CERTIK

Security Assessment

Panther ZKP Vesting

Nov 16th, 2021

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About

Summary

This report has been prepared for Panther Protocol to discover issues and vulnerabilities in the source code of the Panther ZKP Vesting project as well as any contract dependencies that were not part of an officially recognized library. A comprehensive examination has been performed, utilizing Static Analysis and Manual Review techniques.

The auditing process pays special attention to the following considerations:

- Testing the smart contracts against both common and uncommon attack vectors.
- Assessing the codebase to ensure compliance with current best practices and industry standards.
- Ensuring contract logic meets the specifications and intentions of the client.
- Cross referencing contract structure and implementation against similar smart contracts produced by industry leaders.
- Thorough line-by-line manual review of the entire codebase by industry experts.

The security assessment resulted in findings that ranged from critical to informational. We recommend addressing these findings to ensure a high level of security standards and industry practices. We suggest recommendations that could better serve the project from the security perspective:

- Enhance general coding practices for better structures of source codes;
- Add enough unit tests to cover the possible use cases;
- Provide more comments per each function for readability, especially contracts that are verified in public;
- Provide more transparency on privileged activities once the protocol is live.

Overview

Project Summary

Project Name	Panther ZKP Vesting
Platform	other
Language	Solidity
Codebase	https://github.com/pantherprotocol/zkp-token/tree/master/contracts
Commit	• f1e9d857dbd1660d90f1f029511f93417896d792 • ed7262b28e35f561cf35c66b4ac1bf60690d87a4

Audit Summary

Delivery Date	Nov 16, 2021
Audit Methodology	Static Analysis, Manual Review
Key Components	

Vulnerability Summary

Vulnerability Level	Total	Pending	Declined	Acknowledged	Partially Resolved	Resolved
Critical	0	0	0	0	0	0
Major	3	0	0	2	0	1
Medium	3	0	0	2	0	1
Minor	2	0	0	2	0	0
Informational	6	0	0	3	0	3
Discussion	0	0	0	0	0	0

Audit Scope

ID	File	SHA256 Checksum
CCK	interfaces/Constants.sol	262cddb01adf7bff3c3f582e0fb1ef33d8989786cd5c4ad60688bb2a8bb93e8a
IMC	interfaces/IMintable.sol	2e415fee5ca3ef70a3490e00ab957e8fd99f960452327765add2d18de749e37e
IVP	interfaces/IVestingPools.sol	02560eb0c3691fcaeb7f859f793003124ec9f0b54b34b3964ffe5afc37d0caf2
TCK	interfaces/Types.sol	79ebea3762649bf65421a21803ad7b5141cfb8eb76c6abee90ffb9a21fee0afc
CCP	utils/Claimable.sol	cb78483efb0f02b2a69313c5f547d31052a9f7e46c49f910c6fa2094f8460862
DOC	utils/DefaultOwnable.sol	a10d5a3adc25cec3d783da1742321f64fb588083fb76e9a7e427733994a5c01f
LCK	utils/Linking.sol	e6cc61aa66178bb061ee37ddd725403978f5c5b448756f240e215a300aef97e4
PFC	utils/ProxyFactory.sol	9d7e546209c3f60236a462db0d107f64dad7dabadb4fe780f8660cf6fb6d3a4a
SUC	utils/SafeUints.sol	de4d16d060c232460873795102bfef1382bba816f193b102e99d100d9da2c8b4
PSC	PoolStakes.sol	da6535f17682111f07159d3659ccf4035c61cc01d2d6c7fbb5a87e21fa0f1de6
VPC	VestingPools.sol	a78b78849a776b5943e57a44d30489b6f2a102594deffc052f034f57ad8463f8
ZKP	ZKPToken.sol	dae1edcf593ba4e946cce0d860bbd2663b6b65b12865bf6a22af670693bbac89

Understandings

Overview

The Panther Protocol is a blockchain network with a focus on privacy while also providing compliance tools through zero-knowledge proofs. In this report, we looked at the Panther Protocol's ZKP token as well as their implementation of vesting pools. This includes how stakeholders interact with the vesting pool and the implementation of a vesting pool's wallet.

Dependencies

We assume the contracts `PoolStakes`, `VestingPools`, `ZKPToken`, `Constants`, `Claimable`, `DefaultOwnable`, `TokenAddress`, `VestingPoolsAddress`, `DefaultOwnerAddress`, `ProxyFactory`, and `SafeUints` are deployed successfully and triggered correctly within the protocol.

There are a few depending injection contracts or addresses in the current project:

- `DefaultOwnerAddress`, `TokenAddress`, and `VestingPoolsAddress` for the contract `PoolStakes`;
- `TokenAddress` for the contract `VestingPools`;
- `_minter` for the contract `ZKPToken`.

We assume these contracts or addresses are valid and non-vulnerable actors and implementing proper logic to collaborate with the current project.

Privileged Functions

In the contract `PoolStakes`, the roles `_owner` and `_defaultOwner` have the authority over the following functions:

- `PoolStakes.addStakes()`, which adds stakeholders along with their allocations to a proxy;
- `PoolStakes.massWithdraw()`, which sends tokens to stakeholders;
- `PoolStakes.claimErc20()`, which sends the contract's extra tokens to an address;
- `PoolStakes.removeContract()`, which destroys a proxy version of the contract under the conditions that all stakes have been paid and the contract does not contain any vested Tokens;
- `DefaultOwnable.transferOwnership()`, which transfers the `_owner` role to a designated address.

In the contract `VestingPools`, the role `_owner` has the authority over the following functions:

- `VestingPools.addVestingPools()`, which adds a vesting pool and its associated wallet;
- `VestingPools.updatePoolTime()`, which changes the start time and vesting duration of a vesting pool;
- `VestingPools.claimErc20()`, which sends ERC20 tokens or unvested tokens to an address;

- `VestingPools.removeContract()`, which destroys the `VestingPools` contract under the condition that all allocated tokens have been vested;
- `Ownable.renounceOwnership()`, which disables all functions with the `onlyOwner` modifier;
- `Ownable.transferOwnership()`, which transfers the `_owner` role to a different address.

In addition, the wallet associated to the vesting pool has the authority over the following functions:

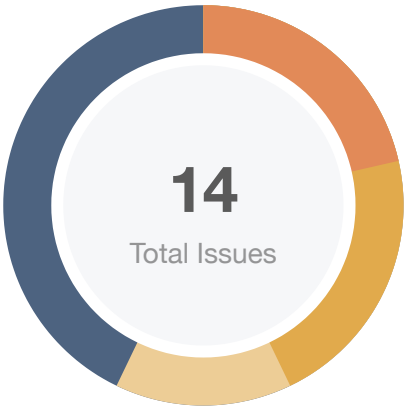
- `VestingPools.release()`, which sends tokens allocated in the vesting pool to the wallet;
- `VestingPools.releaseTo()`, which sends tokens allocated in the vesting pool to a chosen address;
- `VestingPools.updatePoolWallet()`, which changes the address of the wallet for that vesting pool.

In the contract `ZKPToken`, the role `minter` has the authority over the following functions:

- `ZKPToken.mint()`, which mints new ZKP tokens;
- `ZKPToken.setMinter()`, which sets the address for the `minter` role.

To improve the trustworthiness of the project, dynamic runtime updates in the project should be notified to the community. Any plan to invoke the aforementioned functions should be also considered to move to the execution queue of the `Timelock` contract.

Findings



Critical	**0** (0.00%)
Major	**3** (21.43%)
Medium	**3** (21.43%)
Minor	**2** (14.29%)
Informational	**6** (42.86%)
Discussion	**0** (0.00%)

ID	Title	Category	Severity	Status
GLOBAL-01	Unlocked Compiler Version	Language Specific	Informational	Resolved
PSC-01	Centralization Risk	**Centralization / Privilege**	**Major**	Acknowledged
PSC-02	Potential Reentrancy Attack	Logical Issue	Medium	Acknowledged
PSC-03	External Dependency	Volatile Code	Minor	Acknowledged
PSC-04	Missing Error Messages	Coding Style	Informational	Resolved
PSC-05	Missing Emit Events	Coding Style	Informational	Acknowledged
VPC-01	Centralization Risk	**Centralization / Privilege**	**Major**	Acknowledged
VPC-02	Releasable Amount May be Incorrect if Pool Time is Changed After Tokens are Released	Logical Issue	Major	Resolved
VPC-03	Potential Reentrancy Attack	Logical Issue	Medium	Acknowledged
VPC-04	Incorrect Value Assignment of `poolId`	Logical Issue	Medium	Resolved
VPC-05	External Dependency	Volatile Code	Minor	Acknowledged
VPC-06	Missing Error Messages	Coding Style	Informational	Resolved
VPC-07	Missing Event Emissions for Significant Transactions	Coding Style	Informational	Acknowledged

ID	Title	Category	Severity	Status
VPC-08	Inefficient **require** Location	Gas Optimization	Informational	Acknowledged

GLOBAL-01 | Unlocked Compiler Version

Category	Severity	Location	Status
Language Specific	Informational	Global	Resolved

Description

The contract has unlocked compiler version. An unlocked compiler version in the source code of the contract permits the user to compile it at or above a particular version. This, in turn, leads to differences in the generated bytecode between compilations due to differing compiler version numbers. This can lead to an ambiguity when debugging as compiler specific bugs may occur in the codebase that would be hard to identify over a span of multiple compiler versions rather than a specific one.

Recommendation

We advise that the compiler version is instead locked at the lowest version possible that the contract can be compiled at. For example, for version `v0.6.2` the contract should contain the following line:

```
pragma solidity 0.6.2;
```

Alleviation

The development team heeded our advice and applied an exact compiler version (8.4) in the hardhat.config.ts.

PSC-01 | Centralization Risk

Category	Severity	Location	Status
Centralization / Privilege	Major	projects/panther/contracts/PoolStakes.sol (9a05001): 138, 174 , 183, 201	Acknowledged

Description

In the contract `PoolStakes`, the roles `_owner` and `_defaultOwner` have the authority over the following functions:

- `PoolStakes.addStakes()`, which adds stakeholders along with their allocations to a proxy;
- `PoolStakes.massWithdraw()`, which sends tokens to stakeholders;
- `PoolStakes.claimErc20()`, which sends the contract's extra tokens to an address;
- `PoolStakes.removeContract()`, which destroys a proxy version of the contract under the conditions that all stakes have been paid and the contract does not contain any vested Tokens.

Any compromise to the `_owner` or `_defaultOwner` accounts may allow the hacker to take advantage of this and add unwanted stakeholders or steal tokens.

Recommendation

We advise the client to carefully manage the `_owner` and `_defaultOwner` accounts' private key to avoid any potential risks of being hacked. In general, we strongly recommend centralized privileges or roles in the protocol to be improved via a decentralized mechanism or smart-contract-based accounts with enhanced security practices, e.g., Multisignature wallets.

Here are some feasible suggestions that would also mitigate this risk in the short-term and long-term:

- A time-lock with reasonable latency, e.g., 48 hours, for awareness on privileged operations;
- Assignment of privileged roles to multi-signature wallets to prevent a single point of failure due to the private key;
- Introduction of a DAO/governance/voting module to increase transparency and user involvement.

Alleviation

[Panther Team]: the Deployment Plan (docs/deploymentPlan.README.md) and the Contracts Hierarchy diagram (docs/ZKP-contracts-hierarchy.png) explicitly state the DAO Multisig as the PoolStakes._defaultOwner.

Moreover, “governance/voting” smart contracts are the ones planned to be audited next. Furthermore, out of functions mentioned, which the owner has privileges to call, only PoolStakes.addStakes() is potentially harmful for stakeholders; this function is intended to be used once only, on the contract(s) initial initialization, and for the entire available allocation of a vesting pool the contract distributes (which makes this function useless for attacks).

[Certik]: The auditors agree that multi-signature wallets will reduce the centralization risks. The status of this issue will be updated after contract deployment upon request.

PSC-02 | Potential Reentrancy Attack

Category	Severity	Location	Status
Logical Issue	Medium	projects/panther/contracts/PoolStakes.sol (9a05001): 91, 101, 107, 174	Acknowledged

Description

A reentrancy attack can occur when the contract creates a function that makes an external call to another untrusted contract before resolving any effects. If the attacker can control the untrusted contract, they can make a recursive call back to the original function, repeating interactions that would have otherwise not run after the external call resolved the effects.

Recommendation

We recommend using the Checks-Effects-Interactions Pattern to avoid the risk of calling unknown contracts or applying OpenZeppelin ReentrancyGuard library - `nonReentrant` modifier for the aforementioned functions to prevent reentrancy attack.

Alleviation

[Panther Team]: Mentioned functions call the audited smart contracts only, which neither re-enter calling contracts, no call other contracts, which potentially may re-enter.

[Certik]: Considering the auditors cannot ensure the deployment will proceed correctly, the status of this issue will be updated after contract deployment upon request.

PSC-03 | External Dependency

Category	Severity	Location	Status
Volatile Code	Minor	projects/panther/contracts/PoolStakes.sol (9a05001): 10	Acknowledged

Description

The contract is serving as the underlying wallet to interact with `ZKPToken` and `VestingPools`. The scope of the audit treats external dependencies as black boxes and assumes their functional correctness. In order to successfully deploy this contract, the right addresses should be provided, especially the `DefaultOwnerAddress` who is a privileged role in this project.

Recommendation

We encourage the team to constantly monitor the statuses of external parties to mitigate the side effects when unexpected activities are observed.

Alleviation

[Panther Team]: There are no external dependencies - contracts depend only on the audited smart contracts.

[Certik]: Considering the auditors cannot ensure the deployment will proceed correctly, the status of this issue will be updated after contract deployment upon request.

PSC-04 | Missing Error Messages

Category	Severity	Location	Status
Coding Style	Informational	projects/panther/contracts/PoolStakes.sol (9a05001): 292	Resolved

Description

The **require** can be used to check for conditions and throw an exception if the condition is not met. It is better to provide a string message containing details about the error that will be passed back to the caller.

Recommendation

We recommend adding corresponding error messages for the aforementioned **require** statement.

Alleviation

The development team heeded our advice and added an error message to the `require` statement in commit 3510f7bafde4e095341e042d59b1a870444a6d52.

PSC-05 | Missing Emit Events

Category	Severity	Location	Status
Coding Style	Informational	projects/panther/contracts/PoolStakes.sol (9a05001): 183, 201	Acknowledged

Description

The functions affect the status of the contract in important ways and should be able to emit events as notifications:

- `PoolStakes.claimErc20()`
- `PoolStakes.removeContract()`

Recommendation

Consider adding events for sensitive actions and emit them in the function.

Alleviation

The Panther team has relayed to us that the mentioned transactions are not major protocol transactions and do not represent an interest for stakeholders/investors. They are also not emitted to save gas.

VPC-01 | Centralization Risk

Category	Severity	Location	Status
Centralization / Privilege	**Major**	projects/panther/contracts/VestingPools.sol (9a05001): 121, 163, 186, 202, 90, 99, 109	Acknowledged

Description

In the contract `VestingPools`, the role `_owner` has the authority over the following functions:

- `VestingPools.addVestingPools()`, which adds a vesting pool and its associated wallet;
- `VestingPools.updatePoolTime()`, which changes the start time and vesting duration of a vesting pool;
- `VestingPools.claimErc20()`, which sends ERC20 tokens or unvested tokens to an address;
- `VestingPools.removeContract()`, which destroys the `VestingPools` contract under the condition that all allocated tokens have been vested.

In addition, the wallet associated to the vesting pool has the authority over the following functions:

- `VestingPools.release()`, which sends tokens allocated in the vesting pool to the wallet;
- `VestingPools.releaseTo()`, which sends tokens allocated in the vesting pool to a chosen address;
- `VestingPools.updatePoolWallet()`, which changes the address of the wallet for that vesting pool.

Any compromise to the `_owner` account may allow the hacker to sabotage vesting pools or steal tokens while any compromise to the wallet may allow the hacker to steal allocated tokens.

Recommendation

We advise the client to carefully manage the `_owner` account's private key to avoid any potential risks of being hacked. In general, we strongly recommend centralized privileges or roles in the protocol to be improved via a decentralized mechanism or smart-contract-based accounts with enhanced security practices, e.g., Multisignature wallets.

Here are some feasible suggestions that would also mitigate this risk in the short-term and long-term:

- A time-lock with reasonable latency, e.g., 48 hours, for awareness on privileged operations;
- Assignment of privileged roles to multi-signature wallets to prevent a single point of failure due to the private key;
- Introduction of a DAO/governance/voting module to increase transparency and user involvement.

Alleviation

[Panther Team]: the Deployment Plan (docs/deploymentPlan.README.md) and the Contracts Hierarchy diagram (docs/ZKP-contracts-hierarchy.png) explicitly state the DAO Multisig as the owner of the VestingPools instance.

[Certik]: The auditors agree that multi-signature wallets will reduce the centralization risks. The status of this issue will be updated after contract deployment upon request.

VPC-02 | Releasable Amount May be Incorrect if Pool Time is Changed After Tokens are Released

Category	Severity	Location	Status
Logical Issue	Major	projects/panther/contracts/VestingPools.sol (9a05001): 163	Resolved

Description

If a vesting pool has already released allocated tokens and then its start time is changed, this could cause an inaccurate measurement of its releasable amount.

For example, suppose we have a vesting `pool` with the following attributes:

- `pool.isAdjustable = true`,
- `pool.vestingDays = 0`,
- `pool.sAllocation = 100`,
- `pool.sUnlocked = 100`,
- `pool.vested = 0`.

Suppose the current time is greater than the `pool.start`, and all `100 * SCALE` tokens are released to the wallet, so `pool.vested = 100 * SCALE` and `_getReleasable(pool, block.timestamp) = 0`.

If `updatePoolTime()` is called on the same `pool`, changing `pool.start` to some time in the future, then exactly when `block.timestamp = pool.start` (and no later), we will have `_getReleasable(pool, pool.start) = pool.sUnlocked = 100`. This allows `release()` to be called again even though all allocated tokens have already been vested.

Recommendation

We recommend only allowing `updatePoolTime()` to be called if `pool.start > block.timestamp` or changing the logic of `_getReleasable()`.

Alleviation

This issue was resolved by no longer having a special case for when `timeNow == pool.start` in commit ed7262b28e35f561cf35c66b4ac1bf60690d87a4.

VPC-03 | Potential Reentrancy Attack

Category	Severity	Location	Status
Logical Issue	Medium	projects/panther/contracts/VestingPools.sol (9a05001): 90, 99~103	Acknowledged

Description

A reentrancy attack can occur when the contract creates a function that makes an external call to another untrusted contract before resolving any effects. If the attacker can control the untrusted contract, they can make a recursive call back to the original function, repeating interactions that would have otherwise not run after the external call resolved the effects.

Recommendation

We recommend using the Checks-Effects-Interactions Pattern to avoid the risk of calling unknown contracts or applying OpenZeppelin ReentrancyGuard library - `nonReentrant` modifier for the aforementioned functions to prevent reentrancy attack.

Alleviation

[Panther Team]: Mentioned functions call the audited smart contracts only, which neither re-enter calling contracts, no call other contracts, which potentially may re-enter.

[Certik]: Considering the auditors do not know if the deployment will proceed correctly, the status of this issue will be updated after contract deployment upon request.

VPC-04 | Incorrect Value Assignment of `poolId`

Category	Severity	Location	Status
Logical Issue	Medium	projects/panther/contracts/VestingPools.sol (9a05001): 145	Resolved

Description

In the function `addVestingPools`, the `poolId` is assigned as the `pools.length`, which is constant over the iterations. Based on the fundamental logic of pushing a new entry into an array, in order to emit the right information about the newly added pools and wallets, the correct pool ID should be

```
uint256 poolId = _pools.length;
```

Recommendation

We recommend using the following logic to assign the correct `poolId`.

```
uint256 poolId = _pools.length;
```

Alleviation

This was resolved by assigning the correct `poolId` in commit ed7262b28e35f561cf35c66b4ac1bf60690d87a4.

VPC-05 | External Dependency

Category	Severity	Location	Status
Volatile Code	Minor	projects/panther/contracts/VestingPools.sol (9a05001): 12	Acknowledged

Description

The contract is serving as the underlying pool to interact with `ZKPToken`. The scope of the audit treats external dependencies as black boxes and assumes their functional correctness. In order to successfully deploying this contract, the correct address of `TokenAddress` should be provided.

Recommendation

We encourage the team to constantly monitor the statuses of external parties to mitigate the side effects when unexpected activities are observed.

Alleviation

[Panther Team]: There are no external dependencies - contracts depend only on the audited smart contracts.

[Certik]: Considering the auditors do not know if the deployment will proceed correctly, the status of this issue will be updated after contract deployment upon request.

VPC-06 | Missing Error Messages

Category	Severity	Location	Status
Coding Style	Informational	projects/panther/contracts/VestingPools.sol (9a05001): 204	Resolved

Description

The **require** can be used to check for conditions and throw an exception if the condition is not met. It is better to provide a string message containing details about the error that will be passed back to the caller.

Recommendation

We recommend adding corresponding error messages for the aforementioned **require** statement.

Alleviation

An error message was added to the require statement in commit 3510f7bafde4e095341e042d59b1a870444a6d52.

VPC-07 | Missing Event Emissions for Significant Transactions

Category	Severity	Location	Status
Coding Style	Informational	projects/panther/contracts/VestingPools.sol (9a05001): 186, 202	Acknowledged

Description

The functions affect the status of the contract in important ways and should be able to emit events as notifications.

- `VestingPools.claimErc20()`, which sends ERC20 tokens or unvested tokens to an address;
- `VestingPools.removeContract()`, which destroys the `VestingPools` contract under the condition that all allocated tokens have been vested.

Recommendation

We recommend emitting events for all the essential state variables that are possible to be changed during the runtime.

Alleviation

The Panther team has relayed to us that the mentioned transactions are not major protocol transactions and do not represent an interest for stakeholders/investors. They are also not emitted to save gas.

VPC-08 | Inefficient require Location

Category	Severity	Location	Status
Gas Optimization	Informational	projects/panther/contracts/VestingPools.sol (9a05001): 154	Acknowledged

Description

The function `addVestingPools()` adds vesting pools and their corresponding allocations. When adding a new vesting pool, the total allocation for the pool is updated:

```
129         uint256 updAllocation = uint256(totalAllocation);
```

At the end of the loop, a **require** checks the total allocation amount is less than the `MAX_SUPPLY`.

```
154         require(updAllocation <= MAX_SUPPLY, "VPools: supply exceeded");
```

Since the cost of `storage` type data is far more expensive than a **require**, it is more gas efficient to relocate the **require** statement inside the **for** loop in case of reverting.

Recommendation

We recommend relocating the aforementioned the **require** into the **for** loop.

Alleviation

[Panther Team]: Gas costs in this function is intentionally optimized for execution w/o reverting (note, it's supposed to be a one-time call that adds all vesting pools at once on deployment and initial configuration of contracts).

Appendix

Finding Categories

Centralization / Privilege

Centralization / Privilege findings refer to either feature logic or implementation of components that act against the nature of decentralization, such as explicit ownership or specialized access roles in combination with a mechanism to relocate funds.

Gas Optimization

Gas Optimization findings do not affect the functionality of the code but generate different, more optimal EVM opcodes resulting in a reduction on the total gas cost of a transaction.

Logical Issue

Logical Issue findings detail a fault in the logic of the linked code, such as an incorrect notion on how block.timestamp works.

Volatile Code

Volatile Code findings refer to segments of code that behave unexpectedly on certain edge cases that may result in a vulnerability.

Language Specific

Language Specific findings are issues that would only arise within Solidity, i.e. incorrect usage of private or delete.

Coding Style

Coding Style findings usually do not affect the generated byte-code but rather comment on how to make the codebase more legible and, as a result, easily maintainable.

Checksum Calculation Method

The "Checksum" field in the "Audit Scope" section is calculated as the SHA-256 (Secure Hash Algorithm 2 with digest size of 256 bits) digest of the content of each file hosted in the listed source repository under the specified commit.

The result is hexadecimal encoded and is the same as the output of the Linux "sha256sum" command against the target file.

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Founded in 2017 by leading academics in the field of Computer Science from both Yale and Columbia University, CertiK is a leading blockchain security company that serves to verify the security and correctness of smart contracts and blockchain-based protocols. Through the utilization of our world-class technical expertise, alongside our proprietary, innovative tech, we're able to support the success of our clients with best-in-class security, all whilst realizing our overarching vision; provable trust for all throughout all facets of blockchain.