SmartContract.md

CyberLeague 2022 – Space Contract

Challenge

The original challenge stated that we had to look for an image in the CTFd platform itself. Downloading all the images, and running `exiftool` on them shows this suspicious image which had data, the challenge description, appended to the end of the png chunk.

```
Warning                         : [minor] Trailer data after PNG IEND chunk
```

-Challenge Description-

```
Our motherland have engaged a vendor to develop smart contract embedded in
our fuel tank. We wanna make sure that the amount of fuel is recorded in an
immutable blockchain. (In russian) Chert by pobral etikh idiotov! The smart
contract is broken and our funds are stolen. Investigate and find out the
culprit immediately!

Smart contract link:
https://kovan.etherscan.io/address/0x16537776395108789FE5cC5420545CAb210a7D30
```

Solution

1. Analyzing the Code

The first thing that should be analyzed of a Smart Contract is its code. The code not included before this was the standard IERC20 token contract and a basic Pausable parent class to freeze all transactions after the contract has been paused.

```
pragma solidity ^0.8.0;


interface IOracle {
    function getTokenPrice(address token) external view returns (uint, uint);
}

contract Market is Pausable {
    using SafeERC20 for IERC20;

    struct Position {
        uint locked;
        address lockedToken;
        uint borrowed;
        address borrowedToken;
    }

    address public owner;
    address public oracle;
    uint public liquidationThreshold; // in bps
    uint public liquidationBonus; // in bps
    address constant internal WETH = 0xd0A1E359811322d97991E03f863a0C30C2cF029
    uint constant internal ONE = 10 ** 18;
    mapping (address => bool) public allowedLockTokens;
    mapping (address => bool) public allowedBorrowTokens;
    mapping (address => uint8) public tokenDecimals;
    mapping (address => Position[]) public positions;

    event CreatePosition(address user, uint pid);
    event Lock(address user, uint pid, address token, uint amount);
    event Unlock(address user, uint pid, address token, uint amount);
    event Borrow(address user, uint pid, address token, uint amount);
    event Repay(address user, uint pid, address token, uint amount);
    event Liquidated(address liquidator, address user, uint pid, address toker

    modifier onlyOwner() {
        require(msg.sender == owner, "onlyOwner");
        _;
    }

    constructor(address _oracle) {
        owner = msg.sender;
        oracle = _oracle;
    }

    function getTokenPrice(address token) internal view returns (uint) {
        if (token == address(0) || token == WETH) return ONE;
        (uint price, ) = IOracle(oracle).getTokenPrice(token);
        return price;
    }

    function getHealthFactor(Position storage position) internal view returns
        uint lockedTokenPrice = getTokenPrice(position.lockedToken);
        uint borrowedTokenPrice = getTokenPrice(position.borrowedToken);
        uint scaledLocked = position.locked * 10 ** (18 - tokenDecimals[positi
        uint scaledBorrowed = position.borrowed * 10 ** (18 - tokenDecimals[pc
        uint lockedValue = scaledLocked * lockedTokenPrice / ONE;
        uint borrowedValue = scaledBorrowed * borrowedTokenPrice / ONE;
        if (borrowedValue == 0) return ONE;
        uint healthFactor = lockedValue * liquidationThreshold * ONE / (borrow
        return healthFactor;
    }

    function getHealthFactor(address user, uint pid) public view returns (uint
        require(pid < positions[user].length, "InvalidPID");
        Position storage position = positions[user][pid];
        return getHealthFactor(position);
    }

    function isPositionSafe(Position storage position) internal view returns (
        uint healthFactor = getHealthFactor(position);
        return healthFactor >= ONE;
    }

    function isPositionSafe(address user, uint pid) public view returns (bool)
        require(pid < positions[user].length, "InvalidPID");
        Position storage position = positions[user][pid];
        return isPositionSafe(position);
    }

    function createPosition(address lockedToken, address borrowedToken) public
        require(allowedLockTokens[lockedToken] && allowedBorrowTokens[borrowec
        uint pid = positions[msg.sender].length;
        Position memory position = Position({
            locked: 0,
            lockedToken: lockedToken,
            borrowed: 0,
            borrowedToken: borrowedToken
        });
        positions[msg.sender].push(position);
        emit CreatePosition(msg.sender, pid);
    }

    function lock(uint pid, uint amount) public payable whenNotPaused {
        require(pid < positions[msg.sender].length, "InvalidPID");
        Position storage position = positions[msg.sender][pid];
        position.locked += amount;
        receiveToken(position.lockedToken, amount);
        emit Lock(msg.sender, pid, position.lockedToken, amount);
    }

    function unlock(uint pid, uint amount) public whenNotPaused {
        require(pid < positions[msg.sender].length, "InvalidPID");
        Position storage position = positions[msg.sender][pid];
        position.locked -= amount;
        sendToken(position.lockedToken, amount);
        require(isPositionSafe(position), "UnsafePosition");
        emit Unlock(msg.sender, pid, position.lockedToken, amount);
    }

    function borrow(uint pid, uint amount) public whenNotPaused {
        require(pid < positions[msg.sender].length, "InvalidPID");
        Position storage position = positions[msg.sender][pid];
        position.borrowed += amount;
        sendToken(position.borrowedToken, amount);
        require(isPositionSafe(position), "UnsafePosition");
        emit Borrow(msg.sender, pid, position.borrowedToken, amount);
    }

    function repay(uint pid, uint amount) public payable whenNotPaused {
        require(pid < positions[msg.sender].length, "InvalidPID");
        Position storage position = positions[msg.sender][pid];
        position.borrowed -= amount;
        receiveToken(position.borrowedToken, amount);
        emit Repay(msg.sender, pid, position.borrowedToken, amount);
    }

    function liquidate(address user, uint pid, uint amount) public whenNotPaus
        require(pid < positions[user].length, "InvalidPID");
        Position storage position = positions[user][pid];
        require(!isPositionSafe(position), "SafePosition");
        uint borrowedTokenPrice = getTokenPrice(position.borrowedToken);
        uint lockedTokenPrice = getTokenPrice(position.lockedToken);

        uint scaledAmount = amount * 10 ** (18 - tokenDecimals[position.borrow
        uint borrowedValue = scaledAmount * borrowedTokenPrice / ONE;
        uint scaledLiquidated = borrowedValue * (10000 + liquidationBonus) * O
        uint liquidated = scaledLiquidated / 10 ** (18 - tokenDecimals[positic
        if (liquidated > position.locked) liquidated = position.locked;
        position.borrowed -= amount;
        position.locked -= liquidated;

        receiveToken(position.borrowedToken, amount);
        sendToken(position.lockedToken, liquidated);
        emit Liquidated(msg.sender, user, pid, position.lockedToken, liquidate
    }

    function receiveToken(address token, uint amount) internal {
        if (token == address(0)) {
            require(msg.value >= amount, "NotEnoughFunds");
        } else {
            IERC20(token).safeTransferFrom(msg.sender, address(this), amount);
        }
    }

    function sendToken(address token, uint amount) internal {
        if (token == address(0)) {
            (bool success,) = msg.sender.call{value: amount}("");
            require(success, "SendETHError");
        } else {
            IERC20(token).safeTransfer(msg.sender, amount);
        }
    }

    function pause() public onlyOwner {
        _pause();
    }

    function setAllowedLockToken(address token) public onlyOwner {
        allowedLockTokens[token] = true;
    }


    function setAllowedBorrowToken(address token) public onlyOwner {
        allowedBorrowTokens[token] = true;
    }

    function setTokenDecimals(address token, uint8 decimals) public onlyOwner
        tokenDecimals[token] = decimals;
    }

    function setLiquidationThreshold(uint _liquidationThreshold) public onlyOw
        liquidationThreshold = _liquidationThreshold;
    }

    function setLiquidationBonus(uint _liquidationBonus) public onlyOwner {
        liquidationBonus = _liquidationBonus;
    }
}
```

2. Wild Goose Chase 1 - Liquidate

Here are the things that I thought were strange about the code

- The liquidate function looked extremely suspicious, as it was the only function that took in an address of user. I have truncated to the important parts

```
function liquidate(address user, uint pid, uint amount) public whenNotPaused {
    require(pid < positions[user].length, "InvalidPID");
    Position storage position = positions[user][pid];
```

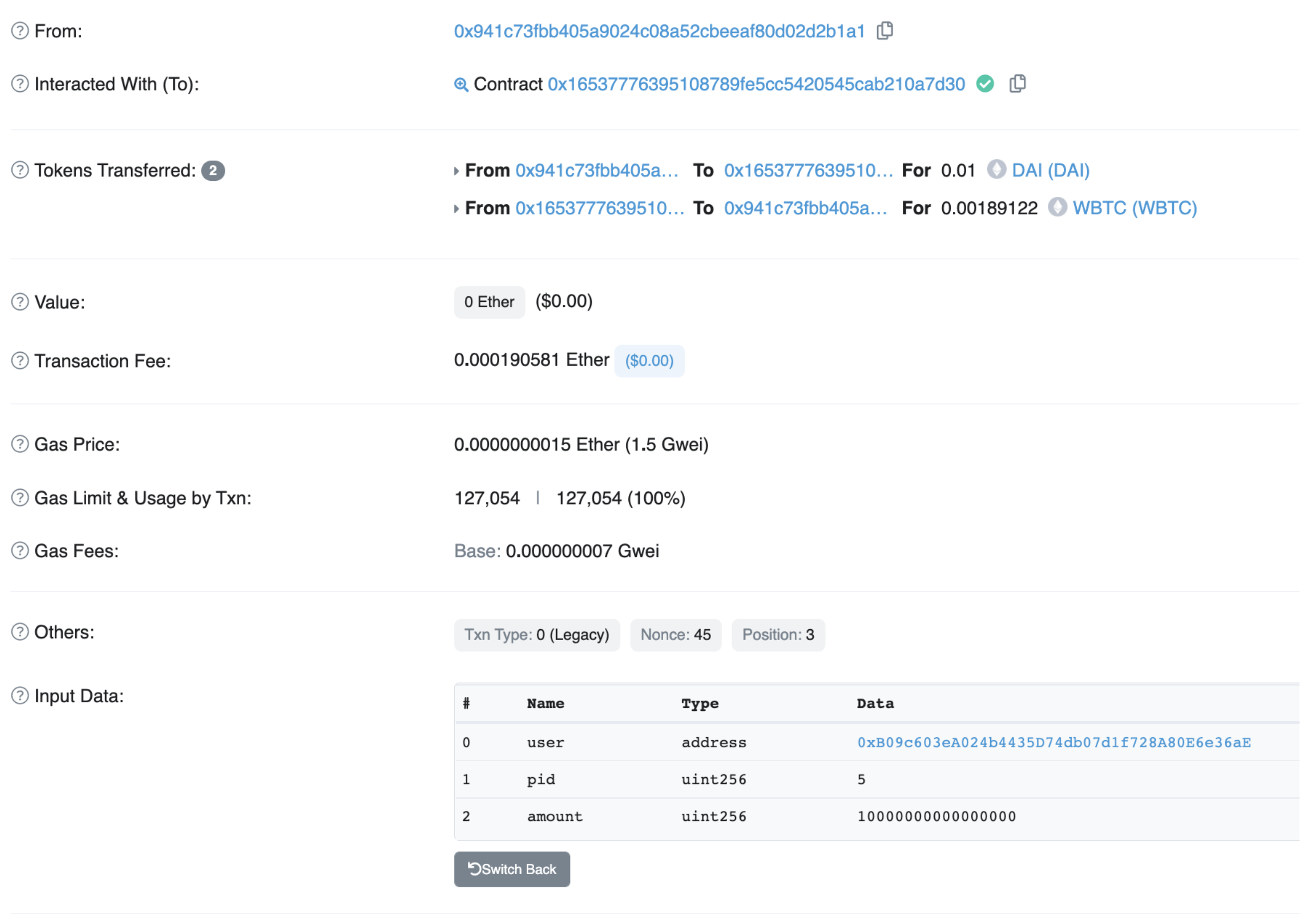
```
        ...
        receiveToken(position.borrowedToken, amount);
        sendToken(position.lockedToken, liquidated);
        emit Liquidated(msg.sender, user, pid, position.lockedToken, liquidated);
    }
```

I suspected that this would allow malicious attackers to call the `liquidate` function and pass in the address of the user that they would like to drain funds from along with a valid pid (from observing past transactions in the contract).

This would fetch the position of the target user, while the subsequent call to `sendToken` would use `msg.sender` as the final address to send the tokens to.

```
    function sendToken(address token, uint amount) internal {
        if (token == address(0)) {
            (bool success,) = msg.sender.call{value: amount}("");
            require(success, "SendETHError");
        } else {
            IERC20(token).safeTransfer(msg.sender, amount);
        }
    }
```

Here is an example of a transaction that I thought was suspicious



From:	0x941c73fbb405a9024c08a52cbeeaf80d02d2b1a1
Interacted With (To):	Contract 0x1653777639510878 9fe5cc5420545cab210a7d30
Tokens Transferred: 2	From 0x941c73fbb405a... To 0x1653777639510... For 0.01 DAI (DAI) From 0x1653777639510... To 0x941c73fbb405a... For 0.00189122 WBTC (WBTC)
Value:	0 Ether ($0.00)
Transaction Fee:	0.000190581 Ether ($0.00)
Gas Price:	0.0000000015 Ether (1.5 Gwei)
Gas Limit & Usage by Txn:	127,054 | 127,054 (100%)
Gas Fees:	Base: 0.000000007 Gwei
Others:	Txn Type: 0 (Legacy) Nonce: 45 Position: 3
Input Data:	

#	Name	Type	Data
0	user	address	0xB09c603eA024b4435D74db07d1f728A80E6e36aE
1	pid	uint256	5
2	amount	uint256	10000000000000000

It passed in an input user address parameter of `0xB09c603eA024b4435D74db07d1f728A80E6e36aE` which was not the caller's actual address `0x941c73fbb405a9024c08a52cbeeaf80d02d2b1a1`.

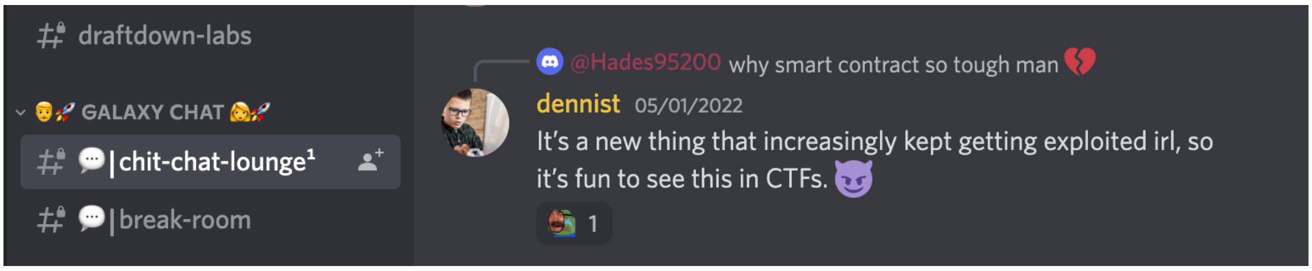
However, closer analysis of code showed that while you can pass in arbitrary user addresses, the `receiveToken` function that gets called *before* the `sendToken` function will transfer funds from the `msg.sender` to the smart contract address. This means that an equivalent amount of tokens will be transferred from the attacker despite passing in another victim user's address. Since this call happens before the `sendToken`, it cannot be manipulated. The user's address passed in simply calculates the equivlaent amount of tokens to be transferred as well as the type of tokens to be transferred based on the user's position in the respective `pid`

```
function receiveToken(address token, uint amount) internal {
    if (token == address(0)) {
        require(msg.value >= amount, "NotEnoughFunds");
    } else {
        IERC20(token).safeTransferFrom(msg.sender, address(this), amount);
    }
}
```

Thus while it seems extremely strange, it doesn't appear to be vulnerable (I would love to chat about this with the authors and whether my assumptions here are correct)

3. Slowly piecing it together

Given the *hint(?)* in the discord chat about how its a "new" thing, I started looking at recent exploits in smart contracts



@Hades95200 why smart contract so tough man

dennist 05/01/2022

It's a new thing that increasingly kept getting exploited irl, so it's fun to see this in CTFs.

1

There was a curious declaration of an `IOracle` at the start of the code and I wondered whether there was any exploit related to that. I came across this article https://hackernoon.com/how-dollar100m-got-stolen-from-defi-in-2021-price-oracle-manipulation-and-flash-loan-attacks-explained-3n6q33r1

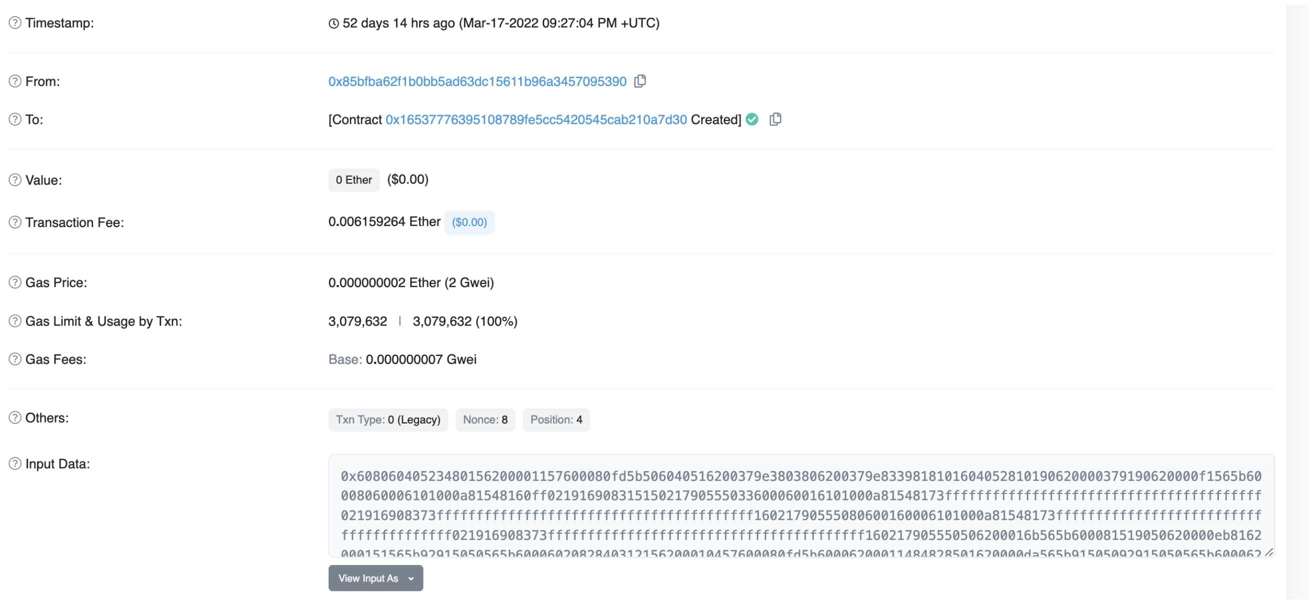
The article detailed how the attacker was able to influence the price ratio of `ETH/BAT` by using a flash loan to borrow heavy amounts of ETH and basically upset the balance between ETH and BAT. The price oracle was vulnerable because it used the available pool of ETH to BAT to determine the ratio/rate of exchange.

I was then curious to see how the oracle determined the token price in this case.

```
function getTokenPrice(address token) internal view returns (uint) {
    if (token == address(0) || token == WETH) return ONE;
    (uint price, ) = IOracle(oracle).getTokenPrice(token);
    return price;
}
```

This function had to be called whenever `liquidate` was called or `getHealthFactor` was called which determines whether the loaner is allowed to borrow (more on this later....)

At first, I thought that I could find the `oracle` address by looking at the first transaction hash, given that it was a parameter passed into the contract's constructor but I couldn't decode the input.



Timestamp: 52 days 14 hrs ago (Mar-17-2022 09:27:04 PM +UTC)

From: 0x85bfba62f1b0bb5ad63dc15611b96a3457095390

To: [Contract 0x16537776395108789fe5cc5420545cab210a7d30 Created]

Value: 0 Ether ($0.00)

Transaction Fee: 0.006159264 Ether ($0.00)

Gas Price: 0.000000002 Ether (2 Gwei)

Gas Limit & Usage by Txn: 3,079,632 | 3,079,632 (100%)

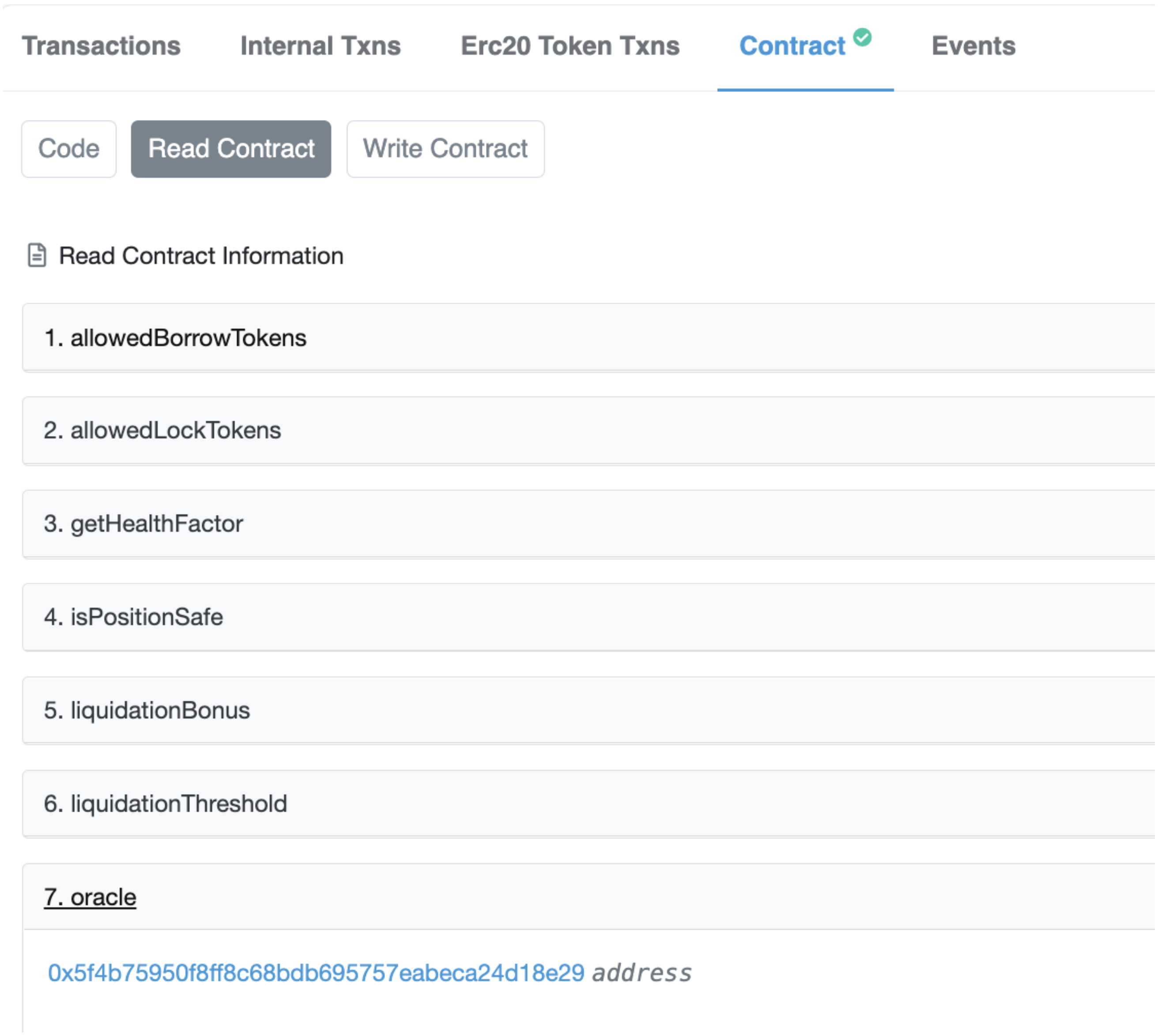
Gas Fees: Base: 0.000000007 Gwei

Others: Txn Type: 0 (Legacy) Nonce: 8 Position: 4

Input Data:

```
0x608060405234801562000011576000 80fd5b506040516200379e3803806200379e833981810160405281019062000379190620000f1565b60
008060006101000a81548160ff02191690831515021790555033600060016101000a81548173fffffffffffffffffffffffffffffffffffffff
021916908373ffffffffffffffffffffffffffffffffffffffff16021790555080600160006101000a81548173fffffffffffffffffffffffff
fffffffffffffff021916908373ffffffffffffffffffffffffffffffffffffffff1602179055505062000016b565b600081519050620000eb8162
000151565b92915050565b6000602082840312156200010457600080fd5b6000620001148482850162000000da565b91505092915050565b600062
```

Turns out, I was just a noob at smart contracts, as `oracle` was a public variable, so I could simply read directly from the contract without viewing the transaction logs.



Read Contract Information

1. allowedBorrowTokens

2. allowedLockTokens

3. getHealthFactor

4. isPositionSafe

5. liquidationBonus

6. liquidationThreshold

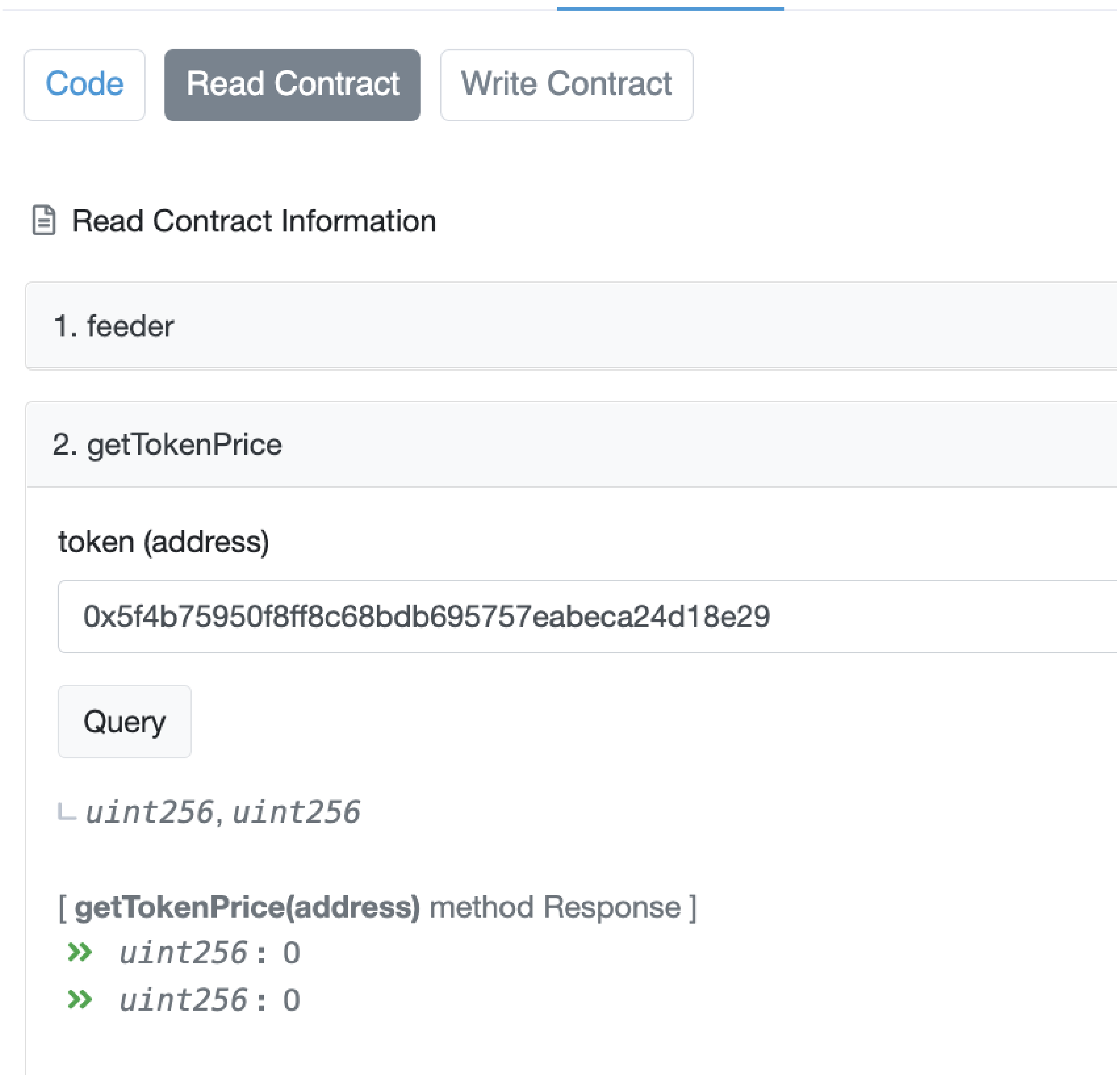
7. oracle

0x5f4b75950f8ff8c68bdb695757eabeca24d18e29 *address*

However, looking at the oracle's smart contract source code, it didn't seem like there were obvious vulnerabilities

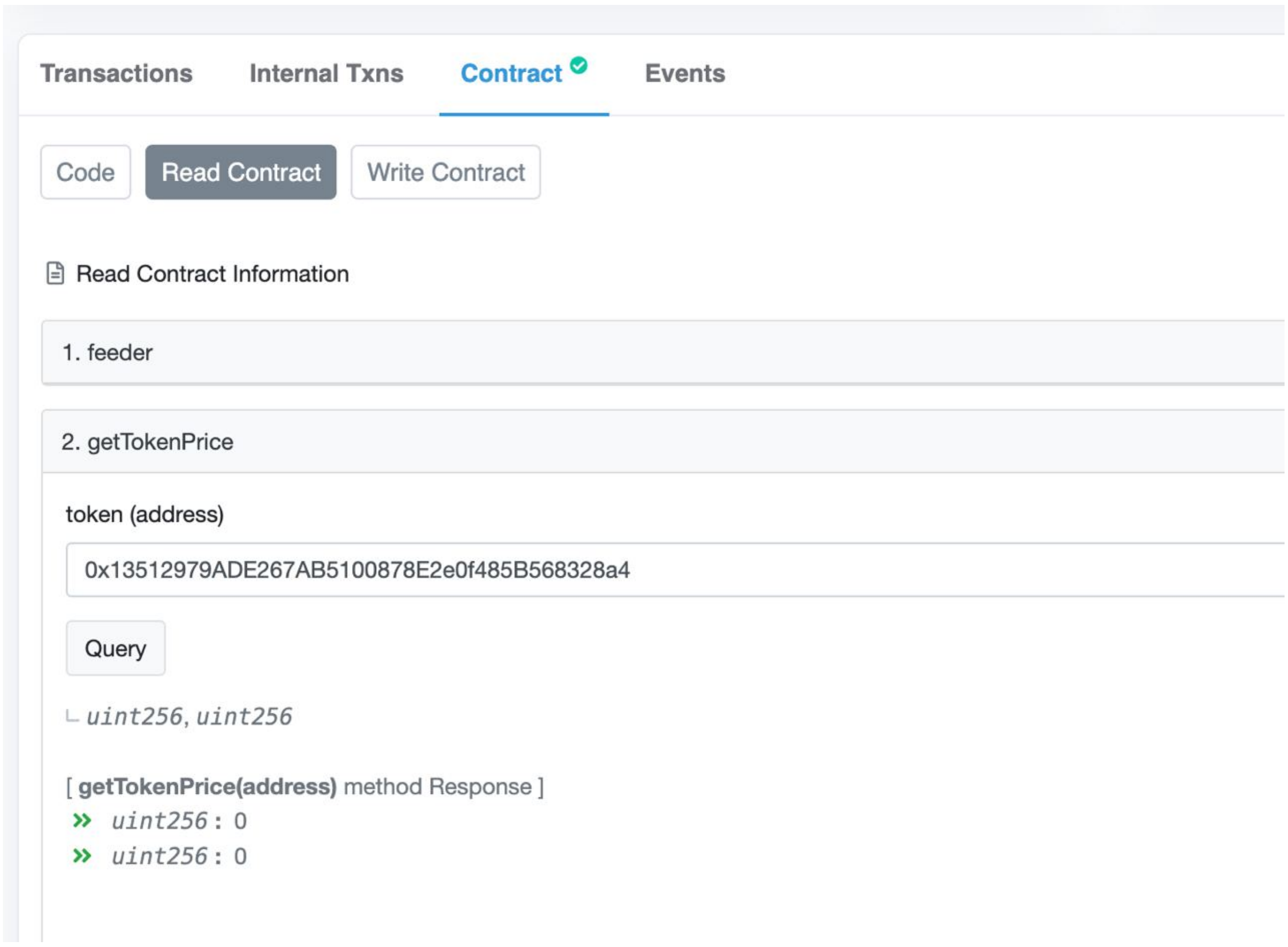
```
pragma solidity ^0.8.0;

contract Oracle {

    struct PriceInfo {
        uint priceToETH;
        uint lastUpdate;
    }

    mapping (address => PriceInfo) priceInfo;
    address public feeder;
    uint constant internal ONE = 10 ** 18;

    modifier onlyFeeder() {
        require(msg.sender == feeder, "OnlyFeeder");
        _;
    }
    constructor(address _feeder) {
        feeder = _feeder;
    }

    function getTokenPrice(address token) public view returns (uint, uint) {
        return (priceInfo[token].priceToETH, priceInfo[token].lastUpdate);
    }

    function setTokenPrice(address token, uint price) public onlyFeeder {
        priceInfo[token].priceToETH = price;
        priceInfo[token].lastUpdate = block.timestamp;
    }
}
```

On a call to `getTokenPrice`, it just returns the hardcoded price that was set with `setTokenPrice`. However what happens if it tries to get the token price of a token that was not set? I tried testing with a "token" address that did not have a price (the oracle address itself) and it returned 0!



```
0x5f4b75950f8ff8c68bdb695757eabeca24d18e29

uint256, uint256

[ getTokenPrice(address) method Response ]
» uint256 : 0
» uint256 : 0
```

This could be the main flaw of the smart contract! I decided to test all the `allowedBorrowedTokens` and `allowedLockTokens` manually. (because I couldn't figure out how to work the api) and this particular borrowedToken was not set, so it returned 0.



0x13512979ADE267AB5100878E2e0f485B568328a4

```
∟ uint256, uint256

[ getTokenPrice(address) method Response ]
» uint256 : 0
» uint256 : 0
```

Returning to the original smart contract code, I checked to see what would fail if the `getTokenPrice` call returned 0 and found the solution

4. Solution

If a user would like to borrow from the contract, it first has to pass a check

```
function borrow(uint pid, uint amount) public whenNotPaused {
    require(pid < positions[msg.sender].length, "InvalidPID");
    Position storage position = positions[msg.sender][pid];
    position.borrowed += amount;
    sendToken(position.borrowedToken, amount);
    require(isPositionSafe(position), "UnsafePosition");
    emit Borrow(msg.sender, pid, position.borrowedToken, amount);
}
```

This check, `isPositionSafe` eventually calls `getHealthFactor` which is the main vulnerability

```
function isPositionSafe(Position storage position) internal view returns (bool
    uint healthFactor = getHealthFactor(position);
    return healthFactor >= ONE;
}

function getHealthFactor(Position storage position) internal view returns (uir
    uint lockedTokenPrice = getTokenPrice(position.lockedToken);
    uint borrowedTokenPrice = getTokenPrice(position.borrowedToken);
    uint scaledLocked = position.locked * 10 ** (18 - tokenDecimals[position.l
    uint scaledBorrowed = position.borrowed * 10 ** (18 - tokenDecimals[positi
    uint lockedValue = scaledLocked * lockedTokenPrice / ONE;
    uint borrowedValue = scaledBorrowed * borrowedTokenPrice / ONE;
    if (borrowedValue == 0) return ONE;
    uint healthFactor = lockedValue * liquidationThreshold * ONE / (borrowedVa
    return healthFactor;
}
```

Particularly, `if (borrowedValue == 0) return ONE;` , this would pass the `isPositionSafe` check that checks whether `healthFactor >= ONE` . In other words, any transactions that involve borrowing this particular token with the `0x13512979ADE267AB5100878E2e0f485B568328a4` address (which is USDT), is able to borrow infinitely!

Now it is just a matter of finding all the transactions that involve the creating of this vulnerable position and the borrowings correlated to this token address. The next part is just the manual work of checking input data of each transaction and copy pasting the relevant transaction hash.

5. Final Script

```
import hashlib

txs = [
#from 0x488dad0ce94f34e33069b8ae5e16826b63f0f575
'0x6705735d1d4c526cd5db6c5810de6b11ba196fb93715a67ae855d037bfeaeaec', #borrow
'0x657b24138cea98eca019de351d60c69210334926c46d9bfb7a59f5c0db5d16f4', #borrow
'0xdb3f9da9cc6600ba9c2ca0685cd5c29818dae632fb3be65d530ef404b3ade202', #borrow
'0x6b52684eda64076701e647911f55019fb18b30d980554dd2df5ee0e777506c3a', #borrow
'0x95bc3879debc5ffbe9932d5a60dd53146374e7dd553fef5f00152371bbb75f38', #borrow
'0xf8cb1d747b53bbd4b4346eb8522fa3df36025dafedeb5b19bf54a9fff946ae8a', #borrow
'0xef40506ae849c17dfbb75f97331860750217602f9c0a9c7718e50d04f0e233b8', #create
'0xcc8ff167cc6a1014f5c4b7445f26b17f68cc95bcc0c578c5330278dda8229d0b', #create

#from 0x941c73fbb405a9024c08a52cbeeaf80d02d2b1a1
'0x99a5722bb73a73c6b47967f9b457e888d6503b0f9e1bf23fbf36de56ebad1522', #borrow
'0x8beb80929a026d68fe9e80d0e46dadf43f9b8c68dc1db7e53b996e9654a3c71c', #borrow
'0x13240bc2ce9333db092704b057083d23fa4e365b1b049ea839eb9955591ffd4d', #borrow
'0x3a109f0754113742eaae4bad747261aa7d9a1a9e2fb4d12704631b333b790006', #borrow
'0x8b0b5a0d65a1272d811f1db90cf7a24e43c64cf0d4767a78accf0dd9afce954c', #borrow
```

```
    '0xdd588f3c2a9f25aa57d27e3257fe93882cf211470bd92e56b5271f95ab3c955f', #borrow
    '0x6287be53eb87e475cfdabfe85c7db800c5262a469a4c270e55b8ddf481b6dae3', #borrow
    '0x6ce3f133f0d925b125b6d8861b582cfd3b9abc8df4ce6ecd9607751b5fa6e796', #borrow
    '0xcfb692d772f8acb90bc14a5da06f72c8ed9d871bbe76787ac0fa8a40e1ef11aa', #borrow
    '0x0635eeabe77d53672c227c0938f73f43c8f43b984e2c02d4e4a7b4e4d9740a09', #borrow
    '0xc20e2ac5792a3350febd9a7e62527faccf4e07de2c1454572380e6f629ecca18', #create
    '0xb1f54b9969ba60075775a3168d2ad16482e672cbf386ba4f9d6f433fe9d86fbe', #create

    #from 0xb09c603ea024b4435d74db07d1f728a80e6e36ae
    '0xea24903d0a72b56457b88bdfd842f4065b0371b9c118dae08aca8dadb43c81b4', #borrow
    '0xf7a6068687cfd85a24c8fd169c3c95133ff7a957c843171733902925990b4b74', #create


    ]

    assert len(txs) == 22
    salt = b'hint: find abnormal transactions'
    m = hashlib.sha256()
    for tx_hash in sorted(txs):
        assert len(tx_hash) == 66 and tx_hash[:2] == '0x'
        m.update(salt + tx_hash.encode() + m.digest())
    print(m.hexdigest())
    assert m.hexdigest()[:16] == 'bf22a2d63563554c'
    print('flag{' + m.hexdigest() + '}')
```

6. Finally!

```
flag{bf22a2d63563554c2073f9480867794e17297ce17c7ec4cc3502979828e4253f}
CYBERLEAGUE{bf22a2d63563554c2073f9480867794e17297ce17c7ec4cc3502979828e4253f}
```

7. Thoughts

I was really quite new to solidity code and smart contract vulnerabilities, so this was a good opportunity to learn. I'm sure there might be many mistakes in my writeup but I hope that readers can follow my train of thought as well as point out any of aforementioned mistakes