SMART CONTRACT AUDIT REPORT

for

Alpies (NFT)

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Contents

1 Introduction

Given the opportunity to review the design document and related source code of the NFT collection of Alpies, 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 is well engineered without security-related issues. due to the presence of several issues related to either security or performance. This document outlines our audit results.

1.1 About Alpies

Alpies are a hand-drawn, limited-edition 10,000-piece NFT collection, which will be released in two sets on BSC and then ETH. Both sets will be bridgeable between BSC and ETH so users may be able to trade them on OpenSea and other marketplaces. The basic information of the audited contracts is as follows:

Table 1.1: Basic Information of the audited protocol

Item	Description
Name	Alpaca Finance
Website	https://alpies.alpacafinance.org/
Type	Ethereum Smart Contract
Platform	Solidity
Audit Method	Whitebox
Latest Audit Report	October 18, 2021

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

- https://github.com/alpaca-finance/alpies-contract.git (754674e)

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

- https://github.com/alpaca-finance/alpies-contract.git (d574982)

1.2 About PeckShield

PeckShield Inc. [6] 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 [5]:

- 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) [4], 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 implementation of the `Alpies` 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	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 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, 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 Audit Findings of Alpies Protocol

ID	Severity	Title	Category	Status
PVE-001	Informational	Suggested Constant/Immutable Usages For Gas Efficiency	Coding Practices	Fixed
PVE-002	Low	Redundant State/Code Removal	Coding Practices	Confirmed

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 Suggested Constant/Immutable Usages For Gas Efficiency

- ID: PVE-001
- Severity: Informational
- Likelihood: N/A
- Impact: N/A
- Target: `pricemodels`
- Category: Coding Practices [3]
- CWE subcategory: CWE-1099 [1]

Description

Since version 0.6.5, `Solidity` introduces the feature of declaring a state as `immutable`. An `immutable` state variable can only be assigned during contract creation, but will remain constant throughout the life-time of a deployed contract. The main benefit of declaring a state as `immutable` is that reading the state is significantly cheaper than reading from regular storage, since it is not stored in storage anymore. Instead, an `immutable` state will be directly inserted into the runtime code.

This feature is introduced based on the observation that the reading and writing of storage-based contract states are gas-expensive. Therefore, it is always preferred if we can reduce, if not eliminate, storage reading and writing as much as possible. Those state variables that are written only once are candidates of `immutable` states under the condition that each fits the pattern, i.e., "a constant, once assigned in the constructor, is read-only during the subsequent operation."

In the following, we show a number of key state variables defined in `AscendingStepModel`, including `blockPerStep`, `priceStep`, `startPrice`, and `priceCeiling`. If there is no need to dynamically update these four key state variables, they can be declared as either constants or `immutable` for gas efficiency. In particular, `blockPerStep`, `priceStep`, `startPrice`, and `priceCeiling` can all be declared as `immutable`.

```
contract AscendingStepModel is IPriceModel {
  using SafeMath for uint256;

  /// @dev states
  uint256 public override startBlock;
  uint256 public override endBlock;
```

```
    uint256 public blockPerStep;
    uint256 public priceStep;

    uint256 public startPrice;
    uint256 public priceCeiling;
    ...
}
```

Listing 3.1: AscendingStepModel.sol

Note that the `DescendingStepModel` contract shares the same issue.

Recommendation Revisit the state variable definition and make extensive use of `constant`/`immutable` states.

Status The issue has been fixed in the following commit: ab69a60.

3.2 Redundant State/Code Removal

- ID: PVE-002
- Severity: Low
- Likelihood: Low
- Impact: Low
- Target: `Alpies`
- Category: Coding Practices [3]
- CWE subcategory: CWE-563 [2]

Description

The `Alpies` protocol makes good use of a number of reference contracts, such as `ERC721Upgradeable`, `OwnableUpgradeable`, `SafeMathUpgradeable`, and `Initializable`, to facilitate its code implementation and organization. For example, the `Alpies` 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 `Alpies` contract, there is a helper routine `_updateUserPurchaseWindow()` that is used to update the user purchase history for current window. It comes to our attention that the check on `_userPurchaseHistory.windowStartBlock == 0` (line 229) is redundant as it is already covered in the earlier check via `_isNewPurchaseWindow(_userPurchaseHistory)()` in the same line. In other words, the `if`-condition can be simplified as `if (_isNewPurchaseWindow(_userPurchaseHistory))`.

```
220   /// @dev update user purchase history for current window
221   /// @param _buyer user address
222   /// @param _amount The amount of alpies that user purchased
223   function _updateUserPurchaseWindow(address _buyer, uint256 _amount) internal {
224     PurchaseHistory storage _userPurchaseHistory = userPurchaseHistory[_buyer];
225     // if first purchase or start new window
226     // 1. update purchase amount
```

```
    // 2. set new windowStartBlock
    // else only update purchase amount
    if (_isNewPurchaseWindow(_userPurchaseHistory)  _userPurchaseHistory.
        windowStartBlock == 0) {
      _userPurchaseHistory.counter = _amount;
      _userPurchaseHistory.windowStartBlock = block.number;
    } else {
      _userPurchaseHistory.counter = _userPurchaseHistory.counter.add(_amount);
    }
  }
```

Listing 3.2: `Alpies::_updateUserPurchaseWindow()`

Recommendation Consider the removal of the redundant code with a simplified, consistent implementation.

Status The issue has been fixed in the following commit: 2507795.

4 Conclusion

In this audit, we have analyzed the design and implementation of Alpies, which are a hand-drawn, limited edition $10,000$-piece NFT collection and will be released in two sets on BSC and then ETH. Both sets will be bridgeable between BSC and ETH so users may be able to trade them on OpenSea and other marketplaces. The current code base is well organized and 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-1099: Inconsistent Naming Conventions for Identifiers. https://cwe.mitre.org/data/definitions/1099.html.

[2] MITRE. CWE-563: Assignment to Variable without Use. https://cwe.mitre.org/data/definitions/563.html.

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

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

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

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