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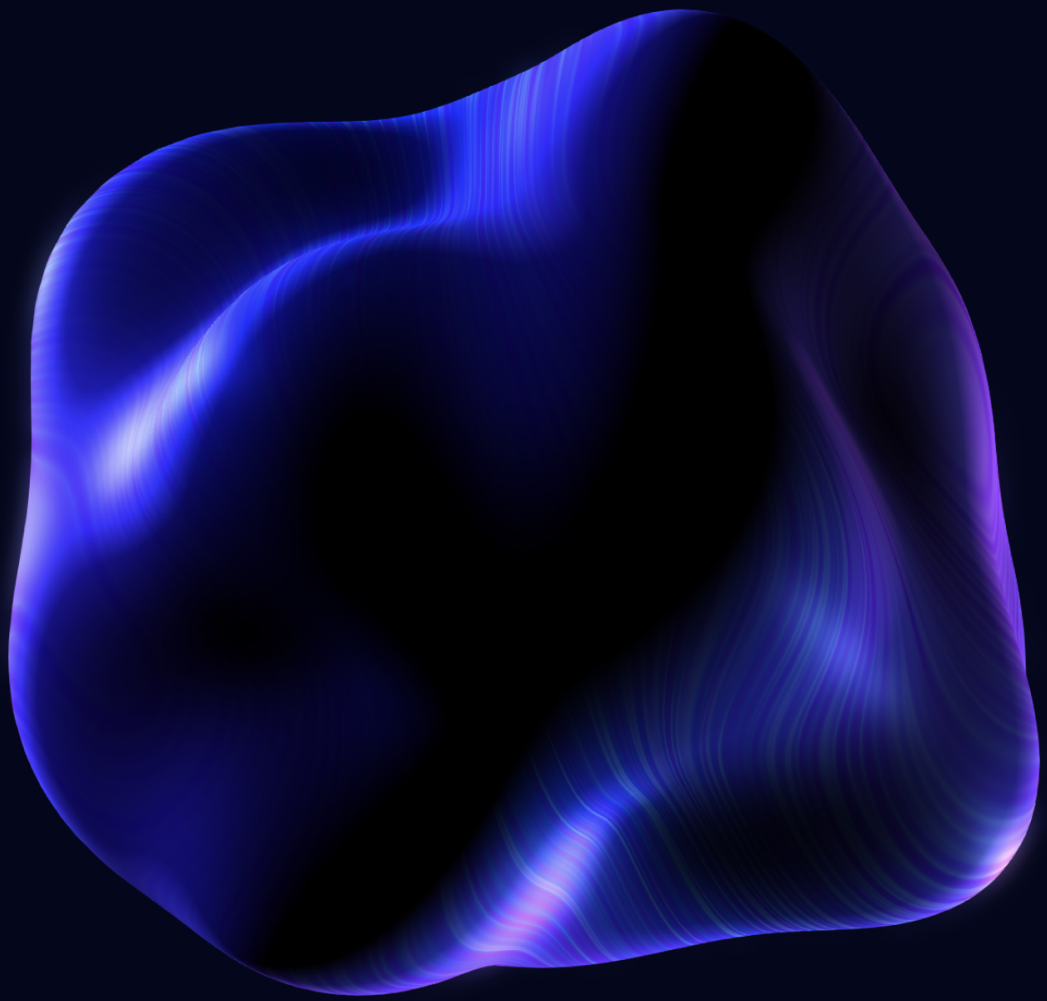
Security
Smart Contract Audit
MahaDAO ARTH



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MahaDAO ARTH security audit

This document may contain confidential information about IT systems and the intellectual property of the Customer as well as information about potential vulnerabilities and methods of their exploitation.
The report containing confidential information can be used internally by the Customer, or it can be disclosed publicly after all vulnerabilities are fixed — upon a decision of the Customer.

Reference information

Name	MahaDAO ARTH
Website	https://mahadao.com/
Language	Solidity
Chain	Ethereum mainnet
Reference repositories	https://github.com/MahaDAO/arth-core https://github.com/MahaDAO/arth-strategies https://github.com/MahaDAO/gmu-oracle-contracts https://github.com/MahaDAO/chainlink-keepers https://github.com/MahaDAO/token https://github.com/MahaDAO/flashloans-arth

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Findings summary

Findings statistics

Severity	Number	After fixes
High	2	0
Medium	3	2
Low	2	2
Informational	16	16
Gas	3	3
Total	**26**	**23**

Finding Severity breakdown

All vulnerabilities discovered during the source code audit are classified based on their potential severity and have the following classification:

Severity	Description
High	Bugs that can trigger a contract failure or theft of assets. Further recovery is possible only by manual modification of the contract state or replacement of the contract.
Medium	Bugs that can break the intended contract logic or expose it to DoS attacks, but do not cause direct loss of funds.
Low	Bugs that do not pose significant danger to the project or its users but are recommended to be fixed nonetheless.
Informational	All other non-essential recommendations.
Gas	Gas optimization recommendations.

Project description

MahaDAO

MahaDAO is a mission to create a decentralized and stable economy. That is driven by the people, for the people.

MahaDAO is a community-powered, decentralized organization on a mission to empower billions with a stable economy through the world's first valuecoin, ARTH.

To do this, MahaDAO uses two tokens to achieve this vision - the governance token MAHA, and the valuecoin ARTH.

ARTH valuecoin

ARTH is a stablecoin that is designed to appreciate overtime against the US dollar while at the same time it remains relatively stable.

ARTH is minted/burnt using decentralized smart contracts that use ETH as collateral to maintain its peg. The interest rate charged to mint ARTH using ETH is 0%, which makes it very cost-effective for borrowing/lending.

ARTH is fully collateralized with mechanisms that give it a backing of at least 110% in ETH.

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Scope of work

Scope of work: ARTH Core

Contract	Address	Repository
ActivePool	0xa443129308556ab06e69a98e1c39c81080e01530	arth-core
BorrowerOperations	0x4c50063f8238dea92c738f23221733a9a6c6888b	arth-core
CollSurplusPool	0xbb719b2d7207e8b8b13ca4dc9c8b6201d79cf7e5	arth-core
CommunityIssuance	0x61274cd1f801b097be7e5197b158999307893d2e	arth-core
DefaultPool	0x47f747fd93eef25cc1e0b6d7a239289c7cfec212	arth-core
Governance	0x91eb23b66beb3467998402ba50aa1c1a98811eb1	arth-core
SortedTroves	0xd60d7a2a8344d4f635bf9ea9f8cd015a614c3659	arth-core
StabilityPool	0x910f16455e5eb4605fe639e2846579c228eed3b5	arth-core
TroveManager	0x8b1da95724b1e376ae49fdb67afe33fe41093af5	arth-core
ARTHValuecoin	0x8cc0f052fff7ead7f2edcccac895502e884a8a71	token

Scope of work: ARTH Periphery

Contract	Address	Repository
ETHTroveStrategy *Proxy*	0xf3f261f54d8397806132598dc2b6b5c00d6eb3ea 0xa9735e594624339f8fbc8a99c57c13c7b4e8bcac	arth-strategies
USDCCurveStrategy *Proxy*	0x9ff6629d08fddaec63b0d855b9c29acdf4dc14e4 0x5480e8beedb3eba5747a4a3aef0850a3759df9b4	arth-strategies
StabilityPoolKeeper	0x5e98d3f8b5074b6389477fd88856f5209748caa7	chainlink-keepers
ARTHFlashMinter	0xc4bbefdc3066b919cd1a6b5901241e11282e625d	flashloans-arth
ETHGMUOracle	0xc31adc9ae073a1f6a9ce5c41b32c18790ea667fe	gmu-oracle-contracts
GMUOracle	0x066a917fa2e1739ccfc306dc73ff78eeca8b6f29	gmu-oracle-contracts

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ARTH Core findings

ID	Severity	Description	Status
01	**Medium**	Wrong depositorETHGain receiver when invoking provideToSPFor method in StabilityPool.sol	Ack.
02	Low	toggleBorrowerOperations contains dangerous centralized logic in ARTHValuecoin.sol	Ack.
03	Informational	Dead code: _requireValidRecipient method in ARTHValueCoin.sol	Ack.
04	Informational	openTroveFor method contains centralized logic in BorrowerOperations.sol	Ack.
05	Informational	Dead code: _getUSDValue and _requireCallerIsBorrower methods in BorrowerOperations.sol	Ack.
06	Informational	sendFeeToEcosystemFund should emit an event in BorrowerOperations.sol	Ack.
07	Informational	receive should emit an event in CollSurplusPool.sol	Ack.
08	Informational	Misleading comments in Governance.sol	Ack.
09	Informational	BORROWING_FEE_FLOOR = MAX_BORROWING_FEE = 0 in Governance.sol	Ack.
10	Informational	ARTH_GAS_COMPENSATION and MIN_NET_DEBT should be constant in Governance.sol	Ack.
11	Informational	_getCollGasCompensation should be pure in LiquityBase.sol	Ack.
12	Gas	MAX_INT and PERCENT_DIVISOR should be constant in LiquityBase.sol	Ack.
13	Gas	IGovernance governance should be immutable in CommunityIssuance.sol	Ack.

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ARTH Periphery findings

ID	Severity	Description	Status
14	High	Insufficient access control for notifyRewardAmount in StakingRewardsChild.sol -> USDCCurveStrategy.sol	Fixed
15	High	Wrong fee mechanism when invoking flashLoan in ARTHFlashMinter.sol	Fixed
16	Medium	minDepositForPermit is never initialized in USDCCurveStrategy.sol	Fixed
17	Medium	Wrong fee value set in ARTHFlashMinter.sol	Ack.
18	Low	Sanity check required in the constructor in GMUOracle.sol	Ack.
19	Informational	increase, deposit and withdraw should emit an event for totalmArthSupplied in ETHTroveStrategy.sol	Ack.
20	Informational	No debt rebalancing logic in case of trove liquidation in ETHTroveStrategy.sol	Ack.
21	Informational	closeTrove method contains dangerous centralized logic in ETHTroveStrategy.sol	Ack.
22	Informational	_deposit and _withdraw should emit events for totalArthBorrowed and totalUsdcSupplied change in USDCCurveStrategy.sol	Ack.
23	Informational	getCurrentEpoch duplicates logic of _getCurrentEpoch in Epoch.sol -> StabilityPoolKeeper.sol	Ack.
24	Informational	updateMahaReward should emit an event in StabilityPoolKeeper.sol	Ack.
25	Informational	Excessive if-clause inside _scalePriceByDigits in ETHGMUOracle.sol	Ack.
26	Gas	maha and arthCommunityIssuance should be immutable in StabilityPoolKeeper.sol	Ack.

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Source code audit

For source code audit purposes we split SoW into two sets of contracts. The first set (we will call it ARTH Core) consists of these contracts:

- ActivePool
- ARTHValuecoin
- BorrowerOperations
- CollSurplusPool
- CommunityIssuance
- DefaultPool
- Governance
- SortedTroves
- StabilityPool
- TroveManager

These contracts are part of arth-core repository (except for ARTHValuecoin. It belongs to the separate token repository). And all of these contracts are derived from Liquity project. For these contracts, SoW was settled as audit of changes made after the last audit of Liquity project in 2021.

The second set (we will call it ARTH Periphery) consists of these contracts:

- ARTHFlashMinter
- USDCCurveStrategy with proxy
- ETHGMUOracle
- ETHTroveStrategy with proxy
- GMUOracle
- StabilityPoolKeeper

For these contracts we performed source code audit as usual.

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Source code audit: ARTH Core

ID-01. **Medium**: Wrong depositorETHGain receiver when invoking provideToSPFor method in StabilityPool.sol

Description

The provideToSPFor method of StabilityPool.sol is a restricted function that allows contract admin to execute the provideToSP method on behalf of another account. In that function, the depositorETHGain is sent to depositor via _sendETHGainToDepositor method. However, the _sendETHGainToDepositor function deals only with msg.sender which means that in the case of using provideToSPFor the depositorETHGain is sent to msg.sender, rather than _who.

Recommendation

Modify the _sendETHGainToDepositor(uint256 amount) function as well as all its use cases to contain the recipient address, i.e. _sendETHGainToDepositor(uint256 amount, _who).

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-02. Low: toggleBorrowerOperations contains dangerous centralized logic in ARTHValuecoin.sol

Description

The toggleBorrowerOperations method of ARTHValuecoin.sol is an access controlled function that can grant access to mint and burn functions at the will of the contract admin.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-03. Informational: Dead code: _requireValidRecipient method in ARTHValueCoin.sol

Description

The _requireValidRecipient method of ARTHValueCoin.sol is never used and should be removed.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-04. Informational: openTroveFor method contains centralized logic in BorrowerOperations.sol

Description

The openTroveFor method of BorrowerOperations.sol is an access controlled function that contains logic able to open troves on behalf of any address.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-05. Informational: Dead code: _getUSDValue and _requireCallerIsBorrower methods in BorrowerOperations.sol

Description

The _getUSDValue and _requireCallerIsBorrower methods of BorrowerOperations.sol are never used and should be removed.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-06. Informational: sendFeeToEcosystemFund should emit an event in BorrowerOperations.sol

Description

The _sendFeeToEcosystemFund method of BorrowerOperations.sol should emit an event when invoked.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-07. Informational: receive should emit an event in CollSurplusPool.sol

Description

The receive method of CollSurplusPool.sol should emit an event when invoked.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-08. Informational: Misleading comments in Governance.sol

Description

The source code of Governance.sol contains misleading comments. The calculated amounts of BORROWING_FEE_FLOOR and MAX_BORROWING_FEE in the comments do not match the actual values.

```
uint256 private BORROWING_FEE_FLOOR = (DECIMAL_PRECISION / 1000) * 0; //
0.5%
uint256 private REDEMPTION_FEE_FLOOR = (DECIMAL_PRECISION / 1000) * 5; //
0.5%
uint256 private MAX_BORROWING_FEE = (DECIMAL_PRECISION / 100) * 0; // 5%
```

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-09. Informational: BORROWING_FEE_FLOOR = MAX_BORROWING_FEE = 0 in Governance.sol

Description

The BORROWING_FEE_FLOOR and MAX_BORROWING_FEE storage variables of Governance.sol are both equal to 0, which contradicts the Liquity's protocol setup.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-10. Informational: ARTH_GAS_COMPENSATION and MIN_NET_DEBT should be constant in Governance.sol

Description

The ARTH_GAS_COMPENSATION and MIN_NET_DEBT variables of Governance.sol should be constant.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-11. Informational: _getCollGasCompensation should be pure in LiquityBase.sol

Description

The _getCollGasCompensation method of LiquityBase.sol should be pure instead of view, provided that Issue 11 is resolved.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-12. Gas: MAX_INT and PERCENT_DIVISOR should be constant in LiquityBase.sol

Description

The MAX_INT and PERCENT_DIVISOR variables of LiquityBase.sol should be constant.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-13. Gas: IGovernance governance should be immutable in CommunityIssuance.sol

Description

The IGovernance governance variable of CommunityIssuance.sol should be immutable.

Alleviation

This issue is acknowledged by the MahaDAO team.

Source code audit: ARTH Periphery

ID-14. High: Insufficient access control for notifyRewardAmount in StakingRewardsChild.sol -> USDCCurveStrategy.sol

Description

The notifyRewardAmount method of StakingRewardsChild.sol in the **USDCCurveStrategy** contract lacks access control. Thus, any account is able to modify the rewardRate, lastUpdateTime and periodFinish state variables of the **USDCCurveStrategy** contract.

Recommendation

Add onlyOwner modifier to the notifyRewardAmount method of StakingRewardsChild.sol.

Alleviation

The issue fix was introduced in commit 7af025d8f401113c7a0b55aab8012e8534c29154. Access to the notifyRewardAmount method is controlled by onlyOperator modifier.

ID-15. High: Wrong fee mechanism when invoking flashLoan in ARTHFlashMinter.sol

Description

The flashLoan method of ARTHFlashMinter.sol is implemented with the wrong fee mechanism. According to the code below, after a successful callback, the amount of receiver's tokens is burned and the _fee is transferred to the ecosystemFund at the expense of the **ARTHFlashMinter** contract (see @audit).

```
require(
  receiver.onFlashLoan(msg.sender, amount, _fee, data) ==
    CALLBACK_SUCCESS,
  "ARTHFlashMinter: Callback failed"
);

token.burn(address(receiver), amount);
token.transfer(ecosystemFund, _fee); // @audit
```

Recommendation

Modify the flashLoan method of ARTHFlashMinter.sol in either of the two following ways

```
// OPTION 1
token.burn(address(receiver), amount);
token.transferFrom(address(receiver), ecosystemFund, fee);

// OR

// OPTION 2
token.burn(address(receiver), amount + _fee);
token.mint(ecosystemFund, _fee);
```

Alleviation

The issue fix was introduced in commit e6c7312768c9c5eb540dc02d356acd0f02f3b3bf. The flashLoan method uses arth.transferFrom to charge fee from borrower.

ID-16. **Medium**: minDepositForPermit is never initialized in USDCCurveStrategy.sol

Description

The minDepositForPermit state variable of USDCCurveStrategy.sol is never initialized.

Alleviation

At the time of initial discovery of this issue the **USDCCurveStrategy** implementation address was 0x122f4530c2c8ed9a7dc4846a155579ede0e23ecb. Since then the MahaDAO team has resolved this issue by deploying a new **USDCCurveStrategy** implementation (0x9ff6629d08fddaec63b0d855b9c29acdf4dc14e4) with proper minDepositForPermit initialization.

ID-17. **Medium**: Wrong fee value set in ARTHFlashMinter.sol

Description

The flashloan fee of the **ARTHFlashMinter** contract is 100 larger than the value stated in the comments to the source code (see @audit).

```
uint256 public fee = 1000; //  1000 == 0.1 %. @audit

...

function _flashFee(uint256 amount) internal view returns (uint256) {
  return (amount * fee) / 10000; @audit
}
```

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-18. Low: Sanity check required in the constructor in GMUOracle.sol

Description

The constructor of GMUOracle.sol relies heavily on _priceHistory30d == 30, but lacks any checks of this assumption.

Recommendation

Modify the constructor of GMUOracle.sol in either of the two following ways (see @audit)

```
// OPTION 1
constructor(
  uint256 _startingPrice18,
  address _oracle,
  uint256[30] memory _priceHistory30d // @audit
) Epoch(86400, block.timestamp, 0)

// OR

// OPTION 2
constructor(
  uint256 _startingPrice18,
  address _oracle,
  uint256[] memory _priceHistory30d
) Epoch(86400, block.timestamp, 0) {
  require(_priceHistory30d.length == 30);
  ...
}
```

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-19. Informational: `increase`, `deposit` and `withdraw` should emit an event for `totalmArthSupplied` in `ETHTroveStrategy.sol`

Description

The `increase`, `deposit` and `withdraw` methods of `ETHTroveStrategy.sol` should emit events for `totalmArthSupplied` change.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-20. Informational: No debt rebalancing logic in case of trove liquidation in `ETHTroveStrategy.sol`

Description

The `ETHTroveStrategy.sol` contains no logic to address the undesirable case of liquidation of the trove attached to the **ETHTroveStrategy** contract.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-21. Informational: closeTrove method contains dangerous centralized logic in ETHTroveStrategy.sol

Description

The closeTrove method of ETHTroveStrategy.sol is an access controlled function that contains logic able to halt the availability of the entire contract.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-22. Informational: _deposit and _withdraw should emit events for totalArthBorrowed and totalUsdcSupplied change in USDCCurveStrategy.sol

Description

The _deposit and _withdraw methods of USDCCurveStrategy.sol should emit events for totalArthBorrowed and totalUsdcSupplied change.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-23. Informational: getCurrentEpoch duplicates logic of _getCurrentEpoch in Epoch.sol -> StabilityPoolKeeper.sol

Description

The getCurrentEpoch() external method of Epoch.sol in the **StabilityPoolKeeper** contract duplicates the logic of _getCurrentEpoch() internal.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-24. Informational: updateMahaReward should emit an event in StabilityPoolKeeper.sol

Description

The updateMahaReward method of StabilityPoolKeeper.sol should emit an event any time the mahaRate is updated.

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-25. Informational: Excessive if-clause inside _scalePriceByDigits in ETHGMUOracle.sol

Description

The _scalePriceByDigits method of ETHGMUOracle.sol contains excessive condition checks (see @audit)

```
if (_answerDigits >= TARGET_DIGITS) {
  ...
}
else if (_answerDigits < TARGET_DIGITS) { // @audit
  ...
}
```

Alleviation

This issue is acknowledged by the MahaDAO team.

ID-26. Gas: maha and arthCommunityIssuance should be immutable in StabilityPoolKeeper.sol

Description

The maha and arthCommunityIssuance of StabilityPoolKeeper.sol should be immutable.

Alleviation

This issue is acknowledged by the MahaDAO team.

Disclaimers

Mundus disclaimer

The smart contracts given for audit have been analyzed in accordance with the best industry practices at the date of this report, in relation to cybersecurity vulnerabilities and issues in smart contract source code, the details of which are disclosed in this report (Source Code); the Source Code compilation, deployment, and functionality (performing the intended functions).

The audit makes no statements or warranties on the security of the code. It also cannot be considered as a sufficient assessment regarding the utility and safety of the code, bug-free status, or any other statements of the contract. While we have done our best in conducting the analysis and producing this report, it is important to note that you should not rely on this report only — we recommend proceeding with several independent audits and a public bug bounty program to ensure the security of smart contracts.

Technical disclaimers

Smart contracts are deployed and executed on a blockchain platform. The platform, its programming language, and other software related to the smart contract can have vulnerabilities that can lead to hacks. Thus, the audit can't guarantee the explicit security of the audited smart contracts.