SMART CONTRACT AUDIT REPORT

for

Anzen

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PeckShield

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1 Introduction

Given the opportunity to review the design document and related smart contract source code of the Anzen protocol, 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 Anzen

Anzen is a RWA-backed stablecoin protocol with USDz as the stablecoin pegged 1:1 to USDC. The peg is fully backed by Anzen Secured Private Credit Token (SPCT), which is backed by a diversified portfolio of private credit assets. The basic information of the audited protocol is as follows:

Table 1.1: Basic Information of The Anzen Protocol

Item	Description
Name	Anzen Finance
Type	EVM Smart Contract
Platform	Solidity
Audit Method	Whitebox
Latest Audit Report	April 28, 2024

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

- https://github.com/Anzen-Finance/protocol-v2.git (7f3e5ce)

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

- https://github.com/Anzen-Finance/protocol-v2.git (5911483)

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).

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 [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 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 deploy contracts on our private testnet and run tests to confirm the findings. If necessary, we would

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

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.

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 `Anzen` protocol. 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	2	
Low	1	
Informational	0	
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 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 2 medium-severity vulnerabilities and 1 low-severity vulnerability.

Table 2.1: Key Anzen Audit Findings

ID	Severity	Title	Category	Status
PVE-001	Medium	Improper Blacklist Enforcement in USDz/sUSDz	Business Logic	Resolved
PVE-002	Low	Revisited Validation Logic in SPCTPool::repay()	Coding Practices	Resolved
PVE-003	Medium	Trust Issue of Admin Keys	Security Features	Mitigated

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 Improper Blacklist Enforcement in USDz/sUSDz

- ID: PVE-001
- Severity: Medium
- Likelihood: Medium
- Impact: Medium
- Target: `USDz`, `sUSDz`
- Category: Business Logic [6]
- CWE subcategory: CWE-837 [3]

Description

To facilitate the management, the `USDz` stablecoin contract has the built-in support of account blacklisting. While examining the blacklist logic, we notice current implementation should be improved.

To elaborate, we show below the code snippet of one example routine `_update()`. This routine will be invoked for every transfer from the given `_sender` to the intended `_recipient`. For the blacklist support, we need to validated both `_sender` and `_recipient`, not only `_recipient` (line 356).

```
355     function _update(address _sender, address _recipient, uint256 _amount) internal
            override {
356         require(!_blacklist[_recipient], "RECIPIENT_IN_BLACKLIST");
357
358         super._update(_sender, _recipient, _amount);
359     }
```

Listing 3.1: `USDz::_update()`

Moreover, both `depositBySPCT()` and `redeemBackSPCT()` routines from the same contract need to check the caller is not blacklisted, i.e., `require(!_blacklist[msg.sender], "RECIPIENT_IN_BLACKLIST");`.

```
    function depositBySPCT(uint256 _amount) external whenNotPaused checkCollateralRate {
        require(mode == false, "PLEASE_MIGRATE_TO_NEW_VERSION");
        require(_amount > 0, "DEPOSIT_AMOUNT_IS_ZERO");

        spct.transferFrom(msg.sender, address(this), _amount);

        // calculate fee with USDz
```

```
        if (mintFeeRate == 0) {
            _mintUSDz(msg.sender, _amount);
        } else {
            uint256 feeAmount = _amount.mul(mintFeeRate).div(FEE_COEFFICIENT);
            uint256 amountAfterFee = _amount.sub(feeAmount);

            _mintUSDz(msg.sender, amountAfterFee);

            if (feeAmount != 0) {
                _mintUSDz(treasury, feeAmount);
            }
        }

        emit Deposit(msg.sender, _amount, block.timestamp);
    }
```

Listing 3.2: `USDz::_update()`

Recommendation Revise the above-mentioned functions to properly enforce the blacklist support. Note `sUSDz` can be similarly improved.

Status This issue has been fixed in the following commit: `1f4c9be`.

3.2 Revisited Validation Logic in SPCTPool::repay()

- ID: PVE-002
- Severity: Low
- Likelihood: Low
- Impact: Low
- Target: `SPCTPool`
- Category: Coding Practices [5]
- CWE subcategory: CWE-1126 [1]

Description

The `Anzen` protocol has a key `SPCTPool` contract, which is a permissioned token to represent `RWA` ownership. It mints `SPCT` on a 1:1 basis when `USDz` is deposited. While examining the built-in repay logic, we notice current validation of user-provide amount can be improved.

To elaborate, we show below the implementation of the related routine `repay()`. Basically, it repays `USDC` from private credit. The logic needs to ensure the repaid amount is less than `executedUSD`, the total executed amount. However, the validation is performed with the `SafeMath` (line 193), which is further checked with the `require` statement (line 193). Since the latter check provides a much meaningful message (when it is reverted), the first check can be avoided. And the suggested revision is shown as follows: `require(executedUSD >= _amount, "REPAY_AMOUNT_EXCEED_EXECUTED_SHARES");`

```
191    function repay(uint256 _amount) external onlyRole(POOL_MANAGER_ROLE) {
```

```
        require(_amount > 0, "REPAY_AMOUNT_IS_ZERO");
        require(executedUSD.sub(_amount) >= 0, "REPAY_AMOUNT_EXCEED_EXECUTED_SHARES");

        executedUSD = executedUSD.sub(_amount);
        reserveUSD = reserveUSD.add(_amount);
        usdc.transferFrom(msg.sender, address(this), _amount);
    }
```

Listing 3.3: `SPCTPool:repay()`

Recommendation Revise the above-mentioned routine to properly validate the repaid amount.

Status This issue has been fixed in the following commit: `1f4c9be`.

3.3 Trust Issue Of Admin Keys

- ID: PVE-003
- Severity: Medium
- Likelihood: Medium
- Impact: Medium
- Target: `Multiple Contracts`
- Category: Security Features [4]
- CWE subcategory: CWE-287 [2]

Description

In the `Anzen` contract, there is a privileged account (with the assigned `POOL_MANAGER_ROLE`) that plays a critical role in governing and regulating the protocol-wide operations (e.g., configure various system parameters, manage oracles, and whitelist accounts). In the following, we show the representative functions potentially affected by the privilege of the privileged account.

```
    function addToBlacklist(address _user) external onlyRole(POOL_MANAGER_ROLE) {
        _blacklist[_user] = true;
    }

    function addBatchToBlacklist(address[] calldata _users) external onlyRole(
        POOL_MANAGER_ROLE) {
        uint256 numUsers = _users.length;
        for (uint256 i; i < numUsers; ++i) {
            _blacklist[_users[i]] = true;
        }
    }

    function removeFromBlacklist(address _user) external onlyRole(POOL_MANAGER_ROLE) {
        _blacklist[_user] = false;
    }

    function removeBatchFromBlacklist(address[] calldata _users) external onlyRole(
        POOL_MANAGER_ROLE) {
        uint256 numUsers = _users.length;
```

```
        for (uint256 i; i < numUsers; ++i) {
            _blacklist[_users[i]] = false;
        }
    }
    ...
    function setMintFeeRate(uint256 newMintFeeRate) external onlyRole(POOL_MANAGER_ROLE)
         {
        require(newMintFeeRate <= maxMintFeeRate, "SHOULD_BE_LESS_THAN_1P");
        mintFeeRate = newMintFeeRate;
        emit mintFeeRateChanged(mintFeeRate, block.timestamp);
    }
    ...
    function setRedeemFeeRate(uint256 newRedeemFeeRate) external onlyRole(
        POOL_MANAGER_ROLE) {
        require(newRedeemFeeRate <= maxRedeemFeeRate, "SHOULD_BE_LESS_THAN_1P");
        redeemFeeRate = newRedeemFeeRate;
        emit redeemFeeRateChanged(redeemFeeRate, block.timestamp);
    }
    ...
    function setTreasury(address newTreasury) external onlyRole(POOL_MANAGER_ROLE) {
        require(newTreasury != address(0), "SET_UP_TO_ZERO_ADDR");
        treasury = newTreasury;
        emit treasuryChanged(treasury, block.timestamp);
    }
    ...
    function setOracle(address newOracle) external onlyRole(POOL_MANAGER_ROLE) {
        require(newOracle != address(0), "SET_UP_TO_ZERO_ADDR");
        oracle = ISPCTPriceOracle(newOracle);
        emit oracleChanged(newOracle, block.timestamp);
    }
```

Listing 3.4: Example Privileged Operations in USDz

We emphasize that the privilege assignment may be necessary and consistent with the protocol design. However, it is worrisome if the privileged account is not governed by a DAO-like structure. Note that a compromised account would allow the attacker to modify a number of sensitive system parameters, which directly undermines the assumption of the protocol design.

Recommendation Promptly transfer the privileged account to the intended DAO-like governance contract. All changed to privileged operations may need to be mediated with necessary timelocks. Eventually, activate the normal on-chain community-based governance life-cycle and ensure the intended trustless nature and high-quality distributed governance.

Status The issue has been confirmed and will be mitigated with the use of a multi-sig to manage the privileged account.

4 Conclusion

In this audit, we have analyzed the design and implementation of the `Anzen` protocol, which is a `RWA`-backed stablecoin protocol with `USDz` as the stablecoin pegged 1:1 to `USDC`. The peg is fully backed by `Anzen Secured Private Credit Token (SPCT)`, which is backed by a diversified portfolio of private credit assets. 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-287: Improper Authentication. https://cwe.mitre.org/data/definitions/287.html.

[3] MITRE. CWE-837: Improper Enforcement of a Single, Unique Action. https://cwe.mitre.org/data/definitions/837.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.

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