SMART CONTRACT AUDIT REPORT

for

Delegate Borrowing in Venus

Prepared By: Xiaomi Huang

PeckShield

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Contact

For more information about this document and its contents, please contact PeckShield Inc.

Name	Xiaomi Huang
Phone	+86 183 5897 7782
Email	contact@peckshield.com

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1 Introduction

Given the opportunity to review the design document and related smart contract source code of the Delegate Borrowing feature, 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 Delegate Borrowing

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 Delegate Borrowing feature allows users to delegate their borrowing power to certain account and allows the privileged owner account to swap one debt position to another for the BNB Bridge exploiter, e.g. by repaying BUSD and borrowing USDT. The conversion is done based on the current oracle price. The basic information of the audited protocol is as follows:

Table 1.1: Basic Information of The Delegate Borrowing

Item	Description
Name	Venus
Website	https://venus.io/
Type	EVM Smart Contract
Platform	Solidity
Audit Method	Whitebox
Latest Audit Report	February 27, 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/211 (30133c7)

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

Impact \ Likelihood	*High*	*Medium*	*Low*
High	Critical	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low

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.

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

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

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 `Delegate Borrowing` feature in `Venus`. 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 logics, 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	1	■
Low	0	
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 that 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, the smart contract is well-designed and engineered, though the implementation can be improved by resolving the identified issues (shown in Table 2.1), including 1 medium-severity vulnerability and 1 informational suggestion.

Table 2.1: Key Delegate Borrowing Audit Findings

ID	Severity	Title	Category	Status
PVE-001	Medium	Incorrect Implementation Logic in SwapDebtDelegate::_repay()	Business Logic	Fixed
PVE-002	Informational	Meaningful Events For Important State Changes	Coding Practices	Fixed

Besides recommending specific countermeasures to mitigate these issues, we also emphasize that 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 need to kick in at the very moment when the contracts are being deployed in mainnet. Please refer to Section 3 for details.

3 Detailed Results

3.1 Incorrect Implementation Logic in SwapDebtDelegate::_repay()

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

Description

The `SwapDebtDelegate` contract allows the privileged `owner` account to swap one debt position to another for certain borrower (e.g., the `BNB Bridge exploiter`). The `owner` firstly repays a borrow in `VToken` on behalf of the borrower, and then borrows another `VToken` of equal value on behalf of the borrower and transfers the borrowed asset to the `owner` account. While examining the `_repay()` routine of the `SwapDebtDelegate` contract, we notice the current implementation logic is not correct.

To elaborate, we show below the related code snippet. It comes to our attention that there is a lack of calling `underlying.safeApprove()` to specify the spending allowance of the `vToken` contract. Thus the execution of the `vToken.repayBorrowBehalf()` (line 91) will revert because this routine will call `underlying.transferFrom()` to transfer the `underlying` asset from the `SwapDebtDelegate` contract to the `vToken` contract. Note for the `safeApprove()` support, there is a need to approve twice: the first time resets the allowance to zero and the second time approves the intended amount.

```
76      /**
77       * @dev Transfers the funds from the sender and repays a borrow in vToken on behalf
            of the borrower
78       * @param vToken VToken to repay the debt to
79       * @param borrower The address of the borrower, whose debt to repay
80       * @param repayAmount The amount to repay in terms of underlying
81       */
82      function _repay(
83          VToken vToken,
```

```
        address borrower,
        uint256 repayAmount
    ) internal returns (uint256 actualRepaymentAmount) {
        IERC20Upgradeable underlying = IERC20Upgradeable(vToken.underlying());
        underlying.safeTransferFrom(msg.sender, address(this), repayAmount);

        uint256 borrowBalanceBefore = vToken.borrowBalanceCurrent(borrower);
        uint256 err = vToken.repayBorrowBehalf(borrower, repayAmount);
        if (err != NO_ERROR) {
            revert RepaymentFailed(err);
        }
        uint256 borrowBalanceAfter = vToken.borrowBalanceCurrent(borrower);
        return borrowBalanceBefore - borrowBalanceAfter;
    }
```

Listing 3.1: `SwapDebtDelegate::_repay()`

Recommendation Specify the spending allowance of the `vToken` contract for the above mentioned routine.

Status This issue has been fixed in the following commit: `e788a80`.

3.2 Meaningful Events For Important State Changes

- ID: PVE-002
- Severity: Informational
- Likelihood: N/A
- Impact: N/A
- Target: `SwapDebtDelegate`
- Category: Coding Practices [3]
- CWE subcategory: CWE-563 [1]

Description

In the design of `DeFi` protocols, the `event` is an indispensable part of a contract and is mainly used to record a variety of runtime dynamics. In particular, when an `event` is emitted, it stores the arguments passed in transaction logs and these logs are made accessible to external analytics and reporting tools. `Events` can be emitted in a number of scenarios. One particular case is when system-wide parameters or settings are being changed. Another case is when tokens are being minted, transferred, or burned.

In the following, we use the `SwapDebtDelegate` contract as an example. While examining the events that reflect the `SwapDebtDelegate` dynamics, we notice there is a lack of emitting related events to reflect important state changes. Specifically, when the `swapDebt()/sweepTokens()` are being called, there are no corresponding events being emitted to reflect the occurrence of `swapDebt()/sweepTokens()`.

```
    /**
     * @notice Repays a borrow in repayTo.underlying() and borrows borrowFrom.underlying()
     * @param borrower The address of the borrower, whose debt to swap
     * @param repayTo VToken to repay the debt to
     * @param borrowFrom VToken to borrow from
     * @param repayAmount The amount to repay in terms of repayTo.underlying()
     */
    function swapDebt(
        address borrower,
        VToken repayTo,
        VToken borrowFrom,
        uint256 repayAmount
    ) external onlyOwner nonReentrant {
        uint256 actualRepaymentAmount = _repay(repayTo, borrower, repayAmount);
        uint256 amountToBorrow = _convert(repayTo, borrowFrom, actualRepaymentAmount);
        _borrow(borrowFrom, borrower, amountToBorrow);
    }

    /**
     * @notice Transfers tokens, accidentally sent to this contract, to the owner
     * @param token ERC-20 token to sweep
     */
    function sweepTokens(IERC20Upgradeable token) external onlyOwner {
        token.safeTransfer(owner(), token.balanceOf(address(this)));
    }
```

Listing 3.2: `SwapDebtDelegate::swapDebt()/sweepTokens()`

Recommendation Properly emit the related events when the above-mentioned functions are being invoked.

Status This issue has been fixed in the following commit: `24e95ba`.

4 Conclusion

In this audit, we have analyzed the design and implementation of the `Delegate Borrowing` support in `Venus`. The audited `Delegate Borrowing` feature allows users to delegate their borrowing power to certain account and allows the privileged `owner` account to swap one debt position to another for the `BNB Bridge` exploiter, e.g. by repaying `BUSD` and borrowing `USDT`. The conversion is done based on the current oracle price. 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-563: Assignment to Variable without Use. https://cwe.mitre.org/data/definitions/563.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.