



SMART CONTRACT AUDIT REPORT

for

CRYPTOZOON



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# 1 | Introduction

Given the opportunity to review the design document and related source code of the `CryptoZoon` smart contracts, 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 CryptoZoon

The `CryptoZoon` protocol is inspired by `Pokemon Story` with the main mission to build a comprehensive platform of digital monsters. The goal is to enable millions of individuals to participate in the NFT and blockchain-based gaming world in a simple, creative, and enjoyable way. In particular, it combines the greatest aspects of gaming and digital collectibles, transforming it into the digital creatures universe. With `CryptoZoon`, players can use their `ZOON` tokens to fight monsters, collect, grow, and join training (battle each other). The basic information of audited contracts is as follows:

Table 1.1: Basic Information of CryptoZoon

Item	Description
Name	CryptoZoon
Type	Binance Smart Chain Contract
Platform	Solidity
Audit Method	Whitebox
Latest Audit Report	August 25, 2021

In the following, we show the link to the smart contract source code for audit. Note that `CryptoZoon` assumes a trusted (external) router that provides the required `evolvers`, `battlefields`, as well as various protocol-wide arguments (e.g., `priceEgg` and `feeEvolve`) and the router itself is not part of this audit.

- <https://bscscan.com/address/0x51d7e502204043432884977976263aca4ef23f09>

## 1.2 About PeckShield

PeckShield Inc. [9] 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](mailto:contact@peckshield.com)).

Table 1.2: Vulnerability Severity Classification

Impact	High	Critical	High	Medium
	Medium	High	Medium	Low
	Low	Medium	Low	Low
		High	Medium	Low
		Likelihood		

## 1.3 Methodology

To standardize the evaluation, we define the following terminology based on OWASP Risk Rating Methodology [8]:

- 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 accordingly classified into four categories, 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
<b>Basic Coding Bugs</b>	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	
<b>Semantic Consistency Checks</b>	Semantic Consistency Checks
<b>Advanced DeFi Scrutiny</b>	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
<b>Additional Recommendations</b>	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	

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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) [7], 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. Moreover, in case there is an issue that may affect an active protocol that has been deployed, the public version of this report may omit such issue, but will be amended with full details right after the affected protocol is upgraded with respective fixes.

## 1.4 Disclaimer

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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
<b>Configuration</b>	Weaknesses in this category are typically introduced during the configuration of the software.
<b>Data Processing Issues</b>	Weaknesses in this category are typically found in functionality that processes data.
<b>Numeric Errors</b>	Weaknesses in this category are related to improper calculation or conversion of numbers.
<b>Security Features</b>	Weaknesses in this category are concerned with topics like authentication, access control, confidentiality, cryptography, and privilege management. (Software security is not security software.)
<b>Time and State</b>	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.
<b>Error Conditions, Return Values, Status Codes</b>	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.
<b>Resource Management</b>	Weaknesses in this category are related to improper management of system resources.
<b>Behavioral Issues</b>	Weaknesses in this category are related to unexpected behaviors from code that an application uses.
<b>Business Logics</b>	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.
<b>Initialization and Cleanup</b>	Weaknesses in this category occur in behaviors that are used for initialization and breakdown.
<b>Arguments and Parameters</b>	Weaknesses in this category are related to improper use of arguments or parameters within function calls.
<b>Expression Issues</b>	Weaknesses in this category are related to incorrectly written expressions within code.
<b>Coding Practices</b>	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 `CryptoZoon` smart contracts. 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	0	
Low	2	
Informational	1	
Total	3	

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 2 low-severity vulnerabilities and 1 informational recommendation.

Table 2.1: Key Audit Findings

ID	Severity	Title	Category	Status
PVE-001	Low	Accommodation of Non-ERC20-Compliant Tokens	Business Logic	Fixed
PVE-002	Informational	Redundant Data/Code Removal	Coding Practices	Fixed
PVE-003	Low	Improved Validation Of Function Arguments	Security Features	Fixed

Beside 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 Accommodation of Non-ERC20-Compliant Tokens

- ID: PVE-001
- Severity: Low
- Likelihood: Low
- Impact: High
- Target: CryptoZoan
- Category: Business Logic [6]
- CWE subcategory: CWE-841 [3]

#### Description

Though there is a standardized ERC-20 specification, many token contracts may not strictly follow the specification or have additional functionalities beyond the specification. In the following, we examine the `transfer()` routine and related idiosyncrasies from current widely-used token contracts.

In particular, we use the popular token, i.e., ZRX, as our example. We show the related code snippet below. On its entry of `transfer()`, there is a check, i.e., `if (balances[msg.sender] >= _value && balances[_to] + _value >= balances[_to])`. If the check fails, it returns `false`. However, the transaction still proceeds successfully without being reverted. This is not compliant with the ERC20 standard and may cause issues if not handled properly. Specifically, the ERC20 standard specifies the following: *“Transfers `_value` amount of tokens to address `_to`, and MUST fire the Transfer event. The function SHOULD throw if the message caller’s account balance does not have enough tokens to spend.”*

```
64     function transfer(address _to, uint _value) returns (bool) {
65         //Default assumes totalSupply can't be over max (2^256 - 1).
66         if (balances[msg.sender] >= _value && balances[_to] + _value >= balances[_to]) {
67             balances[msg.sender] -= _value;
68             balances[_to] += _value;
69             Transfer(msg.sender, _to, _value);
70             return true;
71         } else { return false; }
72     }
74     function transferFrom(address _from, address _to, uint _value) returns (bool) {
```

```
75     if (balances[_from] >= _value && allowed[_from][msg.sender] >= _value &&
76         balances[_to] + _value >= balances[_to]) {
77         balances[_to] += _value;
78         balances[_from] -= _value;
79         allowed[_from][msg.sender] -= _value;
80         Transfer(_from, _to, _value);
81         return true;
82     } else { return false; }
}
```

Listing 3.1: ZRX.sol

Because of that, a normal call to `transfer()` is suggested to use the safe version, i.e., `safeTransfer()`. In essence, it is a wrapper around ERC20 operations that may either throw on failure or return false without reverts. Moreover, the safe version also supports tokens that return no value (and instead revert or throw on failure). Note that non-reverting calls are assumed to be successful. Similarly, there is a safe version of `approve()/transferFrom()` as well, i.e., `safeApprove()/safeTransferFrom()`.

In the following, we show the `recoverZoon()` routine in the `CryptoZoon` contract. If the USDT token is supported as `zoonToken`, the unsafe version of `zoonToken.transfer(msg.sender, amount)` (line 313) may revert as there is no return value in the USDT token contract's `transfer()/transferFrom()` implementation (but the `IERC20` interface expects a return value)!

```
311     function recoverZoon(uint256 amount) public {
312         require(msg.sender == dev);
313         zoonToken.transfer(msg.sender, amount); // dont expect we'll hold tokens here
314         but might as well
    }
```

Listing 3.2: `CryptoZoon::recoverZoon()`

**Recommendation** Accommodate the above-mentioned idiosyncrasy about ERC20-related `approve()/transfer()/transferFrom()`.

**Status** This issue has been resolved as the new version removes this `recoverZoon()` function.

## 3.2 Redundant State/Code Removal

- ID: PVE-002
- Severity: Informational
- Likelihood: N/A
- Impact: N/A
- Target: CryptoZoan
- Category: Coding Practices [5]
- CWE subcategory: CWE-563 [2]

### Description

The `CryptoZoan` protocol makes good use of a number of reference contracts, such as `ERC721Upgradeable`, `ERC20`, `SafeMath`, and `SafeERC20`, to facilitate its code implementation and organization. For example, the `CryptoZoan` smart contract has so far imported at least five reference contracts. However, we observe the inclusion of certain unused code or the presence of unnecessary redundancies that can be safely removed.

For example, if we examine closely the data structures defined in `CryptoZoan`, the `ItemSale` structure is not used throughout the contract. With that, it is suggested to simply remove it.

```

43     struct Zoan {
44         uint256 collections;
45         uint256 generation;
46         Tribe tribe;
47         uint256 exp;
48         uint256 dna;
49         uint256 bornTime;
50     }
51
52     struct ItemSale {
53         uint256 tokenId;
54         address owner;
55         uint256 price;
56     }

```

Listing 3.3: `CryptoZoan::ItemSale`

In addition, a public function `layEgg()` routine can be improved as it contains redundant code. In particular, the `if`-condition (line 209) as well as the `then`-branch (line 209) can be removed. The reason is that the `else`-branch logic (lines 211 – 213) can accommodate the entire the `then`-branch.

```

202     function layEgg(
203         address receiver,
204         Tribe[] memory tribes,
205         uint256 _collections
206     ) external onlyEvolver {
207         uint256 amount = tribes.length;
208         require(amount > 0, "require: >0");
209         if (amount == 1) _layEgg(receiver, tribes[0], _collections);

```

```

210     else
211         for (uint256 index = 0; index < amount; index++) {
212             _layEgg(receiver, tribes[index], _collections);
213         }
214     }

```

Listing 3.4: CryptoZoan::layEgg()

**Recommendation** Consider the removal of the redundant state (or code) with a simplified, consistent implementation.

**Status** The issue has been fixed by taking the above suggestions and removing unused/redundant statements.

### 3.3 Improved Validation Of Function Arguments

- ID: PVE-004
- Severity: Medium
- Likelihood: Low
- Impact: High
- Target: CryptoZoan
- Category: Security Features [4]
- CWE subcategory: CWE-287 [1]

#### Description

The CryptoZoon protocol creates NFT tokens and each is unique with its own `tokenId`. Moreover, the `tokenId` is widely used as the key to index a number of other states, e.g., `zoans`, `isEvolved`, and `latestBlockTransfer`. With that, there is a constant need in validating whether the given `tokenId` is a valid one or not.

In the following, we show two example routines `exp()` and `evolve()`. These two routines are used by authorized callers to update internal states on `zoan`. It comes to our attention that both routines do not properly validate the input arguments of `_tokenId`.

```

155     function exp(uint256 _tokenId, uint256 _exp) public onlyBattlefield {
156         require(_exp > 0, "no exp");
157
158         Zoan storage zoan = zoans[_tokenId];
159         zoan.exp = zoan.exp.add(_exp);
160         emit Exp(_tokenId, _exp);
161     }
162
163     function evolve(
164         uint256 _tokenId,
165         uint256 _dna,
166         uint256 _generation
167     ) public onlyEvolver {

```

```

168     require(
169         latestBlockTransfer[_tokenId] < block.number,
170         "evolve after transfer"
171     );
172
173     Zoan storage zoan = zoans[_tokenId];
174     require(!isEvolved[_tokenId], "require: not evolved");
175
176     zoan.bornTime = block.timestamp;
177     zoan.dna = _dna;
178     zoan.generation = _generation;
179
180     isEvolved[_tokenId] = true;
181
182     emit Evolve(_tokenId, _dna);
183 }

```

Listing 3.5: CryptoZoan::exp()/evolve()

In other words, though there is a constant need to perform sanity checks on the given `tokenId`, the current implementation simply relies on the trust on the authenticated caller to ensure the `tokenId` index stays within the array range `[0, latestTokenId]`. However, considering the importance of validating the given `tokenId` and its numerous occasions, a better alternative is to make explicit the sanity checks by introducing a new modifier, say `validTokenId()`. This new modifier essentially ensures the given `tokenId` indeed points to a valid NFT token, and additionally give semantically meaningful information when it is not!

We highlight that there are a number of functions that can benefit from the new `tokenId`-validating modifier, including `exp()`, `evolve()`, `changeTribe()` and `upgradeGeneration()`.

**Recommendation** Apply necessary sanity checks to ensure the given `tokenId` is legitimate. Accordingly, a new modifier `validTokenId()` can be developed and appended to each function in the above list.

```

155     modifier validTokenId(uint256 _tokenId) {
156         require(tokenId > 0 && _tokenId <= latestTokenId, "Invalid tokenId?");
157         _;
158     }
159
160     function exp(uint256 _tokenId, uint256 _exp) public validTokenId(_tokenId)
161         onlyBattlefield {
162         require(_exp > 0, "no exp");
163
164         Zoan storage zoan = zoans[_tokenId];
165         zoan.exp = zoan.exp.add(_exp);
166         emit Exp(_tokenId, _exp);
167     }
168
169     function evolve(
170         uint256 _tokenId,

```

```
170     uint256 _dna,
171     uint256 _generation
172 ) public validTokenId(_tokenId) onlyEvolver {
173     require(
174         latestBlockTransfer[_tokenId] < block.number,
175         "evolve after transfer"
176     );
177
178     Zoan storage zoan = zoans[_tokenId];
179     require(!isEvolved[_tokenId], "require: not evolved");
180
181     zoan.bornTime = block.timestamp;
182     zoan.dna = _dna;
183     zoan.generation = _generation;
184
185     isEvolved[_tokenId] = true;
186
187     emit Evolve(_tokenId, _dna);
188 }
```

Listing 3.6: Revised `CryptoZoan::exp()/evolve()`

**Status** This issue has been fixed by adding the new `validTokenId()` modifier to the above list of related functions.





## 4 | Conclusion

In this audit, we have analyzed the `CryptoZoon` design and implementation. The `CryptoZoon` protocol allows for flexible creation and customization of `ERC721`-based `NFT` tokens. 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-287: Improper Authentication. <https://cwe.mitre.org/data/definitions/287.html>.
- [2] MITRE. CWE-563: Assignment to Variable without Use. <https://cwe.mitre.org/data/definitions/563.html>.
- [3] MITRE. CWE-841: Improper Enforcement of Behavioral Workflow. <https://cwe.mitre.org/data/definitions/841.html>.
- [4] MITRE. CWE CATEGORY: 7PK - Security Features. <https://cwe.mitre.org/data/definitions/254.html>.
- [5] MITRE. CWE CATEGORY: Bad Coding Practices. <https://cwe.mitre.org/data/definitions/1006.html>.
- [6] MITRE. CWE CATEGORY: Business Logic Errors. <https://cwe.mitre.org/data/definitions/840.html>.
- [7] MITRE. CWE VIEW: Development Concepts. <https://cwe.mitre.org/data/definitions/699.html>.
- [8] OWASP. Risk Rating Methodology. [https://www.owasp.org/index.php/OWASP\\_Risk\\_Rating\\_Methodology](https://www.owasp.org/index.php/OWASP_Risk_Rating_Methodology).
- [9] PeckShield. PeckShield Inc. <https://www.peckshield.com>.