SMART CONTRACT AUDIT REPORT

for

Venus Vault Upgrade

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Contents

1 Introduction

Given the opportunity to review the design document and related smart contract source code of the `Vault Upgrade` feature in `Venus`, we outline in the report our systematic approach to evaluate potential security issues in the smart contract implementation, expose possible semantic inconsistencies between smart contract code and design document, and provide additional suggestions or recommendations for improvement. Our results show that the given version of smart contracts can be further improved due to the presence of several issues related to either security or performance. This document outlines our audit results.

1.1 About Venus Vault Upgrade

The `Venus` protocol is designed to enable a complete algorithmic money market protocol on `Binance Smart Chain (BSC)`. `Venus` enables users to utilize their cryptocurrencies by supplying collateral to the protocol that may be borrowed by pledging over-collateralized cryptocurrencies. The audited `Venus Vault Upgrade` feature makes the `VRTVault`, `VAIVault`, and `XVSVault` pausable by introducing the `AccessControlManager` mechanism. Furthermore, the `VRTVault` implements a new state variable, i.e., `lastAccruingBlock` to stop the `VRT` rewarding from a specific block number. The basic information of the audited protocol is as follows:

Table 1.1: Basic Information of The Venus Vault Upgrade

Item	Description
Name	Venus
Website	https://venus.io/
Type	EVM Smart Contract
Platform	Solidity
Audit Method	Whitebox
Latest Audit Report	April 19, 2023

In the following, we show the Git repository of reviewed files and the commit hash value used in this audit:

- https://github.com/VenusProtocol/venus-protocol/pull/236 (f801e16)

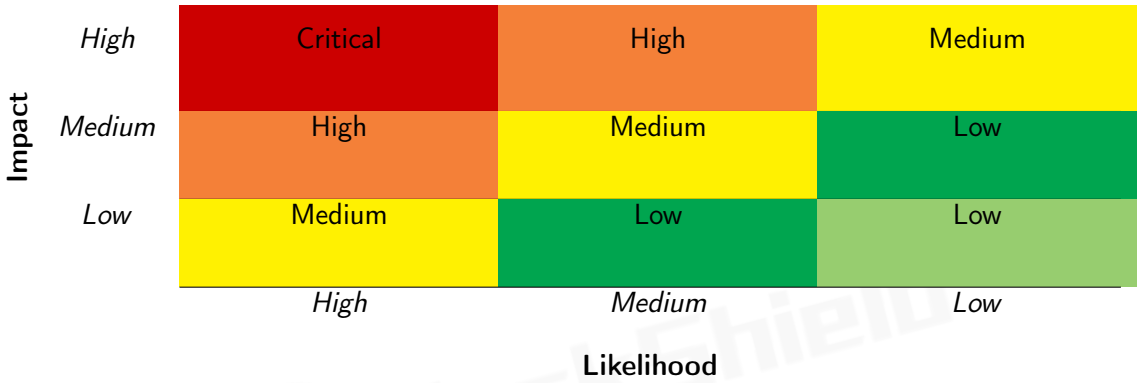
And here is the commit ID after fixes for the issues found in the audit have been checked in:

- https://github.com/VenusProtocol/venus-protocol/pull/236 (dddbefd)

1.2 About PeckShield

PeckShield Inc. [7] is a leading blockchain security company with the goal of elevating the security, privacy, and usability of current blockchain ecosystems by offering top-notch, industry-leading services and products (including the service of smart contract auditing). We are reachable at Telegram (https://t.me/peckshield), Twitter (http://twitter.com/peckshield), or Email (contact@peckshield.com).

Table 1.2: Vulnerability Severity Classification



1.3 Methodology

To standardize the evaluation, we define the following terminology based on OWASP Risk Rating Methodology [6]:

- Likelihood represents how likely a particular vulnerability is to be uncovered and exploited in the wild;
- Impact measures the technical loss and business damage of a successful attack;
- Severity demonstrates the overall criticality of the risk.

Likelihood and impact are categorized into three ratings: *H*, *M* and *L*, i.e., *high*, *medium* and *low* respectively. Severity is determined by likelihood and impact and can be classified into four categories accordingly, i.e., *Critical*, *High*, *Medium*, *Low* shown in Table 1.2.

Table 1.3: The Full List of Check Items

Category	Check Item
Basic Coding Bugs	Constructor Mismatch
	Ownership Takeover
	Redundant Fallback Function
	Overflows & Underflows
	Reentrancy
	Money-Giving Bug
	Blackhole
	Unauthorized Self-Destruct
	Revert DoS
	Unchecked External Call
	Gasless Send
	Send Instead Of Transfer
	Costly Loop
	(Unsafe) Use Of Untrusted Libraries
	(Unsafe) Use Of Predictable Variables
	Transaction Ordering Dependence
	Deprecated Uses
Semantic Consistency Checks	Semantic Consistency Checks
Advanced DeFi Scrutiny	Business Logics Review
	Functionality Checks
	Authentication Management
	Access Control & Authorization
	Oracle Security
	Digital Asset Escrow
	Kill-Switch Mechanism
	Operation Trails & Event Generation
	ERC20 Idiosyncrasies Handling
	Frontend-Contract Integration
	Deployment Consistency
	Holistic Risk Management
Additional Recommendations	Avoiding Use of Variadic Byte Array
	Using Fixed Compiler Version
	Making Visibility Level Explicit
	Making Type Inference Explicit
	Adhering To Function Declaration Strictly
	Following Other Best Practices

To evaluate the risk, we go through a list of check items and each would be labeled with a severity category. For one check item, if our tool or analysis does not identify any issue, the contract is considered safe regarding the check item. For any discovered issue, we might further deploy contracts on our private testnet and run tests to confirm the findings. If necessary, we would additionally build a PoC to demonstrate the possibility of exploitation. The concrete list of check items is shown in Table 1.3.

In particular, we perform the audit according to the following procedure:

- Basic Coding Bugs: We first statically analyze given smart contracts with our proprietary static code analyzer for known coding bugs, and then manually verify (reject or confirm) all the issues found by our tool.
- Semantic Consistency Checks: We then manually check the logic of implemented smart contracts and compare with the description in the white paper.
- Advanced DeFi Scrutiny: We further review business logics, examine system operations, and place DeFi-related aspects under scrutiny to uncover possible pitfalls and/or bugs.
- Additional Recommendations: We also provide additional suggestions regarding the coding and development of smart contracts from the perspective of proven programming practices.

To better describe each issue we identified, we categorize the findings with Common Weakness Enumeration (CWE-699) [5], which is a community-developed list of software weakness types to better delineate and organize weaknesses around concepts frequently encountered in software development. Though some categories used in CWE-699 may not be relevant in smart contracts, we use the CWE categories in Table 1.4 to classify our findings.

1.4 Disclaimer

Note that this security audit is not designed to replace functional tests required before any software release, and does not give any warranties on finding all possible security issues of the given smart contract(s) or blockchain software, i.e., the evaluation result does not guarantee the nonexistence of any further findings of security issues. As one audit-based assessment cannot be considered comprehensive, we always recommend proceeding with several independent audits and a public bug bounty program to ensure the security of smart contract(s). Last but not least, this security audit should not be used as investment advice.

Table 1.4: Common Weakness Enumeration (CWE) Classifications Used in This Audit

Category	Summary
Configuration	Weaknesses in this category are typically introduced during the configuration of the software.
Data Processing Issues	Weaknesses in this category are typically found in functionality that processes data.
Numeric Errors	Weaknesses in this category are related to improper calculation or conversion of numbers.
Security Features	Weaknesses in this category are concerned with topics like authentication, access control, confidentiality, cryptography, and privilege management. (Software security is not security software.)
Time and State	Weaknesses in this category are related to the improper management of time and state in an environment that supports simultaneous or near-simultaneous computation by multiple systems, processes, or threads.
Error Conditions, Return Values, Status Codes	Weaknesses in this category include weaknesses that occur if a function does not generate the correct return/status code, or if the application does not handle all possible return/status codes that could be generated by a function.
Resource Management	Weaknesses in this category are related to improper management of system resources.
Behavioral Issues	Weaknesses in this category are related to unexpected behaviors from code that an application uses.
Business Logics	Weaknesses in this category identify some of the underlying problems that commonly allow attackers to manipulate the business logic of an application. Errors in business logic can be devastating to an entire application.
Initialization and Cleanup	Weaknesses in this category occur in behaviors that are used for initialization and breakdown.
Arguments and Parameters	Weaknesses in this category are related to improper use of arguments or parameters within function calls.
Expression Issues	Weaknesses in this category are related to incorrectly written expressions within code.
Coding Practices	Weaknesses in this category are related to coding practices that are deemed unsafe and increase the chances that an exploitable vulnerability will be present in the application. They may not directly introduce a vulnerability, but indicate the product has not been carefully developed or maintained.

2 Findings

2.1 Summary

Here is a summary of our findings after analyzing the design and implementation of the Venus's Vault Upgrade feature. During the first phase of our audit, we study the smart contract source code and run our in-house static code analyzer through the codebase. The purpose here is to statically identify known coding bugs, and then manually verify (reject or confirm) issues reported by our tool. We further manually review business logic, examine system operations, and place DeFi-related aspects under scrutiny to uncover possible pitfalls and/or bugs.

Severity	# of Findings	
Critical	0	
High	0	
Medium	0	
Low	1	■
Informational	1	■
Total	2	

We have so far identified a list of potential issues: some of them involve subtle corner cases that might not be previously thought of, while others refer to unusual interactions among multiple contracts. For each uncovered issue, we have therefore developed test cases for reasoning, reproduction, and/or verification. After further analysis and internal discussion, we determined a few issues of varying severities need to be brought up and paid more attention to, which are categorized in the above table. More information can be found in the next subsection, and the detailed discussions of each of them are in Section 3.

2.2 Key Findings

Overall, these smart contracts are well-designed and engineered, though the implementation can be improved by resolving the identified issues (shown in Table 2.1), including 1 low-severity vulnerability and 1 informational recommendation.

Table 2.1: Key Venus Vault Upgrade Audit Findings

ID	Severity	Title	Category	Status
PVE-001	Low	Revisited Implementation Logic in VRTVault::_claim()	Business Logic	Fixed
PVE-002	Informational	Improved Sanity Checks For System Parameters	Coding Practices	Fixed

Besides the identified issues, we emphasize that for any user-facing applications and services, it is always important to develop necessary risk-control mechanisms and make contingency plans, which may need to be exercised before the mainnet deployment. The risk-control mechanisms should kick in at the very moment when the contracts are being deployed on mainnet. Please refer to Section 3 for details.

3 Detailed Results

3.1 Revisited Implementation Logic in VRTVault: _claim()

- ID: PVE-001
- Severity: Low
- Likelihood: Low
- Impact: Low
- Target: VRTVault
- Category: Business Logic [4]
- CWE subcategory: CWE-841 [2]

Description

The VRTVault contract is designed for users to deposit the VRT into the VRTVault for a fixed interest rate. To facilitate the claim of the accrued interest from the vault, the VRTVault contract provides an external claim() function for users. While reviewing its logic, we notice the current implementation needs to be revisited.

In the following, we show the related code snippet of the claim() routine. Based on the current implementation, certain corner cases may lead to an undesirable consequence. For example, suppose block.number > lasteAccruingBlock and a user calls claim() to claim rewards from the vault, the accrualStartBlockNumber of this user will be set as block.number (line 217). Then the privileged VIP account calls the setLastAccruingBlock() function to reset the state variable lastAccruingBlock (line 265). If the newly assigned value for lastAccruingBlock is larger than the old one, but smaller than the block.number, the interest during the new lastAccruingBlock and old lastAccruingBlock will never be accumulated for this user.

```
198     /**
199      * @notice claim the accruedInterest of the user's VRTDeposits in the Vault
200      * @param account The account for which to claim rewards
201      */
202     function claim(address account) external nonReentrant isInitialized userHasPosition(
            account) isActive {
203         _claim(account);
204     }
205
```

```
206     /**
207      * @notice Low level claim function
208      * @param account The account for which to claim rewards
209      */
210     function _claim(address account) internal {
211         uint256 accruedInterest = getAccruedInterest(account);
212         if (accruedInterest > 0) {
213             UserInfo storage user = userInfo[account];
214             uint256 vrtBalance = vrt.balanceOf(address(this));
215             require(vrtBalance >= accruedInterest, "Failed to transfer VRT, Insufficient
                    VRT in Vault.");
216             emit Claim(account, accruedInterest);
217             user.accrualStartBlockNumber = getBlockNumber();
218             vrt.safeTransfer(user.userAddress, accruedInterest);
219         }
220     }
```

Listing 3.1: `VRTVault::claim()`

```
262     function setLastAccruingBlock(uint256 _lastAccruingBlock) external {
263         _checkAccessAllowed("setLastAccruingBlock(uint256)");
264         uint256 oldLastAccruingBlock = lastAccruingBlock;
265         lastAccruingBlock = _lastAccruingBlock;
266         emit LastAccruingBlockChanged(oldLastAccruingBlock, _lastAccruingBlock);
267     }
```

Listing 3.2: `VRTVault::setLastAccruingBlock()`

Note the similar issue also exists in the `deposit()` and `withdraw()` routines of the same contract.

Recommendation Revisit the above-mentioned routines to prevent possible interest loss for users.

Status The issue has been fixed by the following pull request: `248`.

3.2 Improved Sanity Checks For System Parameters

- ID: PVE-002
- Severity: Informational
- Likelihood: N/A
- Impact: N/A
- Target: `VRTVault`
- Category: Coding Practices [3]
- CWE subcategory: CWE-1126 [1]

Description

The `VRTVault` contract allows the privileged `VIP` account to stop the `VRT` rewarding from a specific block number. While reviewing the implementation of the `setLastAccruingBlock()` routine, we notice that it can benefit from additional sanity checks.

To elaborate, we show below the related code snippet of the VRTVault contract. Specifically, there is a lack of rationality verification for the input parameter _lastAccruingBlock. If the newly assigned value for lastAccruingBlock is smaller than the old one and smaller than the block.number, then the interest during the block.number and the new lastAccruingBlock may have been accumulated for a user.

```
262     function setLastAccruingBlock(uint256 _lastAccruingBlock) external {
263         _checkAccessAllowed("setLastAccruingBlock(uint256)");
264         uint256 oldLastAccruingBlock = lastAccruingBlock;
265         lastAccruingBlock = _lastAccruingBlock;
266         emit LastAccruingBlockChanged(oldLastAccruingBlock, _lastAccruingBlock);
267     }
```

Listing 3.3: VRTVault::setLastAccruingBlock()

Recommendation Add necessary sanity checks to ensure the newly assigned value for lastAccruingBlock is larger than the block.number if the newly assigned value is smaller than the old one. An example revision is shown as follows:

```
262     function setLastAccruingBlock(uint256 _lastAccruingBlock) external {
263         _checkAccessAllowed("setLastAccruingBlock(uint256)");
264         uint256 oldLastAccruingBlock = lastAccruingBlock;
265         if (_lastAccruingBlock < oldLastAccruingBlock) {
266             require(block.number < _lastAccruingBlock, "...");
267         }
268         lastAccruingBlock = _lastAccruingBlock;
269         emit LastAccruingBlockChanged(oldLastAccruingBlock, _lastAccruingBlock);
270     }
```

Listing 3.4: VRTVault::setLastAccruingBlock()

Status The issue has been fixed by the following pull request: 248.

4 Conclusion

In this audit, we have analyzed the Venus's Vault Upgrade design and implementation. The audited Venus Vault Upgrade feature makes the VRTVault, VAIVault, and XVSVault pausable by introducing the AccessControlManager mechanism. Furthermore, the VRTVault implements a new state variable, i.e., lastAccruingBlock to stop the VRT rewarding from a specific block number. The current code base is well structured and neatly organized. Those identified issues are promptly confirmed and addressed.

Meanwhile, we need to emphasize that Solidity-based smart contracts as a whole are still in an early, but exciting stage of development. To improve this report, we greatly appreciate any constructive feedbacks or suggestions, on our methodology, audit findings, or potential gaps in scope/coverage.

References

[1] MITRE. CWE-1126: Declaration of Variable with Unnecessarily Wide Scope. https://cwe.mitre.org/data/definitions/1126.html.

[2] MITRE. CWE-841: Improper Enforcement of Behavioral Workflow. https://cwe.mitre.org/data/definitions/841.html.

[3] MITRE. CWE CATEGORY: Bad Coding Practices. https://cwe.mitre.org/data/definitions/1006.html.

[4] MITRE. CWE CATEGORY: Business Logic Errors. https://cwe.mitre.org/data/definitions/840.html.

[5] MITRE. CWE VIEW: Development Concepts. https://cwe.mitre.org/data/definitions/699.html.

[6] OWASP. Risk Rating Methodology. https://www.owasp.org/index.php/OWASP_Risk_Rating_Methodology.

[7] PeckShield. PeckShield Inc. https://www.peckshield.com.