HACKEN

SMART CONTRACT CODE REVIEW AND SECURITY ANALYSIS REPORT

Customer: Paribus
Date: May 24th, 2022

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Document

Name	Smart Contract Code Review and Security Analysis Report for Paribus.
Approved By	Evgeniy Bezuglyi | SC Department Head at Hacken OU
Type	Lending/borrowing platform
Platform	EVM
Language	Solidity
Methods	Architecture Review, Functional Testing, Computer-Aided Verification, Manual Review
Website	https://paribus.io
Timeline	20.04.2022 - 24.05.2022
Changelog	09.05.2022 - Initial Review 24.05.2022 - Second Review

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Introduction

Hacken OÜ (Consultant) was contracted by Paribus (Customer) to conduct a Smart Contract Code Review and Security Analysis. This report presents the findings of the security assessment of the Customer's smart contracts.

Scope

The scope of the project is smart contracts in the repository:

Initial review scope
Repository:
https://github.com/Paribus/paribus-protocol
Commit:
da9d3cec639fe1d1f328cd5f0a1a82f4291821be
Technical Documentation:
Type: Litepaper (partial functional requirements provided)
Link: https://paribus.io/documents/PARIBUS-Litepaper-V1.0.pdf

Type: Technical description
Link: https://github.com/Paribus/paribus-protocol/blob/develop/README.md

JS tests: Yes
Contracts:
File: ./contracts/CompoundLens.sol
SHA3: 0b5805b4d05adce8a01f06761ed64d8b6db15b63b39179ab3b6f56e3a6f40ae1

File: ./contracts/Comptroller.sol
SHA3: 20734a3749ed9b3fdba43341b0b8b604007631ed2b52a8ea8da67b2f718b80f7

File: ./contracts/ComptrollerStorage.sol
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File: ./contracts/ErrorReporter.sol
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File: ./contracts/InterestRateModels/DAIInterestRateModelV3.sol
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File: ./contracts/InterestRateModels/LegacyJumpRateModelV2.sol
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File: ./contracts/Liquidator.sol
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File: ./contracts/Maximillion.sol
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File: ./contracts/PriceOracle/SimplePriceOracle.sol
SHA3: bde4c6ccdb78f0b1e05c79ad929d88845d1d8b3fe26dad6dd0a52f47045493ee

File: ./contracts/PToken/PErc20.sol
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File: ./contracts/PToken/PErc20Immutable.sol
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File: ./contracts/Utils/CarefulMath.sol
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File: ./contracts/Utils/Timelock.sol
SHA3: 3c46800318aa5ffe783d5477ab26f53097f6fdd3d37f185b738d7b0bf9c19097

Second review scope

Repository:
https://github.com/Paribus/paribus-protocol

Commit:
d6e83354692f6fd0e6b988ed06ae676c921d58a3

Technical Documentation:
Type: Litepaper (partial functional requirements provided)
Link: https://paribus.io/documents/PARIBUS-Litepaper-V1.0.pdf

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File: ./contracts/PToken/PErc20Delegate.sol
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SHA3: 992820a8d539dd276cff5249507bb2a887fa15ce05fd625b0f572189a561a312

File: ./contracts/PToken/PErc20Immutable.sol
SHA3: 3bbfb582f1b2136e8174412fe863bfb39bc88274ed9999964c70942c7e5f6aa5
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Severity Definitions

Risk Level	Description
Critical	Critical vulnerabilities are usually straightforward to exploit and can lead to assets loss or data manipulations.
High	High-level vulnerabilities are difficult to exploit; however, they also have a significant impact on smart contract execution, e.g., public access to crucial functions.
Medium	Medium-level vulnerabilities are important to fix; however, they cannot lead to assets loss or data manipulations.
Low	Low-level vulnerabilities are mostly related to outdated, unused, etc. code snippets that cannot have a significant impact on execution.

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Executive Summary

The score measurement details can be found in the corresponding section of the methodology.

Documentation quality

The Customer provided superficial functional requirements and technical requirements. The total Documentation Quality score is **5** out of **10**.

Code quality

The total CodeQuality score is **7** out of **10**. Commented code. TODO comments. Unit tests were provided.

Architecture quality

The architecture quality score is **10** out of **10**. Follows best practices.

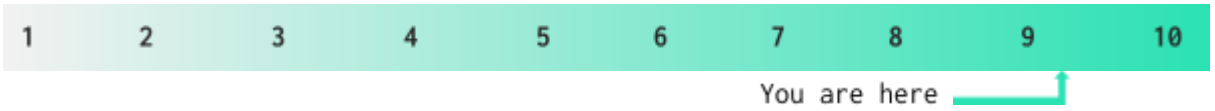
Security score

As a result of the audit, security engineers found **2** medium severity issues, **1** medium issue was fixed and **1** remained. The security score is **10** out of **10**.

All found issues are displayed in the “Findings” section.

Summary

According to the assessment, the Customer's smart contract has the following score: **9.2**.



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Checked Items

We have audited provided smart contracts for commonly known and more specific vulnerabilities. Here are some of the items that are considered:

Item	Type	Description	Status
Default Visibility	SWC-100 SWC-108	Functions and state variables visibility should be set explicitly. Visibility levels should be specified consciously.	Passed
Integer Overflow and Underflow	SWC-101	If unchecked math is used, all math operations should be safe from overflows and underflows.	Passed
Outdated Compiler Version	SWC-102	It is recommended to use a recent version of the Solidity compiler.	Failed
Floating Pragma	SWC-103	Contracts should be deployed with the same compiler version and flags that they have been tested thoroughly.	Failed
Unchecked Call Return Value	SWC-104	The return value of a message call should be checked.	Passed
Access Control & Authorization	CWE-284	Ownership takeover should not be possible. All crucial functions should be protected. Users could not affect data that belongs to other users.	Passed
SELFDESTRUCT Instruction	SWC-106	The contract should not be destroyed until it has funds belonging to users.	Passed
Check-Effect-Interaction	SWC-107	Check-Effect-Interaction pattern should be followed if the code performs ANY external call.	Passed
Uninitialized Storage Pointer	SWC-109	Storage type should be set explicitly if the compiler version is < 0.5.0.	Not Relevant
Assert Violation	SWC-110	Properly functioning code should never reach a failing assert statement.	Passed
Deprecated Solidity Functions	SWC-111	Deprecated built-in functions should never be used.	Passed
Delegatecall to Untrusted Callee	SWC-112	Delegatecalls should only be allowed to trusted addresses.	Passed
DoS (Denial of Service)	SWC-113 SWC-128	Execution of the code should never be blocked by a specific contract state unless it is required.	Passed
Race Conditions	SWC-114	Race Conditions and Transactions Order Dependency should not be possible.	Passed

Authorization through tx.origin	SWC-115	tx.origin should not be used for authorization.	Passed
Block values as a proxy for time	SWC-116	Block numbers should not be used for time calculations.	Passed
Signature Unique Id	SWC-117 SWC-121 SWC-122	Signed messages should always have a unique id. A transaction hash should not be used as a unique id.	Passed
Shadowing State Variable	SWC-119	State variables should not be shadowed.	Passed
Weak Sources of Randomness	SWC-120	Random values should never be generated from Chain Attributes.	Not Relevant
Incorrect Inheritance Order	SWC-125	When inheriting multiple contracts, especially if they have identical functions, a developer should carefully specify inheritance in the correct order.	Passed
Calls Only to Trusted Addresses	EEA-Level-2 SWC-126	All external calls should be performed only to trusted addresses.	Passed
Presence of unused variables	SWC-131	The code should not contain unused variables if this is not justified by design.	Passed
EIP standards violation	EIP	EIP standards should not be violated.	Passed
Assets integrity	**Custom**	Funds are protected and cannot be withdrawn without proper permissions.	Passed
User Balances manipulation	**Custom**	Contract owners or any other third party should not be able to access funds belonging to users.	Passed
Data Consistency	**Custom**	Smart contract data should be consistent all over the data flow.	Passed
Flashloan Attack	**Custom**	When working with exchange rates, they should be received from a trusted source and not be vulnerable to short-term rate changes that can be achieved by using flash loans. Oracles should be used.	Passed
Token Supply manipulation	**Custom**	Tokens can be minted only according to rules specified in a whitepaper or any other documentation provided by the customer.	Passed
Gas Limit and Loops	**Custom**	Transaction execution costs should not depend dramatically on the amount of data stored on the contract. There should not be any cases when execution fails due to the block Gas limit.	Passed

Style guide violation	**Custom**	Style guides and best practices should be followed.	Failed
Requirements Compliance	**Custom**	The code should be compliant with the requirements provided by the Customer.	Passed
Repository Consistency	**Custom**	The repository should contain a configured development environment with a comprehensive description of how to compile, build and deploy the code.	Passed
Tests Coverage	**Custom**	The code should be covered with unit tests. Test coverage should be 100%, with both negative and positive cases covered. Usage of contracts by multiple users should be tested.	Passed
Stable Imports	**Custom**	The code should not reference draft contracts, that may be changed in the future.	Passed

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System Overview

The *Paribus Protocol* is an Ethereum smart contract for supplying or borrowing assets. Through the *pToken* contracts, accounts on the blockchain supply capital (Ether or ERC-20 tokens) to receive pTokens or borrow assets from the protocol (holding other assets as collateral). The *Paribus pToken* contracts track these balances and algorithmically set interest rates for borrowers.

The core contracts in the Paribus Protocol:

- *PToken, PErc20 and PEther* — the *Paribus pTokens*, self-contained borrowing and lending contracts. *PToken* contains the core logic, and *PErc20* and *PEther* add public interfaces for *Erc20* tokens and Ether, respectively. Each *PToken* is assigned an interest rate and risk model, and allows accounts to *mint* (supply capital), *redeem* (withdraw capital), *borrow* and *repay a borrow*. Each *PToken* is an *ERC-20* compliant token where balances represent ownership of the market.
- *Comptroller* — the risk model contract, which validates permissible user actions and disallows actions if they do not fit certain risk parameters. For instance, the *Comptroller* enforces that each borrowing user must maintain a sufficient collateral balance across all *pTokens*.
- *Paribus (PBX)* — the Paribus Governance Token.
- *InterestRateModel* — contracts which define interest rate models. These models algorithmically determine interest rates based on the current utilization of a given market (that is, how much of the supplied assets are liquid versus borrowed).
- *WhitePaperInterestRateModel* — initial interest rate model, as defined in the Whitepaper. This contract accepts a base rate and slope parameter in its constructor.

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Findings

Critical

No critical severity issues were found.

High

No high severity issues were found.

Medium

1. **Unfinished code**

   TODO comments in the code.

   This indicates that the code is not yet complete.

   Contracts: Liquidator.sol, Comptroller.sol, Reservoir.sol, ChainlinkPriceOracle.sol

   Recommendation: complete the code to meet all the requirements and delete the TODO comments.

   Status: Reported

2. **The code does not consider all cases**

   The decimal normalization in the *getUnderlyingPrice* function works correctly only if *underlyingDecimals* is 18 and *priceDecimals* is less than or equal to 18.

   The function may not work properly in some cases.

   Contract: ChainlinkPriceOracle.sol

   Function: getUnderlyingPrice

   Recommendation: change decimals normalization to a more general one that works properly with any decimals values.

   Status: Fixed (Revised commit: d6e8335)

Low

No low severity issues were found.

Disclaimers

Hacken Disclaimer

The smart contracts given for audit have been analyzed by the best industry practices at the date of this report, with cybersecurity vulnerabilities and issues in smart contract source code, the details of which are

disclosed in this report (Source Code); the Source Code compilation, deployment, and functionality (performing the intended functions).

The audit makes no statements or warranties on the security of the code. It also cannot be considered a sufficient assessment regarding the utility and safety of the code, bug-free status, or any other contract statements. While we have done our best in conducting the analysis and producing this report, it is important to note that you should not rely on this report only — we recommend proceeding with several independent audits and a public bug bounty program to ensure the security of smart contracts.

Technical Disclaimer

Smart contracts are deployed and executed on a blockchain platform. The platform, its programming language, and other software related to the smart contract can have vulnerabilities that can lead to hacks. Thus, the audit cannot guarantee the explicit security of the audited smart contracts.