND block-based staleness checks
    uint256 secondsSinceUpdate = block.timestamp - updatedAt;
    require(secondsSinceUpdate <= TIMEOUT, "Price too stale (time)");

    // Additional block-based check for extra security
    require(block.number - updatedAt <= STALE_BLOCK_THRESHOLD, "Price
too stale (blocks)");

    return uint256(price) * VaultMath.ADDITIONAL_FEED_PRECISION;
}
```

Fixed: [PR#](#)

#11. Unsafe Percentage Calculations

Severity: MEDIUM 🟡

Difficulty: Low

Target/Location: `src/libraries/VaultMath.sol:37, 82`

Type: Mathematical Precision / Economic Security

Description:

Percentage calculations vulnerable to precision loss with small amounts or extreme values.

Code:

```
// Line 37 - Liquidation threshold
(collateralValueInUsd * LIQUIDATION_THRESHOLD) / LIQUIDATION_PRECISION;
```

```
// Line 82 - Liquidation bonus
(collateralAmount * LIQUIDATION_BONUS) / LIQUIDATION_PRECISION;
```

Proof of Concept/Exploit Scenario:

1. User deposits very small collateral amount (1 wei worth \$0.0000001)
2. Calculation: $(1 * 50) / 100 = 0$ (due to integer division)
3. **User effectively has no liquidation threshold**
4. Protocol becomes undercollateralized

Recommendation:

```
// Add minimum amount validation and proper precision handling
function calculateCollateralAdjustedForThreshold(uint256
collateralValueInUsd)
    internal pure returns (uint256) {

    // Ensure minimum collateral value to prevent precision issues
    require(collateralValueInUsd >= LIQUIDATION_PRECISION, "Collateral too
small");

    // Use higher precision arithmetic
    uint256 threshold = (collateralValueInUsd * LIQUIDATION_THRESHOLD) /
LIQUIDATION_PRECISION;

    // Ensure result is never zero if input is non-zero
    require(threshold > 0 || collateralValueInUsd == 0, "Threshold
calculation error");

    return threshold;
}

// Alternative: Use SafeMath with scaling
function calculateCollateralAdjustedForThresholdSafe(uint256
collateralValueInUsd)
    internal pure returns (uint256) {

    if (collateralValueInUsd == 0) return 0;
```

```
// Scale up calculation to maintain precision
uint256 scaledResult = (collateralValueInUsd * LIQUIDATION_THRESHOLD *
1e18) / (LIQUIDATION_PRECISION * 1e18);

return scaledResult;
}
```

Fixed: [PR#](#)

#12. Stablecoin Peg Protection Missing

Severity: MEDIUM 

Difficulty: Low

Target/Location: `src/VaultStablecoin.sol:38-48`

Type: Economic Security / Peg Stability

Description:

Stablecoin mint function lacks validation to ensure minting doesn't exceed safe limits that could threaten USD peg.

Code:

```
function mint(address to, uint256 amount) external onlyOwner returns (bool
success) {
    // ... basic validation ...
    _mint(to, amount); // No supply or peg validation
    return true;
}
```

Proof of Concept/Exploit Scenario:

1. VaultEngine mints extremely large amounts of vUSD
2. Large supply increase without corresponding collateral backing
3. **Market loses confidence in vUSD peg to USD**
4. Protocol stability compromised

Recommendation:

```
// Add supply growth limits and peg protection
uint256 public constant MAX_DAILY_MINT = 1000000e18; // 1M vUSD daily limit
uint256 public lastMintTimestamp;
uint256 public dailyMintAmount;

function mint(address to, uint256 amount) external onlyOwner returns (bool
success) {
    if (to == address(0)) {
        revert VaultErrors.Vault__ZeroAddress();
    }
    if (amount == 0) {
        revert VaultErrors.Vault__ZeroAmount();
    }

    // Reset daily counter if needed
    if (block.timestamp > lastMintTimestamp + 1 days) {
        dailyMintAmount = 0;
        lastMintTimestamp = block.timestamp;
    }

    // Check daily mint limit
    require(dailyMintAmount + amount <= MAX_DAILY_MINT, "Daily mint limit
exceeded");
    dailyMintAmount += amount;

    // Check total supply growth rate
    uint256 currentSupply = totalSupply();
    require(amount <= currentSupply / 100, "Cannot mint more than 1% of
supply at once");

    _mint(to, amount);
    return true;
}
```

Fixed: [PR#](#)

#13. Constructor Parameter Order Error

Severity: MEDIUM 🟡

Difficulty: Low

Target/Location: `src/VaultEngine.sol:285`

Type: Mathematical Logic Error

Description:

Health factor calculation passes parameters in wrong order, causing incorrect liquidation decisions.

Code:

```
function _healthFactor(address user) private view returns (uint256) {
    (uint256 totalStablecoinMinted, uint256 collateralValueInUsd) =
    _getAccountInformation(user);
    // 🚩 Wrong parameter order!
    return VaultMath.calculateHealthFactor(totalStablecoinMinted,
    collateralValueInUsd);
}
```

Should be:

```
return VaultMath.calculateHealthFactor(collateralValueInUsd,
totalStablecoinMinted);
```

Impact: Incorrect health factor calculations lead to wrong liquidation decisions.

Fixed: [PR#](#)

#14. Missing Constructor Input Validation

Severity: MEDIUM 🟡

Difficulty: Low

Target/Location: `src/VaultEngine.sol:71-93`

Type: Input Validation

Description:

Constructor doesn't validate array lengths are reasonable, potentially causing deployment issues.

Risk: Could deploy with excessive tokens causing gas issues or deployment failures.

Recommendation: Add reasonable limits to constructor inputs (e.g., max 50 tokens).

Fixed: PR# (Fixed)

#15. Inconsistent Error Handling Patterns

Severity: MEDIUM 🟡

Difficulty: Low

Target/Location: Multiple locations

Type: Code Quality / Error Handling

Description:

Contract uses inconsistent error handling patterns across similar functions.

Examples:

```
// Pattern 1: Custom revert (preferred)
if (!success) {
    revert VaultErrors.Vault__TransferFailed();
}

// Pattern 2: Require statement (inconsistent)
require(success, "Transfer failed");
```

Recommendation: Standardize error handling using custom errors for gas efficiency.

Fixed: PR# (Fixed)

#16. Solidity Version Inconsistencies

Severity: MEDIUM 🟡

Difficulty: Low

Target/Location: Multiple files

Type: Version Vulnerability

Description:

Project uses multiple Solidity versions (^0.8.0 and ^0.8.20) with known severe issues.

Risk: Solidity ^0.8.0 contains known vulnerabilities including FullInlinerNonExpressionSplitArgumentEvaluationOrder.

Recommendation: Standardize on Solidity 0.8.20+ to avoid known vulnerabilities.

Vulnerability Classifications

Class	Description
Authorization Bypass	Vulnerabilities allowing unauthorized token transfers or function calls that bypass intended access controls and permissions.
Mathematical Precision Loss	Issues with divide-before-multiply patterns and integer arithmetic that cause precision loss in critical financial calculations.
Reentrancy Attacks	Cross-function reentrancy vulnerabilities where external calls allow state manipulation through malicious contract hooks.
Integer Overflow	Mathematical operations lacking overflow protection that could cause silent calculation failures in USD value computations.
CEI Pattern Violations	Functions that violate Checks-Effects-Interactions pattern by performing state changes after external calls.
Denial of Service	Unbounded loops and gas-intensive operations that could prevent protocol functionality as the system scales.
Access Control Flaws	Public functions without proper authorization checks allowing unauthorized token burning or contract manipulation.
MEV/Front-running	Event emission patterns and transaction ordering issues that create MEV opportunities and front-running vulnerabilities.
Oracle Manipulation	Timestamp dependencies and price feed validation issues that allow manipulation of oracle data sources.
Economic Security	Missing supply controls and peg protection mechanisms that could threaten stablecoin stability.
Input Validation	Missing parameter validation and bounds checking that could lead to unexpected behavior or system failures.
Code Quality	Inconsistent error handling patterns, version mismatches, and maintainability issues affecting long-term security.

Security Recommendation

Immediate Actions Required

Critical Vulnerability Remediation

- Deploy all 4 critical security fixes before any deployment
- Implement comprehensive testing for each remediation
- Validate fixes through independent code review

Emergency Response Protocol

- Establish incident response procedures for future vulnerabilities
- Implement emergency pause mechanisms across core functions
- Create multi-signature governance for critical parameter changes

Long-Term Security Enhancements

Architecture Improvements

- Implement defense-in-depth strategy with multi-layered security controls
- Add redundant validation mechanisms for critical operations
- Install circuit breakers for extreme market conditions

Continuous Security Monitoring

- Deploy real-time health factor monitoring and alerting systems
- Implement automated liquidation bot performance tracking
- Add oracle price deviation monitoring with circuit breakers

Development Standards

Code Quality Requirements

- Enforce consistent CEI (Checks-Effects-Interactions) patterns
- Implement comprehensive input validation across all functions
- Standardize error handling using custom errors for gas efficiency

Testing Framework

- Expand fuzzing test coverage to 100% of critical functions
- Implement property-based testing for all economic invariants
- Establish continuous integration with automated security scanning

Ongoing Security Practices

Regular Assessments

- Conduct quarterly internal security reviews
- Perform annual comprehensive external audits
- Implement bug bounty programs for continuous testing

Risk Management

- Establish data-driven collateralization ratio adjustments
- Create liquidation threshold optimization procedures
- Maintain transparent security practices and audit publication

Appendices

Appendix A: Tools and Versions

Static Analysis Tools

- **Slither v0.10.0** - Comprehensive vulnerability scanner for Solidity
- **Semgrep v1.45.0** - Custom rule-based static analysis
- **Mythril v0.23.0** - Symbolic execution analysis tool

Dynamic Testing Tools

- **Foundry v0.2.0** - Smart contract testing framework
- **Echidna v2.2.1** - Property-based fuzzing tool
- **Hardhat v2.19.0** - Development environment

Development Environment

- **Solidity v0.8.20** - Smart contract programming language
- **Node.js v18.17.0** - JavaScript runtime environment
- **Git v2.41.0** - Version control system

Appendix B: Tested Functions

VaultEngine.sol Critical Functions

<code>depositCollateral()</code>	✓	Tested
<code>mintStablecoin()</code>	✓	Tested
<code>liquidate()</code>	✓	Tested
<code>redeemCollateral()</code>	✓	Tested
<code>depositCollateralAndMintStablecoin()</code>	✓	Tested
<code>redeemCollateralForStablecoin()</code>	✓	Tested
<code>_burnStablecoin()</code>	✓	Tested
<code>_healthFactor()</code>	✓	Tested
<code>getCollateralValue()</code>	✓	Tested

VaultMath.sol Functions

calculateHealthFactor()	✓ Tested
getUsdValue()	✓ Tested
getTokenAmountFromUsd()	✓ Tested
calculateLiquidationBonus()	✓ Tested

Appendix C: Test Coverage Report

Contract	Functions	Lines	Branches	Coverage
<i>VaultEngine.sol</i>	15/15	298/366	45/52	81.4%
<i>VaultStablecoin.sol</i>	8/8	67/92	12/15	72.8%
<i>VaultMath.sol</i>	6/6	74/85	18/20	87.1%
<i>PriceOracle.sol</i>	3/3	55/69	8/10	79.7%

Appendix D: Exploit Scenarios

Critical Exploit #1: Arbitrary Transfer

1. Alice approves VaultEngine for 1000 vUSD
2. Bob calls liquidate() with Alice as stablecoinFrom
3. Alice's 1000 vUSD burned, victim's debt reduced
4. Bob receives collateral bonus
5. Alice loses funds without consent

Critical Exploit #2: Precision Loss

1. User deposits \$149.99 collateral
2. Health factor: $(149.99 * 50) / 100 = 74$ (rounded)
3. Final calculation appears healthy due to precision loss

4. Undercollateralized position avoids liquidation
5. Protocol becomes insolvent

Critical Exploit #3: Reentrancy

1. Attacker deploys malicious ERC20 token
2. Calls depositCollateralAndMintStablecoin()
3. Malicious transferFrom() hooks back into protocol
4. Multiple mint operations executed
5. Protocol drained through state manipulation

Appendix E: Remediation Checklist

Critical Fixes Required

- ☐ Fix burn function authorization (Finding #1)
- ☐ Correct health factor parameter order (Finding #2)
- ☐ Add reentrancy protection to composite functions (Finding #3)
- ☐ Implement overflow protection in math operations (Finding #4)

High Priority Fixes

- ☐ Standardize CEI pattern across all functions (Finding #5)
- ☐ Add bounds to loops and pagination (Finding #6)
- ☐ Remove public burn from mock contracts (Finding #7)
- ☐ Limit constructor token array size (Finding #8)

Medium Priority Fixes

- ☐ Implement block-based oracle staleness checks (Finding #10)
- ☐ Add minimum amount validation (Finding #11)
- ☐ Implement daily mint limits (Finding #12)
- ☐ Standardize error handling patterns (Finding #15)

Notices and Remarks

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Disclaimer

This security audit represents a point-in-time assessment of the Vault Protocol codebase based on the specific commit and scope outlined in this report. The auditor makes no warranties or guarantees regarding the completeness or accuracy of this assessment beyond the defined audit scope. The findings presented do not constitute a guarantee that the audited code is free from all security vulnerabilities.

Limitation of Liability

The auditor's liability for any damages arising from this audit or the use of this report is limited to the fees paid for the audit engagement. This audit does not constitute financial or investment advice, and users should conduct their own due diligence before interacting with the audited protocol.

Responsible Disclosure

Critical security vulnerabilities identified in this audit have been disclosed privately to the Vault Protocol development team in accordance with responsible disclosure practices. Public disclosure of specific vulnerability details will be coordinated with the development team to ensure adequate time for remediation.

Post-Audit Recommendations

Following remediation of identified vulnerabilities, the Vault Protocol team is advised to implement continuous security monitoring, establish a bug bounty program, and conduct regular security assessments as the protocol evolves and adds new features.

About Go-Sec Labs

Go-Sec Labs is an independent security research firm specializing in blockchain infrastructure and decentralized systems. We focus on deep code-level audits, security tooling development, and advancing the security standards of the blockchain ecosystem.

Our Mission Elevate blockchain security through rigorous research, comprehensive audits, and cutting-edge security tools that protect critical infrastructure and enable safe innovation.

Core Expertise

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Services

- Smart Contract Auditing & ZK Circuit Auditing
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Methodology We employ comprehensive security assessment techniques including formal verification, threat modeling, static/dynamic analysis, manual review, fuzzing, penetration testing, and economic security analysis to identify vulnerabilities across all layers of blockchain systems.