Exactly

Smart Contract Audit

coinspect

Exactly

Exactly Protocol - Rewards

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V230207

Prepared for Exactly Protocol • January 2023

1. Executive Summary

In **January 2023, Exactly Protocol** engaged Coinspect to perform a source code review. The objective of the project was to evaluate the security of the `RewardsController` contract, which implements the rewards distribution, as well as its interoperability with the previously existing contracts

Exactly will distribute rewards for floating borrow and deposit positions, as well as fixed borrows. Every reward-related operation (allocation, accrual and claim) will be handled by the `RewardsController` contract.

The following issues were identified during the initial assessment:

High Risk	Medium Risk	Low Risk
Open **0**	Open **0**	Open **0**
Fixed 0	Fixed 0	Fixed 3
Reported 0	Reported 0	Reported 3

Coinspect identified three low-risk and four informational issues, some involving possible business impacts but based on our analysis of the probabilities (Likelihood) we decided to reduce their risks. Below is a brief summary: **EXA-40** depicts how an arithmetic overflow can break the reward accounting process. **EXA-41** is about how index retrieval would likely return stale values. **EXA-42** explains the lack of mechanisms to rescue unclaimed rewards, if necessary.

2. Assessment and Scope

Exactly is developing a new token reward system for users that perform several actions across the active markets. Floating and fixed borrow operations as well as floating deposit operations will start accruing interests that could be claimed afterwards. This functionality is implemented by a `RewardsController` contract, which handles rewards allocation and provides the reward claim functionality.

The audit started on **Jan 23, 2023** and was conducted on the **next** branch of the git repository at https://github.com/exactly/protocol as of commit **da9ddd7f847ebdad24c21fdae049f9d4523e9313** of **Jan 24, 2023**.

The audited files under the contracts directory have the following `sha256sum` hash:

```
6c5fc95b5134a59190b6ebdc1802d9558481d9fea22a398572708a0862e80140  ./mocks/MockPriceFeed.sol
d30668102bfe67c362b0aa229652c1321dd23a30dd41250247829864c05d8424  ./mocks/MockStETH.sol
a0244349445d4832b7b6947a9d3c66f2329c62eda839b107c9fc5dbf416c8302  ./mocks/MockInterestRateModel.sol
27c2702ebf14d78a9a954ef276b3f037a8a4c8c42d336283fd8e00258c3bfa07  ./mocks/FixedPoolHarness.sol
d2bc0465d7e1b7186c5054219c7947acb0d5e459f810147379b13cb24170fb93  ./mocks/MarketHarness.sol
41a0bb7cfb822ca8198f6522a6494731153b6d98eb41b2ea1638636a298ab3a3  ./Auditor.sol
32c3a3408e2dee4a0d914e3a15ea0d163734312de6b31f25b15ad0caba316f2f  ./utils/import.sol
f776334ac5832e4a7069b94a64814accb7b7014a35ecfe390ee79ff0c304d1a6  ./utils/FixedLib.sol
4440367e3f3319dc33bc73d9297e8a2a8ac389f0a0332aceef1deec793c17757  ./utils/IPriceFeed.sol
d9471e277c77c9c24809f68fa85bdf9e34780c4633977ffdfdf93b49e4144392  ./periphery/Previewer.sol
1a652289b8c16eb9678cabb726013cf0fa7ffd3f59b8f35f7fb9fbf62898f8ca  ./InterestRateModel.sol
faaec0ae09afa35cc453667a33b3ad2b2e642dc61045f0137f7e11b6db87a82f  ./RewardsController.sol
6dd8b8ed18c24d13636401a73d546d6bb34cf651579cb8ade21ebcc2c85d9b0f  ./MarketETHRouter.sol
06a9c0e43354fbdf5ded6e9b0fee4507d26ef715e106678df746f1515696d42f  ./PriceFeedWrapper.sol
5ae02e8f1b81b2be5ba7d43406fb2c0167875db1a51b487c999066a81bd24626  ./PriceFeedDouble.sol
8fe7fff2dacf10badfb47f188d938307b892b2562ba460ef9ac44d31d3d41891  ./Market.sol
```

Coinspect reviewed the security of the newly added `RewardsController` contract, and the modifications included to the market contract that will update the rewards system states. Also, Coinspect reviewed the changes to the Interest Rate Model (IRM) that modify how fixed and floating rates are computed. It is worth mentioning that the Exactly team stated that this implementation is intended to be deployed on the Optimism Chain, which is relevant due to the current gas consumption of the entire rewards logic (update, allocation, and distribution).

The test suite provided for the `RewardsController` was thorough and clear to understand. However, as new functionalities are added to the protocol, Coinspect **strongly recommends updating** previous tests (markets, auditor, etc.) to

contemplate the existence of the rewards contract and evaluate its impact on key parameters such as gas consumptions or token flows, **EXA-45**.

The `RewardsController` contract is in charge of retrieving, processing and allocating rewards to each user. It uses a global borrow and deposit index system to track the current rewards state. Relevant data is collected via two hooks that update borrow and deposit operations performed by each market. The mentioned hooks were added to the market contract and are triggered when depositing (floating only), borrowing (floating and fixed), repaying, minting, transferring, and liquidating among other relevant actions. In relation to this, Coinspect detected that the operating costs were increased considerably by the hooked callbacks, **EXA-43**.

The implementation of the `RewardsController` is based on the rewards system designed by Aave. Coinspect identified several differences between both implementations:

1) Exactly allocates rewards via the `previewAllocation()` function that computes the **result of two integrals yielding in an exponential equation**.
2) Aave has only one update hook whereas Exactly separated this process for borrow and deposit operations.
3) Only self-accrued rewards could be claimed on Exactly. Aave includes a delegated claiming system.
4) Exactly sets all the parameters of a distribution in a single call. Aave has setters for each distribution's parameter.
5) Because Exactly added the borrow and deposit operations differentiation, **all loops are nested one more level** than Aave's.
6) Exactly allows sending zero token transfers while claiming from an account with no accrued rewards, **EXA-46**. On the contrary, Aave returns immediately without executing further logic if the accrued amount is zero.
7) Exactly allows adding multiple reward tokens, **looping over all the allowed tokens** while performing a claim. Aave allows passing the claimed reward address to make single-token claims.
8) When claiming, Exactly updates and processes the claim of the first market, then moves to the next one and performs the same two steps. Aave first updates all the markets and then processes all the claims.

9) Exactly **does not revert if downcasting** from an `uint256` when computing the reward accrual **(EXA-40)** results in an overflow, whereas Aave reverts if that happens.

In addition to the differences mentioned before, more aspects of the `RewardsController` were reviewed. Regarding how borrow and deposit positions' global indexes are retrieved, Coinspect found out that the external view function implemented to do so could return stale values affecting external sources consuming this data, **EXA-41**.

In terms of how each distribution period is configured, an access controlled `config()` function is included in the controller's contract. It is only callable by the owner and allows setting (and modifying) each distribution's parameter. Coinspect identified that upon adding a new distribution period, reward tokens might be unavailable by the time it begins, **EXA-44**. Also, the owner has to set each supported market that will receive information via the `handleBorrow` and `handleDeposit` hooks. Those hooks are not access controlled and use the `msg.sender` assuming that the call will come from a market, however anyone can deploy a spoof market that calls those hooks. Coinspect didn't identify any exploit scenario because states will be updated only for those markets previously added via a `config()` call.

In addition, once funds are sent to the `RewardsController`, the only way they can exit is via rewards claims. In the event of experiencing an attack, having an undisclosed bug or any other unexpected contingency funds won't be recoverable to its safeguard, **EXA-42**.

Regarding the changes introduced to the Interest Rate Model and how curves are calculated, Coinspect found that due to a discontinuity in the curve, the rate slightly decreases with an increase of the utilization, **EXA-47**.

3. Summary of Findings

Id	Title	Total Risk	Fixed
EXA-40	Insecure downcast in rewards accounting	Low	✔
EXA-41	Reward indexes view function might return stale data	Low	✔
EXA-42	Unclaimed rewards might become unrecoverable	Low	✔
EXA-43	Cost to interact with markets is considerably increased	Info	!
EXA-44	Configuration process does not guarantee rewards availability	Info	!
EXA-45	Outdated test suite	Info	!
EXA-46	Zero token transfers triggered by claim logic	Info	✔
EXA-47	Fixed rate curve discontinuity	Info	!

4. Detailed Findings

EXA-40 Insecure downcast in rewards accounting

Total Risk	Impact	Location
Low	Medium	`RewardsController.sol`
Fixed ✔	Likelihood Low	

Description

The current account's index (either for deposits or borrows) might overflow because a downcast from a `uint256` to a `uint104` is performed insecurely. As a result, the update logic will erase previously accruals. Also, accrued rewards could overflow (because of a downcast from `uint256` to `uint128`) meaning that less rewards than expected would be effectively accrued.

Indexes are updated every time an `update()` call is triggered, either by the hooks or by a claim. While updating the rewards accountancy, new indexes are retrieved by calling `previewAllocation()`:

```
    (uint256 borrowIndex, uint256 depositIndex, uint256 newUndistributed) =
previewAllocation(rewardData, market);
```

Later, the indexes are insecurely downcast to `uint104`:

```
        uint256 newAccountIndex;
        ...
        if (ops[i].operation == Operation.Borrow) {
          newAccountIndex = rewardData.borrowIndex;
        } else {
          newAccountIndex = rewardData.depositIndex;
        }
        if (accountIndex != newAccountIndex) {
         rewardData.accounts[account][ops[i].operation].index = uint104(newAccountIndex);
```

The logic inside the preview function computes the new indexes based on current market and reward conditions (such as balances, supplies and configuration

parameters). In the event of having a high amount of custom reward tokens, under specific configuration parameters, the preview allocation might return a value higher than `type(uint104).max` causing an overflow upon its casting.

In addition, the rewards accrual will be mistakenly calculated for the next update as the account's recently assigned index will be smaller than the latest one:

```
    uint256 accountIndex = rewardData.accounts[account][ops[i].operation].index;
       uint256 newAccountIndex;
       ...
       if (accountIndex != newAccountIndex) {
         rewardData.accounts[account][ops[i].operation].index = uint104(newAccountIndex);
         if (ops[i].balance != 0) {
           uint256 rewardsAccrued = accountRewards(ops[i].balance, newAccountIndex,
accountIndex, baseUnit);
           rewardData.accounts[account][ops[i].operation].accrued += uint128(rewardsAccrued);
           emit Accrue(market, reward, account, newAccountIndex, newAccountIndex,
rewardsAccrued);
         }
       }
```

Moreover, the current account's accrued rewards are increased by the downcast `rewardsAccrued` variable (from `uint256` to `uint128`).

This process would not be perceived by users because the `Accrue` event emitted uses `uint256` variables instead of the values effectively used.

This issue is considered low-risk as the scenarios that would allow exploiting it are unlikely.

Recommendation

Perform the downcasting safely by reverting if the `uint256` to be cast is bigger than `type(targetUint).max`. Modify the emitted parameters on the `Accrue` event so it shows the correct values.

Status

Fixed in commit `120163937a5d6e28954c01fd3e6b645e8f933886` by updating the event and reverting on overflow.

EXA-41	Reward indexes view function might return stale data		
Total Risk **Low**	Impact Low	Location `RewardsController.sol`	
Fixed ✔	Likelihood Low		

Description

External sources consuming the returns of `rewardIndexes()` to perform other time-sensitive actions will likely use stale data, affecting subsequent actions they might conduct.

The `rewardIndexes()` is an external view function that returns the current deposit and borrow indexes. As they are updated only when a `handleDeposit()` or `handleBorrow()` hook is triggered, if the update frequency is not high enough, the returned data will be outdated and won't depict the current rewards controller indexes. Unknown scenarios might arise as the retrieved data won't be up-to-date, for example:

- An external oracle gets the current indexes via `rewardIndexes()` and performs calculations with their values. If the markets have low volume of interactions, the returned data will be likely outdated yet consumed by the external source periodically.

It is worth mentioning that the `rewardsData()` function returns the last update of a distribution but this functionality is not provided in `rewardIndexes()`.

Recommendation

Clearly document this behavior. Prevent using the `rewardIndexes()` returns as inputs for time-sensitive calculations (e.g. oracles).

Status

Fixed in commit da90aa7b19dcc8c5e41fb0dd9e8becdf635b6cc9.

An external `previewAllocation` function was added that retrieves the indexes directly by calculating their values with the most recent states instead of getting them via each distribution mapping.

EXA-42	Unclaimed rewards might become unrecoverable		
Total Risk **Low**	Impact Low	Location `RewardsController.sol`	
Fixed ✔	Likelihood Low		

Description

Reward tokens are sent in advance to the `Controller` contract, on each market the administrator has to set the current `Controller's` address to start the rewards process. Unclaimed rewards might get stuck if the address of the `Controller` is changed on a Market.

The `RewardsController` manager first sends the tokens to that contract and once the distribution period begins, users start to accrue rewards on their positions. When the claiming period is up, they can start claiming the reward tokens. In the event of having to change the current rewards contract (e.g. because of a contingency), the admin has no way to get the rewards back.

It is worth mentioning that a rescue mechanism could be by manually adding a spoof market address via `config()` and assigning all the remaining rewards to the administrator. However, if the rewards are at risk for some reason, this process could take critical time.

Recommendation

Consider adding a rescue function that could only be executed if previously defined conditions are met, to allow recovering the funds in case of an emergency.

Status

Fixed in commit `81a11e3ce1e97623b625b956f155de304001791c` by allowing the admin to withdraw the funds.

EXA-43	Cost to interact with markets is considerably increased

Total Risk	Impact	Location
Info	-	`RewardsController.sol`
Fixed	Likelihood	
!	-	

Description

Every key action of each market will trigger an update of the rewards controller by a hook call, and as a consequence, performing transfers, borrows and even liquidations becomes considerably more expensive.

Due to the addition of the rewards feature, the `handleDeposit()` or `handleBorrow()` hooks were added to most functions of each market. Those hooks perform updates of the current rewards state. Each update has nested loops that go over each reward token, operation and market.

Coinspect evaluated the costs to perform some of the core actions of a market and compared their costs without having a rewards controller enabled:

- `transferFrom()`
    a. 2 pools with 2 reward tokens: `200k`
    b. 12 pools with 2 reward tokens: `433k`
    c. Controller disabled: `37k`

- `liquidate()`
    a. 2 pools with 2 reward tokens: `640k`
    b. Controller disabled: `320k`

Also, Coinspect checked the costs to perform a rewards claim via `claimAll()` and the impact of previous updates. The updates are triggered by calling `market.transferFrom()`:

```
Without previous update:
```

```
 Gas used to claimAll: 686368

With previous update
 TransferFrom Cost: 521478
 Gas used to claimAll: 478692

Performing the Claim first and then making a transfer
 Gas used to claimAll: 686368
 TransferFrom Cost: 313794
```

In the event of having considerably high gas prices, this mechanism can be abused in many different ways. For example:

1) Users willing to claim rewards can create liquidatable positions, expecting them to be liquidated by a third party, which would update their rewards state and reduce the gas cost to make the claim.

2) Cost to liquidate users whose reward state was not updated will be higher, **reducing the incentive to perform that liquidation**. Users about to be liquidated have no incentive to make actions that call `update()` via any hook as the incentive to perform a liquidation over their position could increase.

Also, as non approved users can call `transferFrom` passing zero tokens, this opens a new scenario where externals can update other's states and pay for its cost. This transfer mechanism became recently popular known as "Zero Token Transfer Phishing Scam".

This issue is considered informational only as Exactly intends to deploy the rewards system on the Optimism chain.

Note these updated costs could impact the scenarios described in **EXA-06**, **EXA-34** previously reported issues and make them even worse.

Recommendation

Optimize the update process to reduce its consumption and reevaluate incentives alignment if this implementation is going to be deployed on a chain with expensive gas costs such as Ethereum's mainnet.

Status

Open.

EXA-44	Configuration process does not guarantee rewards availability

Total Risk	Impact	Location
Info	-	`RewardsController.sol`
Fixed	Likelihood	
!	-	

Description

The rewards contract can start a distribution period without funds because the distribution's configuration is agnostic to the balance of each reward token.

Rewards are meant to be sent to the contract in advance and the balance of tokens held in the contract must be the same as the distribution's `totalDistribution`. If the amount sent to the contract is less than the `totalDistribution` value, only the first users would be able to claim as the contract might not meet the required transfer amount for the last ones.

The parameter `targetDebt` is used while calculating the reward allocation and current borrow and deposit position indexes. Because of this, the amount set by the manager should consider the same decimals as the reward token used for the configured distribution. A misalignment on the `targetDebt's` decimals would result in a mistakenly calculated amount of rewards.

In addition, if the administrator wants to change only one parameter of a distribution, they need to pass again the entire configuration struct when calling `config()`. This process is error-prone.

Recommendation

Check that the initial amount sent to the contract is the same as the initial `totalDistribution`. Clearly document how each configuration parameter should be set. Evaluate the need to include setters for specific distribution parameters.

Status

Partially fixed in `c25c305a8a21e08ea0355ac5a05e4d3b93c01b22`. It now uses a `baseUnit` instead of the decimals value and keeps the `mintingRate` and the `rewardAssets` with the same decimals. No actions will be performed in rewards availability.

EXA-45	Outdated test suite		
Total Risk **Info**	Impact -	Location -	
Fixed !	Likelihood -		

Description

The development suite includes tests for each main functionality but they are not updated to consider the event of having a `RewardsController` contract.

Adding the rewards contract modifies the overall protocol's functionality as several functions now include updating hooks. In addition, users claiming rewards might decide to modify their positions according to their current rewards status.

Coinspect identified by updating the Market's test suite that using a rewards contract increases considerably the gas costs of each action, for example. Also, some tests were failing after setting a `RewardsController` address.

Recommendation

Update the protocol's test suite to consider the scenario of having a rewards contract deployed and operational.

Status

Open.

EXA-46 Zero token transfers triggered by claim logic

Total Risk	Impact	Location
Info	-	`RewardsController.sol`
Fixed ✔	Likelihood -	

Description

The claim process can be abused to overpopulate the latest transactions feed of the victim with zero token transfers having the `RewardsController` as the sender.

Users that have no positions in any market will have no right to claim any rewards. This state can be leveraged by calling `claimAll()` targeting a victim and the contract will send a zero token transfer emitting the `Transfer` and `Claim` events.

The reward transferring process is handled inside the `claim()` function:

```
for (uint256 r = 0; r < rewardsList.length; ) {
  rewardsList[r].safeTransfer(to, claimedAmounts[r]);
  emit Claim(msg.sender, rewardsList[r], to, claimedAmounts[r]);
  unchecked {
    ++r;
  }
}
```

The malicious user must use an account without any reward-yielding positions as the claim process uses the `msg.sender` to estimate the rewards to accrue and transfer. Under this scenario, `claimAll(victim)` can be called and the following events for each reward token will be emitted:

```
Transfer(from: RewardsController, to: Victim, amount: 0)
Claim(account: Attacker, reward: MockERC20, to: Victim, amount: 0)
```

The following script was used to get the mentioned event emissions:

```
function test_ClaimFakeEvents() external {
     vm.warp(5 days);
```

```
        vm.prank(ATTACKER);
        rewardsController.claimAll(VICTIM);
    }
```

Recommendation

Perform the transfer and event emission only if the `claimedAmounts[r]` is greater than zero.

Status

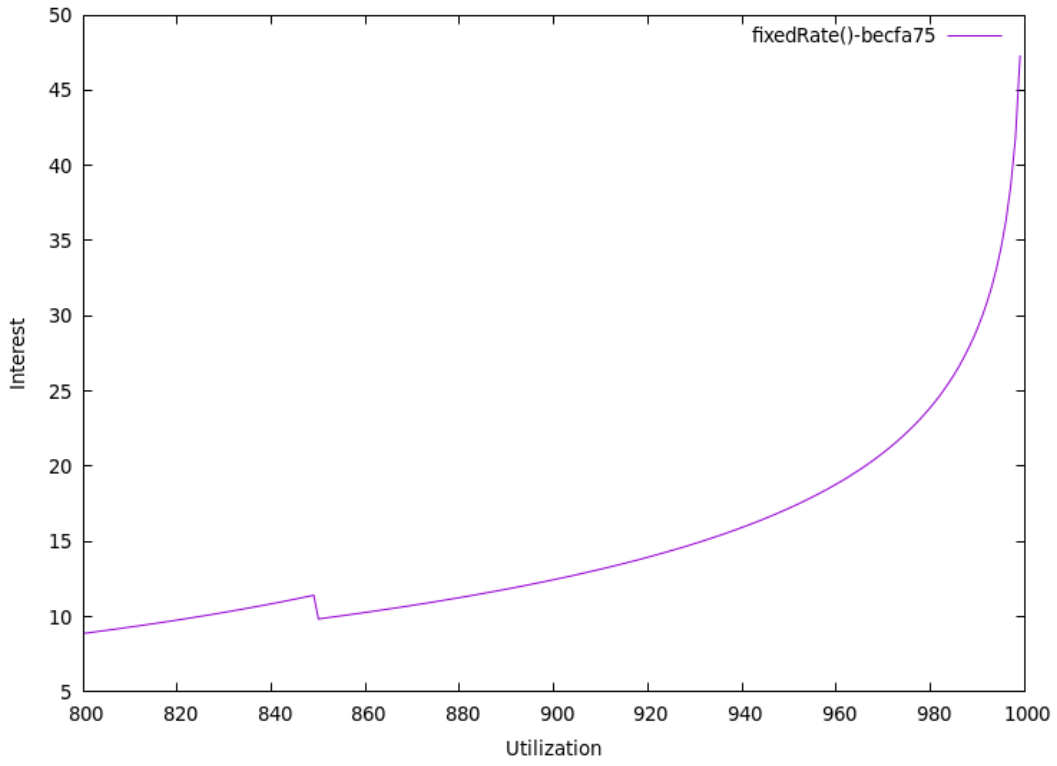
Fixed in commit `2999cd54914b62e7353259654d26b55c12dd5608`. It now transfers only when `claimedAmounts[r]` is greater than zero.

EXA-47 Fixed rate curve discontinuity

Total Risk	Impact	Location
Info	-	`InterestRateModel.sol`
Fixed	Likelihood	
!	-	

Description

Due to the switch from approximation to logarithm-based calculation of the integral, there is a discontinuity in the Fixed rate curve happening at the `PRECISION_THRESHOLD` point. This causes the calculated rate to slightly decrease with an increase of the utilization. In the following figure we can see this effect (greatly amplified for demonstration purposes):



Recommendation

Evaluate if, with the operating parameters selected, the precision of the current algorithm is acceptable.

Status

Open.

5. Disclaimer

The information presented in this document is provided "as is" and without warranty. The present security audit does not cover any off-chain systems or frontends that communicate with the contracts, nor the general operational security of the organization that developed the code.