Smart Contract Audit Report for GoodDollar

Testers

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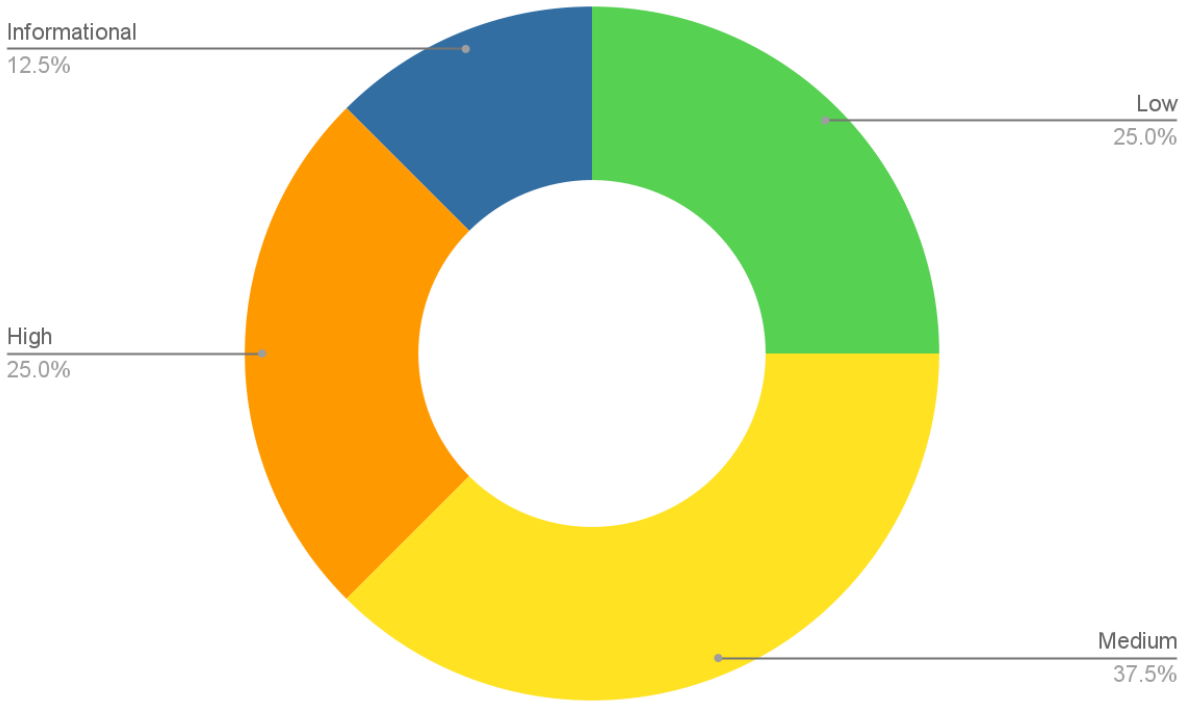
Management Summary

GoodDollar contacted Sayfer to perform a security audit on their smart contracts.

This report documents the research carried out by Sayfer targeting the selected resources defined under the research scope. Particularly, this report displays the security posture review for GoodDollar smart contracts.

Over the audit period of 4 weeks, we discovered 8 vulnerabilities in the contract. There are no critical vulnerabilities yet a couple of medium and high risks that can affect the protocol’s financial funds.

Vulnerabilities by Risk



Risk	Informational	Low	Medium	High	Critical
# of issues	1	2	3	2	0

- **Critical** - Immediate or ongoing part of the business being exploited with direct key business losses.
- **High** – Direct threat to key business processes.
- **Medium** – Indirect threat to key business processes or partial threat to business processes.
- **Low** – No direct threat exists. The vulnerability may be exploited using other vulnerabilities.
- **Informational** – This finding does not indicate vulnerability, but states a comment that notifies about design flaws and improper implementation that might cause a problem in the long run.

Approach

Introduction

GoodDollar contacted Sayfer to perform a security audit on their smart contracts.

This report documents the research carried out by Sayfer targeting the selected resources defined under the research scope. Particularly, this report displays the security posture review for the aforementioned contracts.

Scope Overview

Together with GoodDollar team we define that the scope of the project will be:

1. Smart contracts that have been changed in this pull request up to commit 3b5c223d3cdadc086a5a38c1d7822592d23ae1a4
2. Fixes were shipped up to commit 339be6f17658a29715dd2dec5fb6499437ac9b9f

Our tests were performed between November 11th to December 11th 2022.

Scope Validation

We began by ensuring that the scope defined to us by the client was technically logical. Deciding what scope is right for a given system is part of the initial discussion.

Threat Model

We defined that the largest current threat to the system is the ability of malicious users to steal funds from the contract.

Protocol Overview

Protocol Introduction

The GoodDollar protocol is a community-driven, distributed framework designed to generate, fund, and distribute global basic income via the GoodDollar token (hereafter “G$”). G$ is an ERC-20 digital asset built on the Ethereum blockchain that operates within the emerging ecosystem of decentralized and open finance. GoodDollar leverages new protocols and smart contracts across the ecosystem to deliver its basic income economy.

Security Evaluation

The following test cases were the guideline while auditing the system. This checklist is a modified version of the SCSVS v1.2, with improved grammar, clarity, conciseness, and additional criteria. Where there is a gap in the numbering, an original criterion was removed. Criteria that are marked with an asterisk were added by us.

Architecture, Design and Threat Modeling	Test Name
G1.2	Every introduced design change is preceded by threat modeling.
G1.3	The documentation clearly and precisely defines all trust boundaries in the contract (trusted relations with other contracts and significant data flows).
G1.4	The SCSVS, security requirements or policy is available to all developers and testers.
G1.5	The events for the (state changing/crucial for business) operations are defined.
G1.6	The project includes a mechanism that can temporarily stop sensitive functionalities in case of an attack. This mechanism should not block users' access to their assets (e.g. tokens).
G1.7	The amount of unused cryptocurrencies kept on the contract is controlled and at the minimum acceptable level so as not to become a potential target of an attack.
G1.8	If the fallback function can be called by anyone, it is included in the threat model.
G1.9	Business logic is consistent. Important changes in the logic should be applied in all contracts.
G1.10	Automatic code analysis tools are employed to detect vulnerabilities.
G1.11	The latest major release of Solidity is used.
G1.12	When using an external implementation of a contract, the most recent version is used.
G1.13	When functions are overridden to extend functionality, the super keyword is used to maintain previous functionality.
G1.14	The order of inheritance is carefully specified.
G1.15	There is a component that monitors contract activity using events.
G1.16	The threat model includes whale transactions.
G1.17	The leakage of one private key does not compromise the security of the entire project.

Policies and Procedures	Test Name

G2.2	The system's security is under constant monitoring (e.g. the expected level of funds).
G2.3	There is a policy to track new security vulnerabilities and to update libraries to the latest secure version.
G2.4	The security department can be publicly contacted and that the procedure for handling reported bugs (e.g., thorough bug bounty) is well-defined.
G2.5	The process of adding new components to the system is well defined.
G2.6	The process of major system changes involves threat modeling by an external company.
G2.7	The process of adding and updating components to the system includes a security audit by an external company.
G2.8	In the event of a hack, there's a clear and well known mitigation procedure in place.
G2.9	The procedure in the event of a hack clearly defines which persons are to execute the required actions.
G2.10	The procedure includes alarming other projects about the hack through trusted channels.
G2.11	A private key leak mitigation procedure is defined.

Upgradability	**Test Name**
G2.2	Before upgrading, an emulation is made in a fork of the main network and everything works as expected on the local copy.
G2.3	The upgrade process is executed by a multisig contract where more than one person must approve the operation.
G2.4	Timelocks are used for important operations so that the users have time to observe upcoming changes (please note that removing potential vulnerabilities in this case may be more difficult).
G2.5	*initialize()* can only be called once.
G2.6	*initialize()* can only be called by an authorized role through appropriate modifiers (e.g. *initializer*, *onlyOwner*).
G2.7	The update process is done in a single transaction so that no one can front-run it.
G2.8	Upgradeable contracts have reserved gap on slots to prevent overwriting.
G2.9	The number of reserved (as a gap) slots has been reduced appropriately if new variables have been added.
G2.10	There are no changes in the order in which the contract state variables are declared, nor their types.
G2.11	New values returned by the functions are the same as in previous versions of the contract (e.g. *owner()*, *balanceOf(address)*).
G2.12	The implementation is initialized.
G2.13	The implementation can't be destroyed.

Business Logic	Test Name
G4.2	The contract logic and protocol parameters implementation corresponds to the documentation.
G4.3	The business logic proceeds in a sequential step order and it is not possible to skip steps or to do it in a different order than designed.
G4.4	The contract has correctly enforced business limits.
G4.5	The business logic does not rely on the values retrieved from untrusted contracts (especially when there are multiple calls to the same contract in a single flow).
G4.6	The business logic does not rely on the contract's balance (e.g., *balance == 0*).
G4.7	Sensitive operations do not depend on block data (e.g., *block hash*, *timestamp*).
G4.8	The contract uses mechanisms that mitigate transaction-ordering (front-running) attacks (e.g. pre-commit schemes).
G4.9	The contract does not send funds automatically, but lets users withdraw funds in separate transactions instead.

Access Control	Test Name
G5.2	The principle of the least privilege is upheld. Other contracts should only be able to access functions and data for which they possess specific authorization.
G5.3	New contracts with access to the audited contract adhere to the principle of minimum rights by default. Contracts should have a minimal or no permissions until access to the new features is explicitly granted.
G5.4	The creator of the contract complies with the principle of the least privilege and their rights strictly follow those outlined in the documentation.
G5.5	The contract enforces the access control rules specified in a trusted contract, especially if the dApp client-side access control is present and could be bypassed.
G5.6	Calls to external contracts are only allowed if necessary.
G5.7	Modifier code is clear and simple. The logic should not contain external calls to untrusted contracts.
G5.8	All user and data attributes used by access controls are kept in trusted contracts and cannot be manipulated by other contracts unless specifically authorized.
G5.9	the access controls fail securely, including when a revert occurs.
G5.10	If the input (function parameters) is validated, the positive validation approach (whitelisting) is used where possible.

Communication	Test Name
G6.2	Libraries that are not part of the application (but the smart contract relies on to operate) are identified.

G6.3	Delegate call is not used with untrusted contracts.
G6.4	Third party contracts do not shadow special functions (e.g. revert).
G6.5	The contract does not check whether the address is a contract using *extcodesize* opcode.
G6.6	Re-entrancy attacks are mitigated by blocking recursive calls from other contracts and following the Check-Effects-Interactions pattern. Do not use the *send* function unless it is a must.
G6.7	The result of low-level function calls (e.g. *send*, *delegatecall*, *call*) from other contracts is checked.
G6.8	Contract relies on the data provided by the right sender and does not rely on tx.origin value.

Arithmetic	**Test Name**
G7.2	The values and math operations are resistant to integer overflows. Use SafeMath library for arithmetic operations before solidity 0.8.*.
G7.3	the unchecked code snippets from Solidity ≥ 0.8.* do not introduce integer under/overflows.
G7.4	Extreme values (e.g. maximum and minimum values of the variable type) are considered and do not change the logic flow of the contract.
G7.5	Non-strict inequality is used for balance equality.
G7.6	Correct orders of magnitude are used in the calculations.
G7.7	In calculations, multiplication is performed before division for accuracy.
G7.8	The contract does not assume fixed-point precision and uses a multiplier or store both the numerator and denominator.

Denial of Service	**Test Name**
G8.2	The contract does not iterate over unbound loops.
G8.3	Self-destruct functionality is used only if necessary. If it is included in the contract, it should be clearly described in the documentation.
G8.4	The business logic isn't blocked if an actor (e.g. contract, account, oracle) is absent.
G8.5	The business logic does not disincentivize users to use contracts (e.g. the cost of transaction is higher than the profit).
G8.6	Expressions of functions assert or require have a passing variant.
G8.7	If the fallback function is not callable by anyone, it is not blocking contract functionalities.
G8.8	There are no costly operations in a loop.
G8.9	There are no calls to untrusted contracts in a loop.
G8.10	If there is a possibility of suspending the operation of the contract, it is also

	possible to resume it.
G8.11	If whitelists and blacklists are used, they do not interfere with normal operation of the system.
G8.12	There is no DoS caused by overflows and underflows.

Blockchain Data	Test Name
G9.2	Any saved data in contracts is not considered secure or private (even private variables).
G9.3	No confidential data is stored in the blockchain (passwords, personal data, token etc.).
G9.4	Contracts do not use string literals as keys for mappings. Global constants are used instead to prevent Homoglyph attack.
G9.5	Contract does not trivially generate pseudorandom numbers based on the information from blockchain (e.g. seeding with the block number).

Gas Usage and Limitations	Test Name
G10.2	Gas usage is anticipated, defined and has clear limitations that cannot be exceeded. Both code structure and malicious input should not cause gas exhaustion.
G10.3	Function execution and functionality does not depend on hard-coded gas fees (they are bound to vary).

Clarity and Readability	Test Name
G11.2	The logic is clear and modularized in multiple simple contracts and functions.
G11.3	Each contract has a short 1-2 sentence comment that explains its purpose and functionality.
G11.4	Off-the-shelf implementations are used, this is made clear in comment. If these implementations have been modified, the modifications are noted throughout the contract.
G11.5	The inheritance order is taken into account in contracts that use multiple inheritance and shadow functions.
G11.6	Where possible, contracts use existing tested code (e.g. token contracts or mechanisms like *ownable*) instead of implementing their own.
G11.7	Consistent naming patterns are followed throughout the project.
G11.8	Variables have distinctive names.
G11.9	All storage variables are initialized.
G11.10	Functions with specified return type return a value of that type.

G11.11	All functions and variables are used.
G11.12	*require* is used instead of *revert* in *if* statements.
G11.13	The *assert* function is used to test for internal errors and the *require* function is used to ensure a valid condition in input from users and external contracts.
G11.14	Assembly code is only used if necessary.

Test Coverage	Test Name
G12.2	Abuse narratives detailed in the threat model are covered by unit tests.
G12.3	Sensitive functions in verified contracts are covered with tests in the development phase.
G12.4	Implementation of verified contracts has been checked for security vulnerabilities using both static and dynamic analysis.
G12.5	Contract specification has been formally verified.
G12.6	The specification and results of the formal verification is included in the documentation.

Decentralized Finance	Test Name
G14.1	The lender's contract does not assume its balance (used to confirm loan repayment) to be changed only with its own functions.
G14.2	Functions that change lenders' balance and/or lend cryptocurrency are non-re-entrant if the smart contract allows borrowing the main platform's cryptocurrency (e.g. Ethereum). It blocks the attacks that update the borrower's balance during the flash loan execution.
G14.3	Flash loan functions can only call predefined functions on the receiving contract. If it is possible, define a trusted subset of contracts to be called. Usually, the sending (borrowing) contract is the one to be called back.
G14.4	If it includes potentially dangerous operations (e.g. sending back more ETH/tokens than borrowed), the receiver's function that handles borrowed ETH or tokens can be called only by the pool and within a process initiated by the receiving contract's owner or another trusted source (e.g. multisig).
G14.5	Calculations of liquidity pool share are performed with the highest possible precision (e.g. if the contribution is calculated for ETH it should be done with 18 digit precision - for Wei, not Ether). The dividend must be multiplied by the 10 to the power of the number of decimal digits (e.g. dividend * 10^18 / divisor).
G14.6	Rewards cannot be calculated and distributed within the same function call that deposits tokens (it should also be defined as non-re-entrant). This protects from momentary fluctuations in shares.
G14.7	Governance contracts are protected from flash loan attacks. One possible

	mitigation technique is to require the process of depositing governance tokens and proposing a change to be executed in different transactions included in different blocks.
G14.8	When using on-chain oracles, contracts are able to pause operations based on the oracles' result (in case of a compromised oracle).
G14.9	External contracts (even trusted ones) that are allowed to change the attributes of a project contract (e.g. token price) have the following limitations implemented: thresholds for the change (e.g. no more/less than 5%) and a limit of updates (e.g. one update per day).
G14.10	Contract attributes that can be updated by the external contracts (even trusted ones) are monitored (e.g. using events) and an incident response procedure is implemented (e.g. during an ongoing attack).
G14.11	Complex math operations that consist of both multiplication and division operations first perform multiplications and then division.
G14.12	When calculating exchange prices (e.g. ETH to token or vice versa), the numerator and denominator are multiplied by the reserves (see the *getInputPrice* function in the *UniswapExchange* contract).

Audit Findings

Possible Underflow

Status	Fixed
Risk	High
Location	invite/InvitesV1.sol - *function canCollectBountyFor*
Tools	Manual testing

Description	Underflow occurs when a value is decremented below zero, and it can lead to transaction revet and unexpected behavior.
	
	The subtraction
	`users[_invitee].joinedAt.sub(users[invitedBy].levelStarted)`
	can underflow, causing the whole transaction to revert.
	
	This is explicitly checked for in ***_bountyFor***:
	`joinedAt > users[invitedBy].levelStarted && //prevent overflow in subtraction`
	
	But the check is missing in ***canCollectBountyFor***:
	`bool isLevelExpired = levelExpirationEnabled == true && daysToComplete > 0 && daysToComplete < users[_invitee].joinedAt.sub(users[invitedBy].levelStarted).div(1 days);`

Mitigation	Replace the declaration of ***isLevelExpired*** with: `bool isLevelExpired = levelExpirationEnabled == true && daysToComplete > 0 && users[_invitee].joinedAt > users[invitedBy].levelStarted && daysToComplete < users[_invitee].joinedAt.sub(users[invitedBy].levelStarted).div(1 days);`

checkProofOrdered not validating Merkle tree proof length

Status	Fixed
Risk	Medium
Location	governance/GReputation.sol - function *checkProofOrdered*
Tools	Manual testing
Description	Because the function does not validate the length of the proofs (i.e., does not ensure that it is equal to the tree size), it is possible to submit a proof for intermediate nodes. This is problematic in ***proveBalanceOfAtBlockchain***, where two user-supplied values (***_user*** and ***_balance***) are hashed and passed to ***checkProofOrdered***. An attacker can therefore pass two intermediate nodes as ***_user*** and ***_balance*** to ***proveBalanceOfAtBlockchain*** (converting the nodes from a uint256 to a bytes32 value, i.e. simply interpreting the raw bytes as an unsigned integer) and prove a non-existing balance for a non-existing address. This vulnerability is classified as high because ***_user*** has an address type which is uint160 and the ***_balance*** is unit256, an attacker will need an intermediate node where the upper bytes are zero, which reduces the probability of an exploit
Mitigation	After a couple of different approaches and conversations with GoodDollar team we settled on an off-chain solution that will require minimal dev time and on-chain changes. There will be an additional test that will verify there are no proofs that satisfy the edge case: const danger = (merkleTree.getHexLayers() as any).map(_ => _.find(_ => _.startsWith("0x000000")));

Unsafe Signature Verification Mechanism

Status	Fixed
Risk	Medium
Location	identity/IdentityV2.sol - function *connectAccount*
Tools	Manual testing
Description	Signature verification is the process of ensuring that a signed message was actually created by the claimed signer. This is done using cryptographic algorithms that generate a unique digital signature for each message, which can then be verified against the signer's public key The function uses untyped data signing and not using EIP712 which let the users see the data they are signing rather than the hex representation of it, which is a security concern because it can potentially be used in phishing campaigns. Additionally, there is no replay protection, allowing an attacker to use a previously used signature to reconnect a disconnected account. This lack of replay protection increases the risk of unauthorized access and potential exploitation.
Mitigation	Implement the signature verification using EIP712 and add a mechanism to protect against replay attacks

Wrong Logic for Decreasing whitelistedContracts

Status	Fixed
Risk	Medium
Location	identity/IdentityV2.sol - function *_removeWhitelIsted*
Tools	Manual testing
Description	The function ***_removeWhitelisted*** checks if the provided address is a contract and then decreases ***whitelistedContracts*** (which was increased when the account was added, if it was a contract). However, in theory, it is possible that an address was not a contract when it was whitelisted (i.e., there was no code at this address), but it is now. This can be for instance done by pre-calculating a contract address (very easy with CREATE2 thanks to the user-specified seed). In such a scenario, ***whitelistedContracts*** will still be decreased by one, but it was never increased. This can ultimately lead to a situation where no more contracts can be removed (because the counter will underflow).
Mitigation	Add an underflow check on ***whitelistedContracts***.

Remaining Dust

Status	Acknowledged - Any balance left would be distributed next time
Risk	Low
Location	reserve/DistributionHelper.sol - function *onDistribution*
Tools	Manual testing
Description	The function does not effectively transfer the entire balance in most cases due to the ***toTransfer*** collection rounding down, which leaves a small amount of unspent funds in the contract. This can cause inefficiency and create potential vulnerabilities. `uint256 toTransfer = (toDistribute * r.bps) / 10000;`
Mitigation	Optionally, the last recipient could receive this dust to distribute everything.

Missing transfer Return Value Check

Status	Fixed
Risk	Low
Location	reserve/GoodReserveCDAI.sol - function *sell*
Tools	Manual testing
Description	The function does not check the return value of the cDai transfer. `cERC20(cDaiAddress).transfer(_target, tokenReturn);` While this is not too problematic because the transfer of cDai reverts on failure, the token is upgradeable, so adhering to the ERC20 standard and checking the value is still recommended.
Mitigation	Replace with the following: `require(cERC20(cDaiAddress).transfer(_target, tokenReturn), "Transfer failed");`

Removing Recipients will Revert - Out of Scope

Status	Acknowledged - the array should grow too much
Risk	High
Location	reserve/DistributionHelper.sol - *addOrUpdateRecipient*
Tools	Manual testing
Description	There is no way to remove recipients, their BPS can only be set to 0. As of the comments for the ***addOrUpdateRecipient*** function: `* @notice add or update a recipient details, if address exists it will update, otherwise add to "remove" set recipient bps to 0. only ADMIN_ROLE can call this.` This approach can cause the ***distributionRecipients*** to grow too large at some point because the length is only increased, which would cause distributions to fail (as they would run out of gas). Moreover, it is not validated that the sum of the individual BPS entries is not larger than 100% (which would also cause the distributions to fail, although this error would be recoverable).

Mitigation	Use a function that looks like this pseudo code:
	`function removeRecipient(uint256 index) external {`
	`  if (index >= distributionRecipients.length) return;`
	`  for (uint256 i = index; i < distributionRecipients.length - 1; i++) {`
	`  distributionRecipients[i] = distributionRecipients[i + 1];`
	`  }`
	`  distributionRecipients.pop();`
	`}`

Informational Notes

Status	Acknowledged - Very low impact
Risk	Informational
Location	Multiple locations
Tools	Manual testing
Description	- invite/InvitesV1: There is no need to use SafeMath with Solidity >= 0.8. - Multiple places, i.e governance/CompoundVotingMachine.sol#L584: Commented redundant code
Mitigation	Review and fix each note.