

Warden Finance

Aegis and Aegis L2

Smart Contract Audit Report



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Valix
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Executive Summary

Overview

Valix conducted a smart contract audit to evaluate potential security issues of the **Aegis and Aegis L2 features of the WardenSwap version 1.5**. This audit report was published on *October 6, 2021*. The audit scope is limited to the **Aegis and Aegis L2 features**. Our security best practices strongly recommend that the **Warden Finance team** conduct a full security audit for both on-chain and off-chain components of its infrastructure and their interaction. A comprehensive examination has been performed during the audit process utilizing Valix's Formal Verification, Static Analysis, and Manual Review techniques.

About Aegis and Aegis L2

Aegis is the release version of Warden Finance that implements trading strategies learning algorithm into a smart contract (on chain's machine learning). Aegis uses the learning outcome to optimize future Best Rate swaps.

Aegis L2 is the release version that focuses on gas optimization on the Ethereum Layer 2 Scaling Solution like Optimistic Rollup (e.g., Optimism and Arbitrum). Aegis L2 uses custom data serialization and compression algorithms to reduce calldata bytes and storage slot usage.

Scope of Work

The security audit conducted does not replace the full security audit of the overall Warden Finance protocol. The scope is limited to the **Aegis and Aegis L2 features** and their related smart contracts.

The security audit covered the components at this specific state:

Item	Description
Components	<ul style="list-style-type: none"> ▪ <i>WardenSwap1_5_Aegis smart contract</i> ▪ <i>WardenSwap1_5_Aegis_L2 smart contract</i> ▪ <i>WardenCosmoCore smart contract</i> ▪ <i>WardenDataDeserialize smart contract</i> ▪ <i>BytesLib smart contract library</i> ▪ <i>WardenDataSerialize smart contract</i> ▪ <i>Imported associated smart contracts and libraries</i>
GitHub Repository	<ul style="list-style-type: none"> ▪ https://github.com/Wardenswap/warden-swap
Commit	<ul style="list-style-type: none"> ▪ <i>b03ee7c3190415e62223ede8ee4ad21f4cca6691</i>

Reassessment Commit	<ul style="list-style-type: none"> ▪ 5a8fefcf466e8b8408846694114906f7c625651
Audited Files	<ul style="list-style-type: none"> ▪ <i>WardenSwap1_5_L2.sol</i> ▪ <i>interface/IWardenCosmicBrainForL2.sol</i> ▪ <i>interface/IWardenCosmoCore0_8.sol</i> ▪ <i>interface/IWardenPostTrade.sol</i> ▪ <i>libraries/IWETH.sol</i> ▪ <i>libraries/IWardenTradingRoute0_8.sol</i> ▪ <i>libraries/WardenCosmoCore.sol</i> ▪ <i>libraries/WardenDataDeserialize.sol</i> ▪ <i>library/arbitrum/IArbAddressTable.sol</i> ▪ <i>library/byte/BytesLib.sol</i> ▪ <i>tools/WardenDataSerialize.sol</i>
Excluded Files/Contracts	<ul style="list-style-type: none"> ▪ <i>WardenSwap1_5_L2_dryrun.sol</i> ▪ <i>WardenCosmicBrain smart contract</i> ▪ <i>WardenPostTrade smart contract</i> ▪ <i>WETH smart contract</i> ▪ <i>WardenTradingRoute smart contract</i> ▪ <i>ArbAddressTable smart contract</i>

Remark: Our security best practices strongly recommend that the Warden Finance team conduct a full security audit for both on-chain and off-chain components of its infrastructure and the interaction between them.

Auditors

Phuwanai Thummavet

Sumedt Jitpukdebon

Keerati Torach

Boonpoj Thongakaraniroj

Disclaimer

Our smart contract audit was conducted over a limited period and was performed on the smart contract at a single point in time. As such, the scope was limited to current known risks during the work period. The review does not indicate that the smart contract and blockchain software has no vulnerability exposure.

We reviewed the security of the smart contracts with our best effort, and we do not guarantee a hundred percent coverage of the underlying risk existing in the ecosystem. The audit was scoped only in the provided code repository. The on-chain code is not in the scope of auditing.

This audit report does not provide any warranty or guarantee, nor should it be considered an “approval” or “endorsement” of any particular project. This audit report should also not be used as investment advice nor provide any legal compliance.

Audit Result Summary

From the audit results and the remediation and response from the developer, Valix trusts that the **Aegis and Aegis L2 features** have sufficient security protections to be safe for use.



Initially, Valix was able to identify **19 issues** that were categorized from the “Critical” to “Informational” risk level in the given timeframe of the assessment. On the reassessment, 13 out of 19 issues were fixed. For the acknowledged issues, the Warden Finance team acknowledged each issue but decided to remain the original code. Below is the breakdown of the vulnerabilities found and their associated risk rating for each assessment conducted.

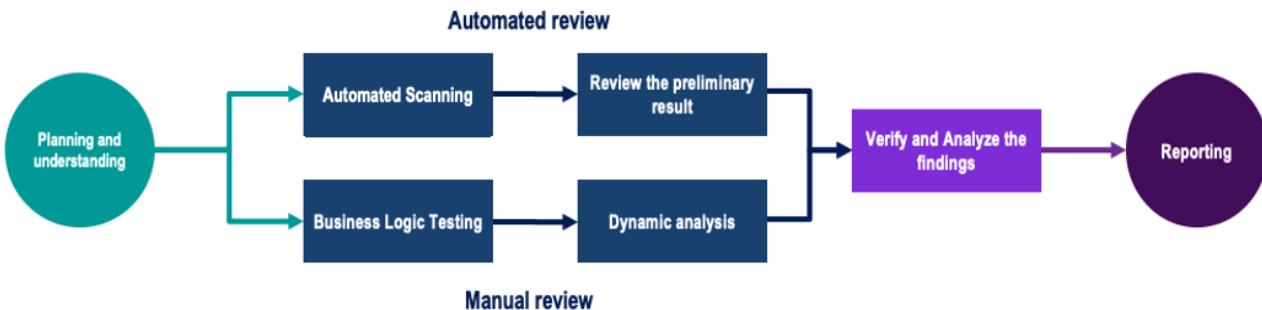
Target	Assessment Result					Reassessment Result				
	C	H	M	L	I	C	H	M	L	I
Aegis and Aegis L2	-	-	-	9	10	-	-	-	3	3

Note: Risk Rating

C Critical, **H** High, **M** Medium, **L** Low, **I** Informational

Methodology

The smart contract security audit methodology is based on Smart Contract Weakness Classification and Test Cases (SWC Registry), CWE, well-known best practices, and smart contract hacking case studies. Manual and automated review approaches can be mixed and matched, including business logic analysis in terms of the malicious doer's perspective. Using automated scanning tools to navigate or find offending software patterns in the codebase along with a purely manual or semi-automated approach, where the analyst primarily relies on one's knowledge, is performed to eliminate the false-positive results.



Planning and Understanding

- Determine the scope of testing and understanding the application's purposes and workflows.
- Identify key risk areas, including technical and business risks.
- Determine which sections to review within the resource constraints and review method – automated, manual or mixed.

Automated Review

- Adjust automated source code review tools to inspect the code for known unsafe coding patterns.
- Verify the tool's output to eliminate false-positive results, and adjust and re-run the code review tool if necessary.

Manual Review

- Analyzing the business logic flaws requires thinking in unconventional methods.
- Identify unsafe coding behavior via static code analysis.

Reporting

- Analyze the root cause of the flaws.
- Recommend improvements for secure source code.

Audit Items

We perform the audit according to the following categories and test names.

Category	ID	Test Name
Security Issue	SEC01	<i>Authorization Through tx.origin</i>
	SEC02	<i>Business Logic Flaw</i>
	SEC03	<i>Delegatecall to Untrusted Callee</i>
	SEC04	<i>DoS With Block Gas Limit</i>
	SEC05	<i>DoS with Failed Call</i>
	SEC06	<i>Function Default Visibility</i>
	SEC07	<i>Hash Collisions With Multiple Variable Length Arguments</i>
	SEC08	<i>Incorrect Constructor Name</i>
	SEC09	<i>Improper Access Control or Authorization</i>
	SEC10	<i>Improper Emergency Response Mechanism</i>
	SEC11	<i>Insufficient Validation of Address Length</i>
	SEC12	<i>Integer Overflow and Underflow</i>
	SEC13	<i>Outdated Compiler Version</i>
	SEC14	<i>Outdated Library Version</i>
	SEC15	<i>Private Data On-Chain</i>
	SEC16	<i>Reentrancy</i>
	SEC17	<i>Transaction Order Dependence</i>
	SEC18	<i>Unchecked Call Return Value</i>
	SEC19	<i>Unexpected Token Balance</i>
	SEC20	<i>Unprotected Assignment of Ownership</i>
	SEC21	<i>Unprotected SELFDESTRUCT Instruction</i>
	SEC22	<i>Unprotected Token Withdrawal</i>
	SEC23	<i>Unsafe Type Inference</i>
	SEC24	<i>Use of Deprecated Solidity Functions</i>
	SEC25	<i>Use of Untrusted Code or Libraries</i>
	SEC26	<i>Weak Sources of Randomness from Chain Attributes</i>
	SEC27	<i>Write to Arbitrary Storage Location</i>

Category	ID	Test Name
Functional Issue	FNC01	<i>Arithmetic Precision</i>
	FNC02	<i>Permanently Locked Fund</i>
	FNC03	<i>Redundant Fallback Function</i>
	FNC04	<i>Timestamp Dependence</i>
Operational Issue	OPT01	<i>Code With No Effects</i>
	OPT02	<i>Message Call with Hardcoded Gas Amount</i>
	OPT03	<i>The Implementation Contract Flow or Value and the Document is Mismatched</i>
	OPT04	<i>The Usage of Excessive Byte Array</i>
	OPT05	<i>Unenforced Timelock on An Upgradeable Proxy Contract</i>
Developmental Issue	DEV01	<i>Assert Violation</i>
	DEV02	<i>Other Compilation Warnings</i>
	DEV03	<i>Presence of Unused Variables</i>
	DEV04	<i>Shadowing State Variables</i>
	DEV05	<i>State Variable Default Visibility</i>
	DEV06	<i>Typographical Error</i>
	DEV07	<i>Uninitialized Storage Pointer</i>
	DEV08	<i>Violation of Solidity Coding Convention</i>
	DEV09	<i>Violation of Token (ERC20) Standard API</i>

Risk Rating

To prioritize the vulnerabilities, we have adopted the scheme of five distinct levels of risk: **Critical**, **High**, **Medium**, **Low**, and **Informational**, based on OWASP Risk Rating Methodology. The risk level definitions are presented in the table.

Risk Level	Definition
Critical	The code implementation does not match the specification, and it could disrupt the platform.
High	The code implementation does not match the specification, or it could result in the loss of funds for contract owners or users.
Medium	The code implementation does not match the specification under certain conditions, or it could affect the security standard by losing access control.
Low	The code implementation does not follow best practices or use suboptimal design patterns, which may lead to security vulnerabilities further down the line.
Informational	Findings in this category are informational and may be further improved by following best practices and guidelines.

The **risk value** of each issue was calculated from the product of the **impact** and **likelihood values**, as illustrated in a two-dimensional matrix below.

- **Likelihood** represents how likely a particular vulnerability is exposed and exploited in the wild.
- **Impact** measures the technical loss and business damage of a successful attack.
- **Risk** demonstrates the overall criticality of the risk.

Impact \ Likelihood	High	Medium	Low
High	Critical	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Informational

The shading of the matrix visualizes the different risk levels. Based on the acceptance criteria, the risk levels "Critical" and "High" are unacceptable. Any issue obtaining the above levels must be resolved to lower the risk to an acceptable level.

Findings

Review Findings Summary

The table below shows the summary of our assessments.

No.	Issue	Risk	Status	Functionality is in use
1	Potential Stealing of Leftover Ether and WETH	Low	Fixed	In use
2	Potential Lock of Ether	Low	Fixed	In use
3	Recommended Updating The <i>PostTrade</i> Contract With Extra Care	Low	Acknowledged	In use
4	Unchecking Duplication of Trading Route On The <i>addTradingRoute</i> Function	Low	Acknowledged	In use
5	Unchecking Duplication of Trading Route On The <i>updateTradingRoute</i> Function	Low	Acknowledged	In use
6	The Split Volume May Be Inconsistent With The Actual Amount	Low	Fixed	In use
7	Lack of Some Edge Case In Input Validation	Low	Fixed	In use
8	The Compiler May Be Susceptible To The Publicly Disclosed Bugs	Low	Fixed	In use
9	The Compiler Is Not Locked To A Specific Version	Low	Fixed	In use
10	Transparency Improvement For The <i>collectRemainingToken</i> Function	Informational	Fixed	In use
11	Transparency Improvement For The <i>collectRemainingEther</i> Function	Informational	Fixed	In use
12	Gas Optimization and Readability Improvement On The <i>_split2</i> Function	Informational	Fixed	In use
13	Inconsistent Comments/Error Messages With The Code	Informational	Fixed	In use
14	Recommended Explicit Trading Route Validation Checks	Informational	Acknowledged	In use
15	Unchecked Call Return Value	Informational	Acknowledged	In use
16	Gas Optimization On Redundant Code	Informational	Acknowledged	In use
17	Duplicate Function Implementation	Informational	Fixed	In use

No.	Issue	Risk	Status	Functionality is in use
18	Generic Typographic Error	Informational	Fixed	In use
19	Misleading Function Name	Informational	Fixed	In use

The statuses of the issues are defined as follows:

Fixed: The issue has been completely resolved and has no further complications.

Partially Fixed: The issue has been partially resolved.

Acknowledged: The issue's risk has been reported and acknowledged.

Detailed Result

This section provides all issues that we found in detail.

No. 1	Potential Stealing of Leftover Ether and WETH		
Risk	Low	Likelihood	Low
		Impact	Medium
Functionality is in use	In use	Status	Fixed
Associated Files	<i>WardenSwap1_5_L2.sol</i>		
Locations	<p><i>_tradeStrategiesWithSafeGuard(IERC20, uint256, IERC20, uint256, uint256[], IERC20[], address, uint256) L: 196 - 285</i></p> <p><i>_splitTradesWithSafeGuard(uint256[], uint256[], IERC20, uint256, IERC20) L: 409 - 458</i></p> <p><i>tradeEthToWeth(address) L: 524 - 536</i></p> <p><i>tradeWethToEth(uint256, address) L: 544 - 558</i></p>		

Detailed Issue

The state variable *weth* (line no. 20) points to the external *WETH* contract responsible for wrapping the *Ether* (native ETH) to the ERC20 token, *WETH*, and vice versa.

In exchange, when we deposit the *Ether* to the *WETH* contract, the deposited *Ether* will be locked, and the same amount in *WETH* will be minted and returned to us. On the other hand, we can withdraw the locked *Ether* by transferring the same amount in *WETH* to the *WETH* contract to burn.

However, if the *weth* variable is initialized with the rogue (forged) *WETH* contract by mistake, the rogue contract could secretly steal the *Ethers* or *WETHs* leftover in the *WardenSwap1_5_Aegis* contract.

Note that the leftover Ether and WETH mean the tokens are mistakenly transferred by a user and locked in the WardenSwap1_5_Aegis contract.

Consider the following attack scenario for better understanding.

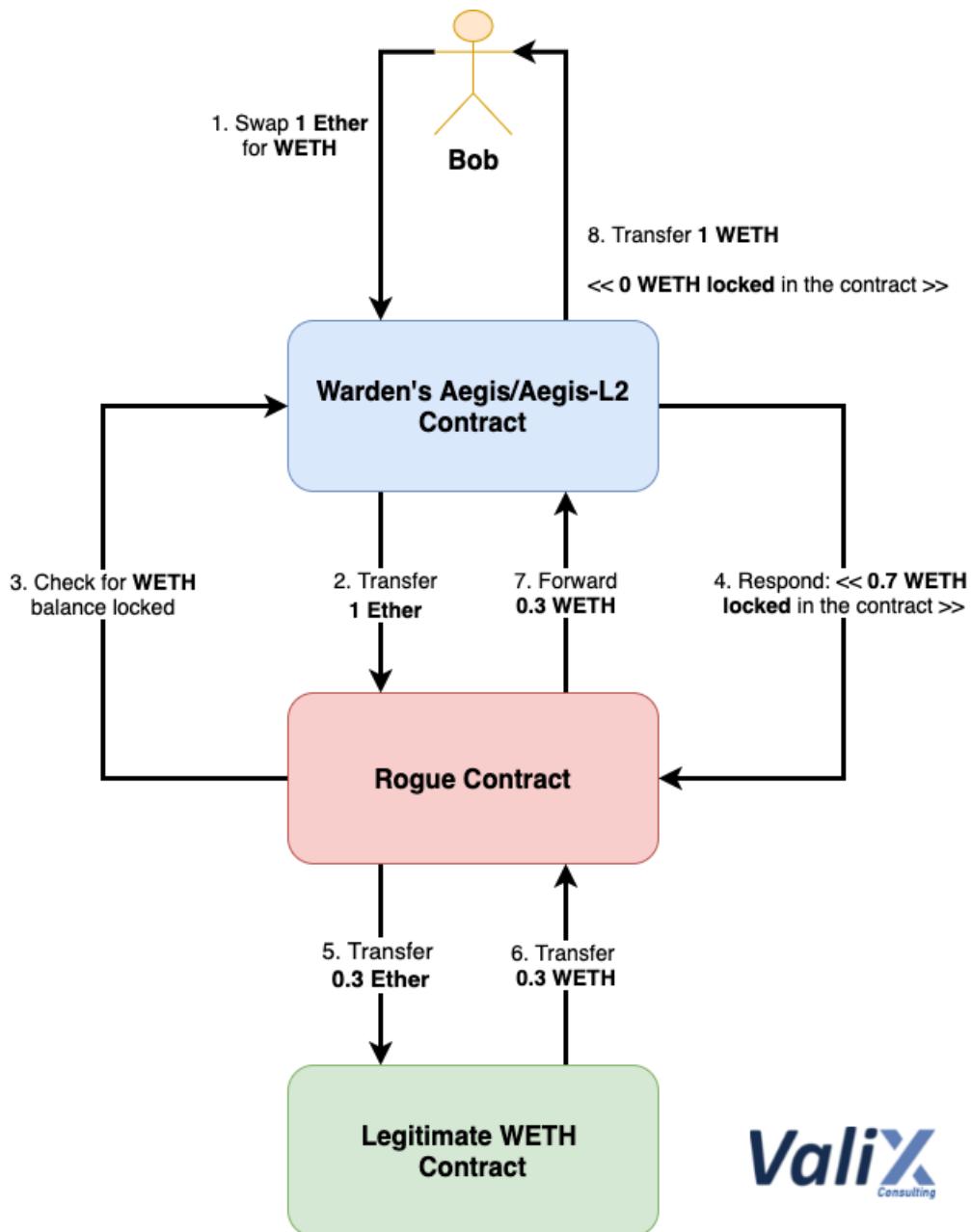


Figure 1.1 The **Rogue** contract can steal the leftover *Ether* and *WETH* from the **Aegis** contract

1. **Bob** initiates a swap transaction of *1 Ether* for *WETH* to **Aegis** contract
2. **Aegis** contract transfers *1 Ether* to **Rogue** contract
3. **Rogue** contract checks for the *WETH balance locked* in **Aegis** contract
4. **Aegis** contract has *0.7 WETH locked in*, for instance
5. **Rogue** contract transfers *0.3 Ether* (*instead of 1 Ether*) to **WETH** contract
6. **WETH** contract locks *0.3 Ether*, mints the same amount in *WETH*, and transfers *the minted WETH* to **Rogue** contract
7. **Rogue** contract transfers only *0.3 WETH* (*instead of 1 WETH*) to **Aegis** contract

8. Aegis contract transfers 1 WETH to Bob (without checking its WETH balance)

The **Rogue** contract can privately steal all *Ether* and *WETH tokens* locked in the **Aegis** contract by swapping the tokens using the attack scenario above. This attack scenario can be triggered by an attacker itself or just a regular user.

The functions affected with this issue include `_tradeStrategiesWithSafeGuard` (line no's. 196 - 285), `_splitTradesWithSafeGuard` (line no's. 409 - 458), `tradeEthToWeth` (line no's. 524 - 536), and `tradeWethToEth` (line no's. 544 - 558). The following code snippets show the affected functions.

WardenSwap1_5_L2.sol

```

196 function _tradeStrategiesWithSafeGuard(
197     IERC20      _src,
198     uint256     _srcAmount,
199     IERC20      _dest,
200     uint256     _minDestAmount,
201     uint256[]   memory _subRoutes,
202     IERC20[]    memory _correspondentTokens,
203     address     _receiver,
204     uint256     _learnedId
205 )
206     private
207     returns(uint256 _destAmount)
208 {
209     require(_subRoutes.length - 1 == _correspondentTokens.length, "WardenSwap:
210     routes and tokens length mismatched");
211     {
212         IERC20 adjustedSrc;
213         IERC20 adjustedDest = ETHER ERC20 == _dest ? IERC20(address(weth)) :
214         _dest;
215         address fromAddress;
216
217         // Wrap ETH
218         if (ETHER ERC20 == _src) {
219             require(msg.value == _srcAmount, "WardenSwap: Ether source amount
220             mismatched");
221             weth.deposit{value: _srcAmount}();
222
223             adjustedSrc = IERC20(address(weth));
224             fromAddress = address(this);
225         } else {
226             adjustedSrc = _src;
227             fromAddress = msg.sender;
228         }
229
230         // Record src/dest asset for later consistency check.
231         uint256 srcAmountBefore = adjustedSrc.balanceOf(fromAddress);
232         uint256 destAmountBefore = adjustedDest.balanceOf(address(this));
233
234         _destAmount = _tradeStrategies(

```

```

232         adjustedSrc,
233         _srcAmount,
234         adjustedDest,
235         _subRoutes,
236         _correspondentTokens,
237         fromAddress
238     );
239
240     // Sanity check
241     // Recheck if src/dest amount correct
242     require(adjustedSrc.balanceOf(fromAddress) == srcAmountBefore -
243     _srcAmount, "WardenSwap: source amount mismatched after trade");
244     require(adjustedDest.balanceOf(address(this)) == destAmountBefore +
245     _destAmount, "WardenSwap: destination amount mismatched after trade");
246   }
247
248   // Unwrap ETH
249   if (ETHER_ERC20 == _dest) {
250     weth.withdraw(_destAmount);
251   }
252
253   // Collect fee
254   _destAmount = _postTradeAndCollectFee(
255     _src,
256     _dest,
257     _srcAmount,
258     _destAmount,
259     msg.sender,
260     _receiver,
261     false
262   );
263
264   // Throw exception if destination amount doesn't meet user requirement.
265   require(_destAmount >= _minDestAmount, "WardenSwap: destination amount is too
266   low.");
267   if (ETHER_ERC20 == _dest) {
268     (bool success, ) = _receiver.call{value: _destAmount}(""); // Send back
269     ether to sender
270     require(success, "WardenSwap: Transfer ether back to caller failed.");
271   } else { // Send back token to sender
272     _dest.safeTransfer(_receiver, _destAmount);
273   }
274
275   uint256 learnedId = _learnedId;
276   if (0 == _learnedId) {
277     learnedId = cosmicBrain.train(_subRoutes, _correspondentTokens);
278   }
279   cosmicBrain.trainTradingPair(
280     _src,
281     _dest,
282

```

```

279         _srcAmount,
280         _destAmount,
281         learnedId
282     );
283
284     emit Trade(address(_src), _srcAmount, address(_dest), _destAmount,
285     msg.sender, _receiver, 0 != _learnedId, false);
285 }
```

Listing 1.1 The affected `_tradeStrategiesWithSafeGuard` function**WardenSwap1_5_L2.sol**

```

409 function _splitTradesWithSafeGuard(
410     uint256[] memory _learnedIds,
411     uint256[] memory _volumns,
412     IERC20           _src,
413     uint256          _totalSrcAmount,
414     IERC20           _dest
415 )
416 private
417 returns(uint256 _destAmount)
418 {
419     IERC20 adjustedSrc;
420     IERC20 adjustedDest = ETHER ERC20 == _dest ? IERC20(address(weth)) : _dest;
421     address fromAddress;
422
423     // Wrap ETH
424     if (ETHER ERC20 == _src) {
425         require(msg.value == _totalSrcAmount, "WardenSwap: Ether source amount
mismatched");
426         weth.deposit{value: _totalSrcAmount}();
427
428         adjustedSrc = IERC20(address(weth));
429         fromAddress = address(this);
430     } else {
431         adjustedSrc = _src;
432         fromAddress = msg.sender;
433     }
434
435     // Record src/dest asset for later consistency check.
436     uint256 srcAmountBefore = adjustedSrc.balanceOf(fromAddress);
437     uint256 destAmountBefore = adjustedDest.balanceOf(address(this));
438
439     _destAmount = _split2(
440         _learnedIds,
441         _volumns,
442         adjustedSrc,
443         _totalSrcAmount,
```

```

444         adjustedDest,
445         fromAddress
446     );
447
448     // Sanity check
449     // Recheck if src/dest amount correct
450     require(adjustedSrc.balanceOf(fromAddress) == srcAmountBefore -
451     _totalSrcAmount, "WardenSwap: source amount mismatched after trade");
452     require(adjustedDest.balanceOf(address(this)) == destAmountBefore +
453     _destAmount, "WardenSwap: destination amount mismatched after trade");
454
455     // Unwrap ETH
456     if (ETHER_ERC20 == _dest) {
457         weth.withdraw(_destAmount);
458     }
  
```

Listing 1.2 The affected `_splitTradesWithSafeGuard` function**WardenSwap1_5_L2.sol**

```

524     function tradeEthToWeth(
525         address      _receiver
526     )
527         external
528         payable
529         nonReentrant
530         returns(uint256 _destAmount)
531     {
532         weth.deposit{value: msg.value}();
533         IERC20(address(weth)).safeTransfer(_receiver, msg.value);
534         _destAmount = msg.value;
535         emit Trade(address(ETHER_ERC20), msg.value, address(weth), _destAmount,
536         msg.sender, _receiver, false, false);
  
```

Listing 1.3 The affected `tradeEthToWeth` function

WardenSwap1_5_L2.sol

```

544   function tradeWethToEth(
545     uint256 _srcAmount,
546     address _receiver
547   )
548     external
549     nonReentrant
550     returns(uint256 _destAmount)
551   {
552     IERC20(address(weth)).safeTransferFrom(msg.sender, address(this),
553     _srcAmount);
553     weth.withdraw(_srcAmount);
554     (bool success, ) = _receiver.call{value: _srcAmount}("");
555     // Send back ether
556     // to sender
557     require(success, "WardenSwap: Transfer ether back to caller failed.");
558     _destAmount = _srcAmount;
559     emit Trade(address(weth), _srcAmount, address(ETHER_ERC20), _destAmount,
560     msg.sender, _receiver, false, false);
561   }

```

Listing 1.4 The affected *tradeWethToEth* function

The root cause of this issue is because the affected functions did not verify the balance of *Ether* or *WETH* after the *Ether* wrapping or unwrapping process.

Recommendations

We recommend updating the affected functions to verify that the *Ether* or *WETH* is still in the balance after the *Ether* wrapping or unwrapping process. Consider the following code snippets for the improved functions.

WardenSwap1_5_L2.sol

```

196   function _tradeStrategiesWithSafeGuard(
197     IERC20 _src,
198     uint256 _srcAmount,
199     IERC20 _dest,
200     uint256 _minDestAmount,
201     uint256[] memory _subRoutes,
202     IERC20[] memory _correspondentTokens,
203     address _receiver,
204     uint256 _learnedId
205   )
206     private
207     returns(uint256 _destAmount)
208   {
209     require(_subRoutes.length - 1 == _correspondentTokens.length, "WardenSwap:
210     routes and tokens length mismatched");

```

```

210      {
211          IERC20 adjustedSrc;
212          IERC20 adjustedDest = ETHER_ERC20 == _dest ? IERC20(address(weth)) :
213          _dest;
214          address fromAddress;
215
216          // Wrap ETH
217          if (ETHER_ERC20 == _src) {
218              require(msg.value == _srcAmount, "WardenSwap: Ether source amount
219              mismatched");
220
221              uint256 wethAmountBefore =
222                  IERC20(address(weth)).balanceOf(address(this));
223              weth.deposit{value: _srcAmount}();
224              uint256 wethAmountAfter =
225                  IERC20(address(weth)).balanceOf(address(this));
226
227              // Verify the balance of WETH after wrapping
228              require(wethAmountAfter == wethAmountBefore + _srcAmount,
229                      "WardenSwap: received unexpected WETH amount");
230
231              adjustedSrc = IERC20(address(weth));
232              fromAddress = address(this);
233          } else {
234              adjustedSrc = _src;
235              fromAddress = msg.sender;
236          }
237
238          // Record src/dest asset for later consistency check.
239          uint256 srcAmountBefore = adjustedSrc.balanceOf(fromAddress);
240          uint256 destAmountBefore = adjustedDest.balanceOf(address(this));
241
242          _destAmount = _tradeStrategies(
243              adjustedSrc,
244              _srcAmount,
245              adjustedDest,
246              _subRoutes,
247              _correspondentTokens,
248              fromAddress
249          );
250
251          // Sanity check
252          // Recheck if src/dest amount correct
253          require(adjustedSrc.balanceOf(fromAddress) == srcAmountBefore -
254              _srcAmount, "WardenSwap: source amount mismatched after trade");
255          require(adjustedDest.balanceOf(address(this)) == destAmountBefore +
256              _destAmount, "WardenSwap: destination amount mismatched after trade");
257      }
258
259      // Unwrap ETH

```

```

254     if (ETHER_ERC20 == _dest) {
255         uint256 etherAmountBefore = address(this).balance;
256         weth.withdraw(_destAmount);
257         uint256 etherAmountAfter = address(this).balance;
258
259         // Verify the balance of Ether after unwrapping
260         require(etherAmountAfter == etherAmountBefore + _destAmount, "WardenSwap:
261             received unexpected Ether amount");
262     }
263
264     // Collect fee
265     _destAmount = _postTradeAndCollectFee(
266         _src,
267         _dest,
268         _srcAmount,
269         _destAmount,
270         msg.sender,
271         _receiver,
272         false
273     );
274
275     // Throw exception if destination amount doesn't meet user requirement.
276     require(_destAmount >= _minDestAmount, "WardenSwap: destination amount is too
277     low.");
278     if (ETHER_ERC20 == _dest) {
279         (bool success, ) = _receiver.call{value: _destAmount}(""); // Send back
280         ether to sender
281         require(success, "WardenSwap: Transfer ether back to caller failed.");
282     } else { // Send back token to sender
283         _dest.safeTransfer(_receiver, _destAmount);
284     }
285
286     uint256 learnedId = _learnedId;
287     if (0 == _learnedId) {
288         learnedId = cosmicBrain.train(_subRoutes, _correspondentTokens);
289     }
290     cosmicBrain.trainTradingPair(
291         _src,
292         _dest,
293         _srcAmount,
294         _destAmount,
295         learnedId
296     );
297
298     emit Trade(address(_src), _srcAmount, address(_dest), _destAmount,
299     msg.sender, _receiver, 0 != _learnedId, false);
300 }
```

Listing 1.5 The improved `_tradeStrategiesWithSafeGuard` function

WardenSwap1_5_L2.sol

```

409 function _splitTradesWithSafeGuard(
410     uint256[] memory _learnedIds,
411     uint256[] memory _volumns,
412     IERC20           _src,
413     uint256          _totalSrcAmount,
414     IERC20           _dest
415 )
416 private
417 returns(uint256 _destAmount)
418 {
419     IERC20 adjustedSrc;
420     IERC20 adjustedDest = ETHER ERC20 == _dest ? IERC20(address(weth)) : _dest;
421     address fromAddress;
422
423     // Wrap ETH
424     if (ETHER ERC20 == _src) {
425         require(msg.value == _totalSrcAmount, "WardenSwap: Ether source amount
mismatched");
426
427         uint256 wethAmountBefore =
428             IERC20(address(weth)).balanceOf(address(this));
429         weth.deposit{value: _totalSrcAmount}();
430         uint256 wethAmountAfter = IERC20(address(weth)).balanceOf(address(this));
431
432         // Verify the balance of WETH after wrapping
433         require(wethAmountAfter == wethAmountBefore + _totalSrcAmount,
434             "WardenSwap: received unexpected WETH amount");
435
436         adjustedSrc = IERC20(address(weth));
437         fromAddress = address(this);
438     } else {
439         adjustedSrc = _src;
440         fromAddress = msg.sender;
441     }
442
443     // Record src/dest asset for later consistency check.
444     uint256 srcAmountBefore = adjustedSrc.balanceOf(fromAddress);
445     uint256 destAmountBefore = adjustedDest.balanceOf(address(this));
446
447     _destAmount = _split2(
448         _learnedIds,
449         _volumns,
450         adjustedSrc,
451         _totalSrcAmount,
452         adjustedDest,
453         fromAddress
454     );
455
456     // Sanity check

```

```

455     // Recheck if src/dest amount correct
456     require(adjustedSrc.balanceOf(fromAddress) == srcAmountBefore -
457     _totalSrcAmount, "WardenSwap: source amount mismatched after trade");
458     require(adjustedDest.balanceOf(address(this)) == destAmountBefore +
459     _destAmount, "WardenSwap: destination amount mismatched after trade");
460
461     // Unwrap ETH
462     if (ETHER_ERC20 == _dest) {
463         uint256 etherAmountBefore = address(this).balance;
464         weth.withdraw(_destAmount);
465         uint256 etherAmountAfter = address(this).balance;
466
467         // Verify the balance of Ether after unwrapping
468         require(etherAmountAfter == etherAmountBefore + _destAmount, "WardenSwap:
469         received unexpected Ether amount");
470     }

```

Listing 1.6 The improved `_splitTradesWithSafeGuard` function**WardenSwap1_5_L2.sol**

```

524     function tradeEthToWeth(
525         address      _receiver
526     )
527         external
528         payable
529         nonReentrant
530         returns(uint256 _destAmount)
531     {
532         uint256 wethAmountBefore = IERC20(address(weth)).balanceOf(address(this));
533         weth.deposit{value: msg.value}();
534         uint256 wethAmountAfter = IERC20(address(weth)).balanceOf(address(this));
535
536         // Verify the balance of WETH after wrapping
537         require(wethAmountAfter == wethAmountBefore + msg.value, "WardenSwap:
538         received unexpected WETH amount");
539
540         IERC20(address(weth)).safeTransfer(_receiver, msg.value);
541         _destAmount = msg.value;
542         emit Trade(address(ETHER_ERC20), msg.value, address(weth), _destAmount,
543         msg.sender, _receiver, false, false);
544     }

```

Listing 1.7 The improved `tradeEthToWeth` function

WardenSwap1_5_L2.sol

```

544   function tradeWethToEth(
545     uint256 _srcAmount,
546     address _receiver
547   )
548     external
549     nonReentrant
550     returns(uint256 _destAmount)
551   {
552     IERC20(address(weth)).safeTransferFrom(msg.sender, address(this),
553     _srcAmount);
554
555     uint256 etherAmountBefore = address(this).balance;
556     weth.withdraw(_srcAmount);
557     uint256 etherAmountAfter = address(this).balance;
558
559     // Verify the balance of Ether after unwrapping
560     require(etherAmountAfter == etherAmountBefore + _srcAmount, "WardenSwap:
561     received unexpected Ether amount");
562
563     (bool success, ) = _receiver.call{value: _srcAmount}("");
564     // Send back ether to sender
565     require(success, "WardenSwap: Transfer ether back to caller failed.");
566     _destAmount = _srcAmount;
567     emit Trade(address(weth), _srcAmount, address(ETHER_ERC20), _destAmount,
568     msg.sender, _receiver, false, false);
569   }

```

Listing 1.8 The improved *tradeWethToEth* function

Reassessment

The developer opted to remediate this issue by changing the visibility of the state variable *weth* from *private* to *public* (line no. 20 in Listing 1.9) instead of modifying the affected functions to trade for minimal gas use.

The public visibility of the *weth* enables a user to inspect the legitimacy of the *WETH* contract. Since the *weth* variable can be assigned only once in the constructor (line no. 78 in Listing 1.10), if the *weth* is initialized correctly during the smart contract deployment, the *weth* cannot be updated later.

WardenSwap1_5_L2.sol

```

13 ... (SNIP) ...
14 contract WardenSwap1_5_Aegis is Ownable, ReentrancyGuard {
15   using SafeERC20 for IERC20;
16
17   IWardenCosmoCore public cosmoCore;
18   IWardenCosmicBrain public cosmicBrain;
19   IWardenPostTrade public postTrade;
20
21   IWETH public immutable weth;
22   IERC20 private constant ETHER_ERC20 =
23     IERC20(0xEeeeeEeeeEeEeEeeEEEeeeeEeeeeeeeEEeE);
24 ... (SNIP) ...

```

Listing 1.9 The public state variable *weth***WardenSwap1_5_L2.sol**

```

69 constructor(
70   IWardenCosmoCore _cosmoCore,
71   IWardenCosmicBrain _cosmicBrain,
72   IWardenPostTrade _postTrade,
73   IWETH _weth
74 ) {
75   cosmoCore = _cosmoCore;
76   cosmicBrain = _cosmicBrain;
77   postTrade = _postTrade;
78   weth = _weth;
79
80   emit UpdatedWardenCosmoCore(_cosmoCore);
81   emit UpdatedWardenCosmicBrain(_cosmicBrain);
82   emit UpdatedWardenPostTrade(_postTrade);
83 }

```

Listing 1.10 The contract constructor is the only place that can assign the *weth* variable

No. 2	Potential Lock of Ether		
Risk	Low	Likelihood	Low
Functionality is in use	In use	Impact	Medium
Associated Files	<i>WardenSwap1_5_L2.sol</i>		
Locations	<i>receive() L: 583</i>		

Detailed Issue

The *WardenSwap1_5_Aegis* contract implements the *receive* function in line no. 583. The *receive* function receives the *Ethers* (native ETHs) from the *WETH* contract (after the best rate swapping) in case a user wants to receive the *Ether* as the destination token.

However, the *receive* function also receives *Ethers* from EOA (Externally Owned Account) wallets, resulting in the lock of *Ethers* by mistake. Even though the contract has implemented the *collectRemainingEther* function to enable the platform developer to withdraw the locked *Ethers*, the user mistake can be avoided by receiving only the *Ethers* from the *WETH* contract.

The code snippet below shows the associated *receive* function.

WardenSwap1_5_L2.sol

```
583  receive() external payable {}
```

Listing 2.1 The *receive* function

Recommendations

We advise enforcing receiving only the *Ethers* from the *WETH* contract by changing the *receive* function as follows.

WardenSwap1_5_L2.sol

```
583  receive() external payable {
584      require(msg.sender == address(weth), "WardenSwap: Receive Ether only from
585      WETH");
}
```

Listing 2.2 The improved *receive* function

If the `receive` function is implemented according to our advice, the `collectRemainingEther` function (line no's. 572 - 580) can be removed since there will be no *Ether* withholding in the WardenSwap1_5_Aegis contract anymore.

Note that there is still a case that the *Ether* can be enforced to deposit to the WardenSwap1_5_Aegis contract by using the `selfdestruct` instruction. However, we consider that is a special case that would not mistakenly happen by an end-user.

WardenSwap1_5_L2.sol

```
572 function collectRemainingEther(
573     uint256 _amount
574 )
575     external
576     onlyOwner
577 {
578     (bool success, ) = msg.sender.call{value: _amount}(""); // Send back ether to
579     sender
580     require(success, "WardenSwap: Transfer ether back to caller failed.");
581 }
```

Listing 2.3 The `collectRemainingEther` function that can be removed

Reassessment

The developer updated the `receive` function according to our advice to enforce receiving only the *Ethers* from the *WETH* contract.

No. 3	Recommended Updating The <i>PostTrade</i> Contract With Extra Care		
Risk	Low	Likelihood	Low
Functionality is in use	In use	Impact	Medium
Associated Files	<i>WardenSwap1_5_L2.sol</i>		
Locations	<i>_postTradeAndCollectFee(IERC20, IERC20, uint256, uint256, address, address, bool)</i> L: 585 - 615		

Detailed Issue

The *_postTradeAndCollectFee* function (line no's. 585 - 615) is responsible for collecting a trading fee based on the source and destination token amounts and the user's current WAD tokens holding.

Specifically, the function will call the *postTradeAndFee* function of the *PostTrade* contract (line no's. 598 - 606) to calculate the trading fee. Then, the trading fee will be deducted from the destination token (line no's. 608 - 612) by the *_collectFee* function (line no's. 617 - 631).

In other words, the *_postTradeAndCollectFee* function will collect a trading fee according to the result from the *postTradeAndFee* function of the *PostTrade* contract. And, the trading fee calculation algorithm may be subject to change in the future based on Warden Protocol's tokenomics changes.

WardenSwap1_5_L2.sol

```

585 function _postTradeAndCollectFee(
586     IERC20      _src,
587     IERC20      _dest,
588     uint256    _srcAmount,
589     uint256    _destAmount,
590     address     _trader,
591     address     _receiver,
592     bool        _isSplit
593 )
594 private
595 returns (uint256 _newDestAmount)
596 {
597     // Collect fee
598     (uint256 fee, address feeWallet) = postTrade.postTradeAndFee(
599         _src,
600         _dest,
601         _srcAmount,
602         _destAmount,
603         _trader,
604         _receiver,

```

```
605     _isSplit
606 );
607 if (fee > 0) {
608     _collectFee(
609         _dest,
610         fee,
611         feeWallet
612     );
613 }
614 return _destAmount - fee;
615 }
```

Listing 3.1 The `_postTradeAndCollectFee` function

Recommendations

Since the trading fee calculation algorithm may be subject to change in the future based on Warden Protocol's tokenomics changes, the platform developer has to exercise extra care when updating the `PostTrade` contract (new contract deployment), such as using the unit and integration testings, to ensure that the `postTradeAndFee` function will calculate the accurate trading fee.

Reassessment

The developer considered and acknowledged our recommendation to update the `PostTrade` contract with extra care.

No. 4	Unchecking Duplication of Trading Route On The <i>addTradingRoute</i> Function		
Risk	Low	Likelihood	Medium
Functionality is in use	In use	Impact	Low
Associated Files	<i>libraries/WardenCosmoCore.sol</i>		
Locations	<i>addTradingRoute(string, IWardenTradingRoute)</i> L: 27 - 40		

Detailed Issue

The *addTradingRoute* function of the *WardenCosmoCore* contract allows the platform developer to add new trading routes (line no's. 27 - 40). However, the function lacked verifying the duplication of the trading route being added, as shown below.

WardenCosmoCore.sol

```

27 function addTradingRoute(
28     string calldata _name,
29     IWardenTradingRoute _routingAddress
30 )
31     external
32     onlyOwner
33 {
34     _tradingRoutes.push(Route({
35         name: _name,
36         enable: true,
37         route: _routingAddress
38     }));
39     emit AddedTradingRoute(msg.sender, _name, _routingAddress,
40     _tradingRoutes.length - 1);
41 }
```

Listing 4.1 The *addTradingRoute* function

The duplicated trading routes may interfere with the process of best rate querying, such as slowing down a query or pushing a dispensable load to the best rate query engine.

Recommendations

We recommend detecting whether the given trading route is duplicated with an existing route. The trading route can be added only when there is no duplication. Consider the following code snippet.

WardenCosmoCore.sol

```

27  function checkTradingRouteDuplicate(IWardenTradingRoute _routingAddress) public
28  {
29      uint256 length = _tradingRoutes.length;
30      for (uint256 rid = 0; rid < length; rid++) {
31          require(_tradingRoutes[rid].route != _routingAddress, "Duplicate trading
32              route");
33      }
34
35  function addTradingRoute(
36      string calldata _name,
37      IWardenTradingRoute _routingAddress
38  )
39      external
40      onlyOwner
41  {
42      checkTradingRouteDuplicate(_routingAddress);
43      _tradingRoutes.push(Route({
44          name: _name,
45          enable: true,
46          route: _routingAddress
47      }));
48      emit AddedTradingRoute(msg.sender, _name, _routingAddress,
49      _tradingRoutes.length - 1);
50  }

```

Listing 4.2 The improved *addTradingRoute* function

Reassessment

The developer acknowledged the issue but decided to remain the original code to preserve the minimal gas use. The developer also took note of adding new trading routes with care.

No. 5	Unchecking Duplication of Trading Route On The <i>updateTradingRoute</i> Function		
Risk	Low	Likelihood	Medium
Functionality is in use	In use	Impact	Low
Associated Files	<i>libraries/WardenCosmoCore.sol</i>		
Locations	<i>updateTradingRoute(uint256, string, IWardenTradingRoute)</i> L: 48 - 59		

Detailed Issue

The *updateTradingRoute* function of the *WardenCosmoCore* contract allows the platform developer to update an existing trading route (line no's. 48 - 59). However, the function lacked verifying the duplication of the trading route being updated, as shown below.

WardenCosmoCore.sol

```

48 function updateTradingRoute(
49   uint256 _index,
50   string calldata _name,
51   IWardenTradingRoute _route
52 )
53   external
54   onlyOwner
55 {
56   _tradingRoutes[_index].name = _name;
57   _tradingRoutes[_index].route = _route;
58   emit UpdatedTradingRoute(msg.sender, _name, _route, _index);
59 }
```

Listing 5.1 The *updateTradingRoute* function

The duplicated trading routes may interfere with the process of best rate querying, such as slowing down a query or pushing a dispensable load to the best rate query engine.

Recommendations

We recommend detecting whether the given trading route is duplicated with an existing route. The trading route can be updated only when there is no duplication. Consider the following code snippet.

WardenCosmoCore.sol

```

48 function checkTradingRouteDuplicate(IWardenTradingRoute _routingAddress) public
49 {
50     uint256 length = _tradingRoutes.length;
51     for (uint256 rid = 0; rid < length; rid++) {
52         require(_tradingRoutes[rid].route != _routingAddress, "Duplicate trading
53             route");
54     }
55
56 function updateTradingRoute(
57     uint256 _index,
58     string calldata _name,
59     IWardenTradingRoute _route
60 )
61 external
62 onlyOwner
63 {
64     checkTradingRouteDuplicate(_route);
65     _tradingRoutes[_index].name = _name;
66     _tradingRoutes[_index].route = _route;
67     emit UpdatedTradingRoute(msg.sender, _name, _route, _index);
68 }
```

Listing 5.2 The improved *updateTradingRoute* function

Reassessment

The developer acknowledged the issue but decided to remain the original code to preserve the minimal gas use. The developer also took note of updating trading routes with care.

No. 6	The Split Volume May Be Inconsistent With The Actual Amount		
Risk	Low	Likelihood	Medium
Functionality is in use	In use	Impact	Low
Associated Files	<i>WardenSwap1_5_L2.sol</i>		
Locations	<code>_split2(uint256[],uint256[],address,uint256,address,address) L:380-406</code> <code>decodeLearnedIdsAndColumns(bytes,uint256) L:339-346</code>		

Detailed Issue

The relevant split trading functions namely `splitTrades`, `splitTradesC1`, `splitTradesC2`, and `splitTradesC3` are consequently call the internal functions namely `_split2` and `decodeLearnedIdsAndColumns`, allowing a user to split volumes of a trading token by percentages. Therefore, the split volumes should be accumulated to 100. However, the above-mentioned internal functions do not check the sum of percentage volumes which may lead to an accounting issue when the percentage of split volumes and the actual token amount are unmatched.

For example, in the `splitTrades` function, the `_volumns` variable is an array containing the split percentages of the `_totalSourceAmount` variable in which the `_LearnedIds` variable can have 2 or more elements. There is a requirement that the length of the `_LearnedIds` must be equal to the length of the `_volumns`. However, the function does not check that the sum of all percentage elements inside the `_volumns` variable should not exceed 100.

WardenSwap1_5_L2.sol

```

471 function splitTrades(
472     uint256[] memory _learnedIds,
473     uint256[] memory _volumns,
474     IERC20 _src,
475     uint256 _totalSrcAmount,
476     IERC20 _dest,
477     uint256 _minDestAmount,
478     address _receiver
479 )
480 public
481 payable
482 nonReentrant
483 returns(uint256 _destAmount)
484 {
485     require(_learnedIds.length > 0, "WardenSwap: learnedIds can not be empty");
486     require(_learnedIds.length == _volumns.length, "WardenSwap: learnedIds and
487 volumns lengths mismatched");
488     ... (SNIP)...

```

Listing 6.1 Lengths of the `_volumns` and `LearnedIds` variables are checked,
but the sum of the `_volumns` variable is not checked

In the `_split2` function, the `_volumns` will be used to split the `_totalSrcAmount` by its percentages to actual split amounts. If the sum of all split volumes is more than 100, the actual amount and the percentage volumes may be inconsistent.

For example, given `[70, 40]` is the `_volumns` of the `_LearnedIds[1, 2]` with 1000 `_totalSrcAmount`. The first learned ID would split 70% of the `_totalSrcAmount`, that is 700. The second learned ID uses the remaining `_totalSrcAmount`, that is 300 which is inconsistent with the specified 40%.

WardenSwap1_5_L2.sol

```

366 function _split2(
367     uint256[] memory _learnedIds,
368     uint256[] memory _volumns,
369     IERC20 _src,
370     uint256 _totalSrcAmount,
371     IERC20 _dest,
372     address _fromAddress
373 )
374 private
375 returns (
376     uint256 _destAmount
377 )
378 {
379     // Trade with routes
380     uint256 amountRemain = _totalSrcAmount;
381     for (uint i = 0; i < _learnedIds.length; i++) {

```

```

382     uint256 amountForThisRound;
383     if (i == _learnedIds.length - 1) {
384         amountForThisRound = amountRemain;
385     } else {
386         amountForThisRound = _totalSrcAmount * _volumns[i] / 100;
387         amountRemain = amountRemain - amountForThisRound;
388     }
... (SNIP) ...

```

Listing 6.2 Amount is splitted by percentage volumes on the `_split2` function

Recommendations

The `amountForThisRound` variable should be calculated to be consistent with each split percentage from the `_volumns` variable.

Reassessment

The `splitTrades` function was fixed by checking that the `LearnedIds` length must be equal to the `volumes` length - 1.

WardenSwap1_5_L2.sol

```

481 function splitTrades(
482     uint256[] memory _learnedIds,
483     uint256[] memory _volumes,
484     IERC20           _src,
485     uint256          _totalSrcAmount,
486     IERC20           _dest,
487     uint256          _minDestAmount,
488     address          _receiver
489 )
490 public
491 payable
492 nonReentrant
493 returns(uint256 _destAmount)
494 {
495     require(_learnedIds.length > 0, "WardenSwap: learnedIds can not be empty");
496     require(_learnedIds.length == _volumes.length - 1, "WardenSwap: learnedIds and volumes lengths mismatched");
... (SNIP) ...

```

Listing 6.3 The fixed `splitTrades` function

No. 7	Lack of Some Edge Case In Input Validation		
Risk	Low	Likelihood	Low
Functionality is in use	In use	Impact	Medium
Associated Files	<i>tools/WardenDataSerialize.sol</i>		
Locations	<i>tradeStrategiesSerialize(address, uint256, address, uint256, uint256[], address[])</i> <i>L: 88 - 148</i>		

Detailed Issue

On the *tradeStrategiesSerialize* function (line no's. 88 - 148), we found that the function lacked validating the following edge case:

```
_subRoutes.length - 1 == _correspondentTokens.length
```

The function could not detect the case when the *_correspondentTokens.length* is more than *_subRoutes.length*. The code snippet below shows the *tradeStrategiesSerialize* function.

WardenDataSerialize.sol

```

88 function tradeStrategiesSerialize(
89     address      _src,
90     uint256      _srcAmount,
91     address      _dest,
92     uint256      _minDestAmount,
93     uint256[]    calldata _subRoutes,
94     address[]    calldata _correspondentTokens
95 )
96     external
97     view
98     returns(
99         bytes memory _data
100    )
101 {
102     require(_srcAmount <= type(uint96).max,
103             "WardenDataSerialize:tradeStrategiesSerialize _srcAmount is too large, uint96
104             support only.");
105     require(_minDestAmount <= type(uint96).max,
106             "WardenDataSerialize:tradeStrategiesSerialize _minDestAmount is too large,
107             uint96 support only.");
108     // tokenLookup

```

```
106     uint256 srcIndex = addressTable.lookup(_src);
107     uint256 destIndex = addressTable.lookup(_dest);
108
109     require(srcIndex <= type(uint24).max,
110 "WardenDataSerialize:tradeStrategiesSerialize srcIndex is too large, uint24
111 support only.");
110     require(destIndex <= type(uint24).max,
111 "WardenDataSerialize:tradeStrategiesSerialize destIndex is too large, uint24
112 support only.");
113
114     _data = abi.encodePacked(
115         uint24(srcIndex),
116         uint24(destIndex),
117         uint96(_srcAmount),
118         uint96(_minDestAmount)
119     );
120
121     require(_subRoutes.length < 64, "WardenDataSerialize:tradeStrategiesSerialize
122 _subRoutes.length is too large, uint6 support only.");
123     uint8 routeLength = uint8(_subRoutes.length);
124     // token instruction: 2 (24-bit)
125     uint8 instructions = 2 << 6;
126     instructions += routeLength;
127
128     _data = abi.encodePacked(
129         _data,
130         instructions
131     );
132
133     for (uint256 i = 0; i < routeLength; i++) {
134         require(_subRoutes[i] <= type(uint16).max,
135 "WardenDataSerialize:tradeStrategiesSerialize _subRoutes[i] is too large, uint16
136 support only.");
137         _data = abi.encodePacked(
138             _data,
139             uint16(_subRoutes[i])
140         );
141     }
142
143     for (uint256 i = 0; i < routeLength - 1; i++) {
144         address tokenAddress = address(_correspondentTokens[i]);
145         uint256 tokenId = addressTable.lookup(tokenAddress);
146         require(tokenId <= type(uint24).max,
147 "WardenDataSerialize:tradeStrategiesSerialize tokenId is too large, uint24
148 support only.");
149
150         _data = abi.encodePacked(
151             _data,
152             uint24(tokenId)
153         );
154     }
155 }
```

148 }

Listing 7.1 The *tradeStrategiesSerialize* function

Recommendations

We recommend adding the lacking validation logic using the *require* statement as follows.

WardenDataSerialize.sol

```

88  function tradeStrategiesSerialize(
89    address      _src,
90    uint256      _srcAmount,
91    address      _dest,
92    uint256      _minDestAmount,
93    uint256[]    calldata _subRoutes,
94    address[]    calldata _correspondentTokens
95  )
96  external
97  view
98  returns(
99    bytes memory _data
100 )
101 {
102   require(_srcAmount <= type(uint96).max,
103 "WardenDataSerialize:tradeStrategiesSerialize _srcAmount is too large, uint96
104 support only.");
105   require(_minDestAmount <= type(uint96).max,
106 "WardenDataSerialize:tradeStrategiesSerialize _minDestAmount is too large,
107 uint96 support only.");
108
109   // tokenLookup
110   uint256 srcIndex = addressTable.lookup(_src);
111   uint256 destIndex = addressTable.lookup(_dest);
112
113   require(srcIndex <= type(uint24).max,
114 "WardenDataSerialize:tradeStrategiesSerialize srcIndex is too large, uint24
115 support only.");
116   require(destIndex <= type(uint24).max,
117 "WardenDataSerialize:tradeStrategiesSerialize destIndex is too large, uint24
118 support only.");
119
120   _data = abi.encodePacked(
121     uint24(srcIndex),
122     uint24(destIndex),
123     uint96(_srcAmount),
124     uint96(_minDestAmount)
125   );
126 }
```

```

119     require(_subRoutes.length - 1 == _correspondentTokens.length,
120             "WardenDataSerialize:tradeStrategiesSerialize routes and tokens length
121             mismatched");
122     require(_subRoutes.length < 64, "WardenDataSerialize:tradeStrategiesSerialize
123             _subRoutes.length is too large, uint6 support only.");
124     uint8 routeLength = uint8(_subRoutes.length);
125     // token instruction: 2 (24-bit)
126     uint8 instructions = 2 << 6;
127     instructions += routeLength;
128
129     _data = abi.encodePacked(
130         _data,
131         instructions
132     );
133
134     for (uint256 i = 0; i < routeLength; i++) {
135         require(_subRoutes[i] <= type(uint16).max,
136                 "WardenDataSerialize:tradeStrategiesSerialize _subRoutes[i] is too large, uint16
137                 support only.");
138         _data = abi.encodePacked(
139             _data,
140             uint16(_subRoutes[i])
141         );
142     }
143
144     for (uint256 i = 0; i < routeLength - 1; i++) {
145         address tokenAddress = address(_correspondentTokens[i]);
146         uint256 tokenId = addressTable.lookup(tokenAddress);
147         require(tokenId <= type(uint24).max,
148                 "WardenDataSerialize:tradeStrategiesSerialize tokenId is too large, uint24
149                 support only.");
150         _data = abi.encodePacked(
151             _data,
152             uint24(tokenId)
153         );
154     }
155 }
```

Listing 7.2 The improved *tradeStrategiesSerialize* function

Reassessment

The developer added the recommended `require` statement to check the corresponding lengths of `_subRoutes` and `_correspondentTokens`.

WardenDataSerialize.sol

```
77 function tradeStrategiesSerialize(
78     address      _src,
79     uint256      _srcAmount,
80     address      _dest,
81     uint256      _minDestAmount,
82     uint256[]    calldata _subRoutes,
83     address[]    calldata _correspondentTokens
84 )
85     external
86     view
87     returns(
88         bytes memory _data
89     )
90 {
... (SNIP)...
108     require(_subRoutes.length - 1 == _correspondentTokens.length,
109             "WardenDataSerialize:tradeStrategiesSerialize routes and tokens length
mismatched");
110     require(_subRoutes.length < 64, "WardenDataSerialize:tradeStrategiesSerialize
_subRoutes.length is too large, uint6 support only.");
... (SNIP)...
```

Listing 7.3 The fixed `tradeStrategiesSerialize` function

No. 8	The Compiler May Be Susceptible To The Publicly Disclosed Bugs		
Risk	Low	Likelihood	Low
		Impact	Medium
Functionality is in use	In use	Status	Fixed
Associated Files	<i>WardenSwap1_5_L2.sol</i> <i>interface/IWardenCosmicBrainForL2.sol</i> <i>interface/IWardenCosmoCore0_8.sol</i> <i>interface/IWardenPostTrade.sol</i> <i>libraries/IWETH.sol</i> <i>libraries/IWardenTradingRoute0_8.sol</i> <i>libraries/WardenCosmoCore.sol</i> <i>libraries/WardenDataDeserialize.sol</i> <i>library/arbitrum/IArbAddressTable.sol</i> <i>library/byte/BytesLib.sol</i> <i>tools/WardenDataSerialize.sol</i>		
Locations	<i>WardenSwap1_5_L2.sol</i> L: 2 <i>IWardenCosmicBrainForL2.sol</i> L: 2 <i>IWardenCosmoCore0_8.sol</i> L: 3 <i>IWardenPostTrade.sol</i> L: 2 <i>IWETH.sol</i> L: 3 <i>IWardenTradingRoute0_8.sol</i> L: 3 <i>WardenCosmoCore.sol</i> L: 3 <i>WardenDataDeserialize.sol</i> L: 10 <i>IArbAddressTable.sol</i> L: 2 <i>BytesLib.sol</i> L: 5 <i>WardenDataSerialize.sol</i> L: 10		

Detailed Issue

The WardenSwap smart contracts use an outdated Solidity compiler version which may be susceptible to publicly disclosed vulnerabilities. The compiler version currently used by the WardenSwap is v0.8.0, which contains the list of known bugs as the following link:

<https://docs.soliditylang.org/en/v0.8.0/bugs.html>

The known bugs may not directly lead to the vulnerability, but it may increase an opportunity to trigger some attacks further.

An example of the Solidity code that does not use the latest patch version (v0.8.8) is shown below.

WardenCosmoCore.sol

```
1 // SPDX-License-Identifier: MIT
2
3 pragma solidity ^0.8.0;
4
5 import
6     "https://github.com/OpenZeppelin/openzeppelin-contracts/blob/v4.2.0/contracts/ac
7     cess/Ownable.sol";
8 import "../interface/IWardenCosmoCore0_8.sol";
9
10 contract WardenCosmoCore is Ownable, IWardenCosmoCore {
```

Listing 8.1 An example of the Solidity code that does not use the latest patch version (v0.8.8)

Recommendations

We recommend using the latest patch version, v0.8.8, that fixes all known bugs.

Reassessment

The developer fixed this issue by specifying the latest patch version, v0.8.8.

No. 9	The Compiler Is Not Locked To A Specific Version		
Risk	Low	Likelihood	Low
	Impact	Medium	
Functionality is in use	In use	Status	Fixed
Associated Files	<i>WardenSwap1_5_L2.sol</i> <i>interface/IWardenCosmicBrainForL2.sol</i> <i>interface/IWardenCosmoCore0_8.sol</i> <i>interface/IWardenPostTrade.sol</i> <i>libraries/IWETH.sol</i> <i>libraries/IWardenTradingRoute0_8.sol</i> <i>libraries/WardenCosmoCore.sol</i> <i>libraries/WardenDataDeserialize.sol</i> <i>library/arbitrum/IArbAddressTable.sol</i> <i>library/byte/BytesLib.sol</i> <i>tools/WardenDataSerialize.sol</i>		
Locations	<i>WardenSwap1_5_L2.sol</i> L: 2 <i>IWardenCosmicBrainForL2.sol</i> L: 2 <i>IWardenCosmoCore0_8.sol</i> L: 3 <i>IWardenPostTrade.sol</i> L: 2 <i>IWETH.sol</i> L: 3 <i>IWardenTradingRoute0_8.sol</i> L: 3 <i>WardenCosmoCore.sol</i> L: 3 <i>WardenDataDeserialize.sol</i> L: 10 <i>IArbAddressTable.sol</i> L: 2 <i>BytesLib.sol</i> L: 5 <i>WardenDataSerialize.sol</i> L: 10		

Detailed Issue

The WardenSwap smart contracts should be deployed with the compiler version used in the development and testing process.

The compiler version that is not strictly locked via the *pragma* statement may make the contracts incompatible against unforeseen circumstances.

An example of the Solidity code that is not locked to a specific version (e.g., using `>=` or `^` directive) is shown below.

WardenCosmoCore.sol

```
1 // SPDX-License-Identifier: MIT
2
3 pragma solidity ^0.8.0;
4
5 import
6   "https://github.com/OpenZeppelin/openzeppelin-contracts/blob/v4.2.0/contracts/ac
7   cess/Ownable.sol";
8 import "../interface/IWardenCosmoCore0_8.sol";
9
10 contract WardenCosmoCore is Ownable, IWardenCosmoCore {
```

Listing 9.1 An example of the Solidity code that is not locked to a specific version

Recommendations

We recommend locking the *pragma* version like the example code snippet below.

```
pragma solidity 0.8.8;
// or
pragma solidity =0.8.8;
contract SemVerFloatingPragmaFixed {
```

Reference: <https://swcregistry.io/docs/SWC-103>

Reassessment

The developer fixed this issue by locking the *pragma* version to the latest patch version, v0.8.8.

No. 10	Transparency Improvement For The <code>collectRemainingToken</code> Function		
Risk	Informational	Likelihood	Low
		Impact	Low
Functionality is in use	In use	Status	Fixed
Associated Files	<code>WardenSwap1_5_L2.sol</code>		
Locations	<code>collectRemainingToken(IERC20, uint256)</code> L: 561 - 569		

Detailed Issue

The `collectRemainingToken` function lets the platform developer collect the leftover ERC20 tokens from the WardenSwap1_5_Aegis contract. This function is helpful in case a user mistakenly transfers ERC20 tokens to the contract.

However, the function does not implement an event emission after the token collecting, affecting transparency and traceability. The `collectRemainingToken` function is shown below.

WardenSwap1_5_L2.sol

```

561   function collectRemainingToken(
562     IERC20 _token,
563     uint256 _amount
564   )
565     external
566     onlyOwner
567   {
568     _token.safeTransfer(msg.sender, _amount);
569   }

```

Listing 10.1 The `collectRemainingToken` function

Recommendations

We recommend emitting the event `CollectedRemainingToken` on the `collectRemainingToken` function to improve transparency and traceability. See the improved function below.

WardenSwap1_5_L2.sol

```

561 function collectRemainingToken(
562     IERC20 _token,
563     uint256 _amount
564 )
565     external
566     onlyOwner
567 {
568     _token.safeTransfer(msg.sender, _amount);
569     emit CollectedRemainingToken(address(_token), _amount, msg.sender);
570 }
```

Listing 10.2 The improved `collectRemainingToken` function

Reassessment

The developer emitted the `CollectedRemainingToken` event as per our recommendation.

WardenSwap1_5_L2.sol

```

571 function collectRemainingToken(
572     IERC20 _token,
573     uint256 _amount
574 )
575     external
576     onlyOwner
577 {
578     _token.safeTransfer(msg.sender, _amount);
579     emit CollectedRemainingToken(address(_token), _amount);
580 }
```

Listing 10.3 The fixed `collectRemainingToken` function

No. 11	Transparency Improvement For The <code>collectRemainingEther</code> Function		
Risk	Informational	Likelihood	Low
		Impact	Low
Functionality is in use	In use	Status	Fixed
Associated Files	<code>WardenSwap1_5_L2.sol</code>		
Locations	<code>collectRemainingEther(uint256)</code> L: 572 - 580		

Detailed Issue

The `collectRemainingEther` function lets the platform developer collect the leftover Ether (native ETH) from the WardenSwap1_5_Aegis contract. This function is helpful in case a user mistakenly transfers Ethers to the contract.

However, the function does not implement an event emission after the coin collecting, affecting transparency and traceability. The `collectRemainingEther` function is shown below.

WardenSwap1_5_L2.sol

```

572 function collectRemainingEther(
573     uint256 _amount
574 )
575     external
576     onlyOwner
577 {
578     (bool success, ) = msg.sender.call{value: _amount}("");
      // Send back ether to
      sender
579     require(success, "WardenSwap: Transfer ether back to caller failed.");
580 }
```

Listing 11.1 The `collectRemainingEther` function

Recommendations

We recommend emitting the event `CollectedRemainingEther` on the `collectRemainingEther` function to improve transparency and traceability. See the improved function below.

WardenSwap1_5_L2.sol

```

572 function collectRemainingEther(
573     uint256 _amount
574 )
575     external
576     onlyOwner
577 {
578     (bool success, ) = msg.sender.call{value: _amount}(""); // Send back ether to
579     require(success, "WardenSwap: Transfer ether back to caller failed.");
580     emit CollectedRemainingEther(_amount, msg.sender);
581 }
```

Listing 11.2 The improved `collectRemainingEther` function

Reassessment

The developer emitted the `CollectedRemainingEther` event as per our recommendation.

WardenSwap1_5_L2.sol

```

583 function collectRemainingEther(
584     uint256 _amount
585 )
586     external
587     onlyOwner
588 {
589     (bool success, ) = msg.sender.call{value: _amount}(""); // Send back ether to
590     receiver
591     require(success, "WardenSwap: Transfer ether back to receiver failed.");
592     emit CollectedRemainingEther(_amount);
593 }
```

Listing 11.3 The fixed `collectRemainingEther` function

No. 12	Gas Optimization and Readability Improvement On The _split2 Function		
Risk	Informational	Likelihood	Low
Functionality is in use	In use	Impact	Low
Associated Files	<i>WardenSwap1_5_L2.sol</i>		
Locations	<i>_split2(uint256[], uint256[], IERC20, uint256, IERC20, address)</i> <i>L: 381, 383, 387, and 396</i>		

Detailed Issue

We found that the source code of the `_split2` function can be improved to optimize gas usage and enhance code readability. The associated line numbers that can be improved include 381, 383, 387, and 396. The following shows the `_split2` function.

WardenSwap1_5_L2.sol

```

366 function _split2(
367     uint256[] memory _learnedIds,
368     uint256[] memory _volumns,
369     IERC20 _src,
370     uint256 _totalSrcAmount,
371     IERC20 _dest,
372     address _fromAddress
373 )
374     private
375     returns (
376         uint256 _destAmount
377     )
378 {
379     // Trade with routes
380     uint256 amountRemain = _totalSrcAmount;
381     for (uint i = 0; i < _learnedIds.length; i++) {
382         uint256 amountForThisRound;
383         if (i == _learnedIds.length - 1) {
384             amountForThisRound = amountRemain;
385         } else {
386             amountForThisRound = _totalSrcAmount * _volumns[i] / 100;
387             amountRemain = amountRemain - amountForThisRound;
388         }
389         bytes32 learnedHash = cosmicBrain.learnedHashes(_learnedIds[i]);
390         (
391

```

```

392         uint256[] memory subRoutes,
393         IERC20[] memory correspondentTokens
394     ) = cosmicBrain.fetchRoutesAndTokens(learnedHash);
395
396     _destAmount = _destAmount +
397         _tradeStrategies(
398             _src,
399             amountForThisRound,
400             _dest,
401             subRoutes,
402             correspondentTokens,
403             _fromAddress
404         )
405     ;
406 }
407 }
```

Listing 12.1 The `_split2` function that can be improved

Recommendations

We recommend changing the associated source code to optimize gas usage and enhance code readability as follows.

WardenSwap1_5_L2.sol

```

366 function _split2(
367     uint256[] memory _learnedIds,
368     uint256[] memory _volumns,
369     IERC20 _src,
370     uint256 _totalSrcAmount,
371     IERC20 _dest,
372     address _fromAddress
373 )
374 private
375 returns (
376     uint256 _destAmount
377 )
378 {
379 // Trade with routes
380 uint256 amountRemain = _totalSrcAmount;
381 uint256 learnedIdsLength = _learnedIds.length;
382 for (uint i = 0; i < learnedIdsLength; i++) {
383     uint256 amountForThisRound;
384     if (i == learnedIdsLength - 1) {
385         amountForThisRound = amountRemain;
386     } else {
387         amountForThisRound = _totalSrcAmount * _volumns[i] / 100;
388         amountRemain -= amountForThisRound;
```

```

389         }
390
391         bytes32 learnedHash = cosmicBrain.learnedHashes(_learnedIds[i]);
392         (
393             uint256[] memory subRoutes,
394             IERC20[] memory correspondentTokens
395         ) = cosmicBrain.fetchRoutesAndTokens(learnedHash);
396
397         _destAmount += _tradeStrategies(
398             _src,
399             amountForThisRound,
400             _dest,
401             subRoutes,
402             correspondentTokens,
403             _fromAddress
404         )
405     ;
406 }
407 }
```

Listing 12.2 The optimized `_split2` function

Reassessment

The developer updated the associated function according to our recommendation. The developer also renamed the function from `_split2` to `_loopSplit` to describe its functionality better.

WardenSwap1_5_L2.sol

```

375 function _loopSplit(
376     uint256[] memory _learnedIds,
377     uint256[] memory _volumes,
378     IERC20 _src,
379     uint256 _totalSrcAmount,
380     IERC20 _dest,
381     address _fromAddress
382 )
383     private
384     returns (
385         uint256 _destAmount
386     )
387 {
388     // Trade with routes
389     uint256 amountRemain = _totalSrcAmount;
390     uint256 learnedIdsLength = _learnedIds.length;
391     for (uint i = 0; i < learnedIdsLength; i++) {
392         uint256 amountForThisRound;
393         if (i == learnedIdsLength - 1) {
394             amountForThisRound = amountRemain;
```

```
395     } else {
396         amountForThisRound = _totalSrcAmount * _volumes[i] / 100;
397         amountRemain -= amountForThisRound;
398     }
399
400     bytes32 learnedHash = cosmicBrain.learnedHashes(_learnedIds[i]);
401     (
402         uint256[] memory subRoutes,
403         IERC20[] memory correspondentTokens
404     ) = cosmicBrain.fetchRoutesAndTokens(learnedHash);
405
406     _destAmount +=
407         _tradeStrategies(
408             _src,
409             amountForThisRound,
410             _dest,
411             subRoutes,
412             correspondentTokens,
413             _fromAddress
414         )
415     ;
416 }
417 }
```

Listing 12.3 The fixed *_LoopSplit* function

No. 13	Inconsistent Comments/Error Messages With The Code		
Risk	Informational	Likelihood	Low
		Impact	Low
Functionality is in use	In use	Status	Fixed
Associated Files	<i>WardenSwap1_5_L2.sol</i> <i>libraries/WardenCosmoCore.sol</i>		
Locations	<i>WardenSwap1_5_L2.sol</i> L: 266, 267, 268, 510, 511, 512, 554, 555, 578, 579, and 625 <i>WardenCosmoCore.sol</i> L: 25, 64, and 80		

Detailed Issue

We found comments and error messages inconsistent with the source code, leading to misunderstandings among users.

The associated comments and error messages are in the following line numbers in *WardenSwap1_5_L2.sol*: 266, 267, 268, 510, 511, 512, 554, 555, 578, 579, and 625, and in the following line numbers in *WardenCosmoCore.sol*: 25, 64, and 80. The following shows an example of an inconsistent comment.

WardenSwap1_5_L2.sol	
617	function _collectFee(618 IERC20 _token, 619 uint256 _fee, 620 address _feeWallet 621) 622 private 623 { 624 if (ETHER_ERC20 == _token) { 625 (bool success,) = payable(_feeWallet).call{value: _fee}(""); // Send back ether to sender 626 require(success, "Transfer fee of ether failed."); 627 } else { 628 _token.safeTransfer(_feeWallet, _fee); 629 } 630 emit CollectFee(_token, _feeWallet, _fee); 631 }

Listing 13.1 An example of an inconsistent comment

Recommendations

We recommend changing the associated comments and error messages to reflect how the source code is doing.

Reassessment

The developer changed all associated comments and error messages to describe the source code better.

WardenSwap1_5_L2.sol

```
631 function _collectFee(
632     IERC20 _token,
633     uint256 _fee,
634     address _feeWallet
635 )
636     private
637 {
638     if (ETHER_ERC20 == _token) {
639         (bool success, ) = payable(_feeWallet).call{value: _fee}(""); // Send
ether to fee collector
640         require(success, "Transfer fee of ether failed.");
641     } else {
642         _token.safeTransfer(_feeWallet, _fee); // Send token to fee collector
643     }
644     emit CollectFee(_token, _feeWallet, _fee);
645 }
```

Listing 13.2 An example of updated comments

No. 14	Recommended Explicit Trading Route Validation Checks		
Risk	Informational	Likelihood	Low
		Impact	Low
Functionality is in use	In use	Status	Acknowledged
Associated Files	<i>libraries/WardenCosmoCore.sol</i>		
Locations	<i>WardenCosmoCore.sol</i> L: 12, 17, 56, 73, 89, 104, and 121		

Detailed Issue

The implementation of the *WardenCosmoCore* contract relies on the implicit compiler-generated bound-checks of the *_tradingRoutes* array to ensure that the routing index is within the array range $[0, _tradingRoutes.Length - 1]$.

The associated checks include the following line numbers 12, 17, 56, 73, 89, 104, and 121. The code snippet below is an example of the implicit bound check.

WardenCosmoCore.sol

```

48 function updateTradingRoute(
49     uint256 _index,
50     string calldata _name,
51     IWardenTradingRoute _route
52 )
53     external
54     onlyOwner
55 {
56     _tradingRoutes[_index].name = _name;
57     _tradingRoutes[_index].route = _route;
58     emit UpdatedTradingRoute(msg.sender, _name, _route, _index);
59 }
```

Listing 14.1 The *updateTradingRoute* function that uses the implicit bound check

The explicit sanity checks may be required to enable the contract to handle a revert transaction with a proper error message for a better debugging solution.

Recommendations

We recommend implementing a `validateTradingRoute` modifier and attaching the modifier to the associated functions. Consider the following example code snippet.

WardenCosmoCore.sol

```

48 modifier validateTradingRoute(uint256 _index) {
49     require (_index < _tradingRoutes.length, "Trading route index out of bounds")
50     ;
51 }
52
53 function updateTradingRoute(
54     uint256 _index,
55     string calldata _name,
56     IWardenTradingRoute _route
57 )
58 external
59 onlyOwner
60 validateTradingRoute(_index)
61 {
62     _tradingRoutes[_index].name = _name;
63     _tradingRoutes[_index].route = _route;
64     emit UpdatedTradingRoute(msg.sender, _name, _route, _index);
65 }
```

Listing 14.2 The improved `updateTradingRoute` function that uses the explicit sanity check

With the explicit sanity checks, the contract can handle a revert transaction with a proper error message, improving a transaction debugging solution.

Reassessment

The developer acknowledged this issue but decided to remain the original code to preserve the minimal gas use.

No. 15	Unchecked Call Return Value		
Risk	Informational	Likelihood	Low
		Impact	Low
Functionality is in use	In use	Status	Acknowledged
Associated Files	<i>WardenSwap1_5_L2.sol</i>		
Locations	<i>_tradeStrategiesWithSafeGuard(address,uint256,address,uint256,uint256[],address[],address,uint256) L:276</i>		

Detailed Issue

The *_tradeStrategiesWithSafeGuard* function does not check the return value when performing an external call which may lead to unexpected behaviors of the application logic.

The external functions will return the data and result. The result indicates whether the call fails or succeeds which is represented by the following boolean value:

- 0x0 -> false -> fails
- 0x1 -> true -> succeeds

If the return value is not checked, the remaining code would be continuously executed even if the external call is accidentally or deliberately failed, this may lead to unexpected behaviors of the subsequent logic.

On the *IWardenCosmicBrainForL2* interface, the *trainTradingPair* function returns the boolean value, *_isAlreadyLearned*.

IWardenCosmicBrainForL2.sol

```

14 function trainTradingPair(
15     IERC20      _src,
16     IERC20      _dest,
17     uint256     _srcAmount,
18     uint256     _destAmount,
19     uint256     _learnedId
20 )
21     external
22     returns (bool _isAlreadyLearned);

```

Listing 15.1 The return value of the *trainTradingPair* function

The `trainTradingPair` function is called by the `_tradeStrategiesWithSafeGuard` function but the return value is not checked.

WardenSwap1_5_L2.sol

```

196  function _tradeStrategiesWithSafeGuard(
197      IERC20      _src,
198      uint256     _srcAmount,
199      IERC20      _dest,
200      uint256     _minDestAmount,
201      uint256[]   memory _subRoutes,
202      IERC20[]    memory _correspondentTokens,
203      address     _receiver,
204      uint256     _learnedId
205  )
206  ... (SNIP) ...
207  cosmicBrain.trainTradingPair(
208      _src,
209      _dest,
210      _srcAmount,
211      _destAmount,
212      learnedId
213  );
214  ... (SNIP) ...

```

Listing 15.2 The `trainTradingPair` function is called, but the return value is not checked

Recommendations

The return value of the external call should be checked and handled. The function needs to decide and clarify the expected value returned by the callee. The unexpected return value should be handled depending on the application logic.

Reassessment

The developer acknowledged this issue but decided to remain the original code.

No. 16	Gas Optimization On Redundant Code		
Risk	Informational	Likelihood	Low
		Impact	Low
Functionality is in use	In use	Status	Acknowledged
Associated Files	<i>libraries/WardenDataDeserialize.sol</i>		
Locations	<code>decodeSubRoutesAndCorrespondentTokens(bytes,uint256) L:278-279</code> <code>lookupSrcDestReceiverAddresses(bytes,uint256) L:439</code> <code>_decodeSrcMinAmountsLearnedId(bytes,uint256,bool) L:186</code> <code>decodeLearnedIdsAndVolumns(bytes,uint256) L:329</code> <code>lookupSrcDestReceiverAddresses(bytes,uint256) L:439</code>		

Detailed Issue

The excessive code might consume more gas. The examples of redundant behaviours are as follows:

- The value is recomputed even if it is previously computed.
- The comparison of booleans.
- The unreachable code.

In line 275, 6 bits of the *instructions* variable are removed by right shifting. Therefore, the 6 most significant bits after bit shifting will only be 0. Therefore, the AND (&) instruction is unnecessary to zero out the unwanted bits.

To illustrate, suppose the 8 bits of the *instructions* variable is 0xFF. When the code in line 275 is executed, the *instructions* will be 0000 0011 which is equal to 0x03. In line 277, the function tries to zero out the 6 most significant bits to obtain only 2 least significant bits and assign it to the variable *tokenInstruction*. However, the 6 most significant bits are already zeroed since the right shifting. Therefore, zeroing out the unwanted bits by 0x03 is unnecessary.

In addition, in line 278, the *instructions* variable is shifted to the right to remove the 2 least significant bits from the *instructions* itself. But, the *instructions* variable is not used anymore after this operation. The code in line 278, therefore, is unnecessary.

WardenDataDeserialize.sol

```

234   function decodeSubRoutesAndCorrespondentTokens(
235     bytes memory _data,
236     uint256 _cursor
237   ) public
238   view
239   returns (
240     uint256[] memory _subRoutes, // 16-bit, 65,536 possible
241     IERC20[] memory _correspondentTokens,
242     uint256 _newCursor
243   )
244 {
245   ...(SNIP)...
271   uint8 instructions = _data.toUint8(_cursor);
272   _cursor += 1;
273
274   uint256 routeLength = instructions & 0x3F;
275   instructions = instructions >> 6;
276
277   uint8 tokenInstruction = instructions & 0x03;
278   instructions = instructions >> 2;
246   ...(SNIP)...

```

Listing 16.1 An example code being redundant when decompressing the variable *instructions*

Recommendations

Remove the redundant code for saving gas.

In the example case, consider removing AND (&) operation from the last instruction extraction (line no. 277) since the prior right shift (line no. 275) already removes unwanted bits. The code could be simplified to

uint8 tokenInstruction = instructions;

and remove the unnecessary right shift operation in line 278.

Reassessment

The developer acknowledged this issue but decided to remain the original code.

No. 17	Duplicate Function Implementation		
Risk	Informational	Likelihood	Low
		Impact	Low
Functionality is in use	In use	Status	Fixed
Associated Files	<i>tools/WardenDataSerialize.sol</i>		
Locations	<i>toBytes32(bytes, uint256) L: 26 - 35</i>		

Detailed Issue

The implementation of the *toBytes32* function (line no's. 26 - 35) is duplicated with the function in the imported *BytesLib* library. The following shows the duplicated function.

WardenDataSerialize.sol

```

26  function toBytes32(bytes memory _bytes, uint256 _start) internal pure returns
27    (bytes32) {
28      require(_bytes.length >= _start + 32, "toBytes32_outOfBounds");
29      bytes32 tempBytes32;
30
31      assembly {
32        tempBytes32 := mload(add(add(_bytes, 0x20), _start))
33      }
34
35      return tempBytes32;
}
```

Listing 17.1 The duplicated *toBytes32* function

The *toBytes32* function is used in the *tradeWithLearnedSerialize* function (line no. 84) to convert the *tradeWithLearned* data in *bytes* to *bytes32*, as shown below.

WardenDataSerialize.sol

```

49  function tradeWithLearnedSerialize(
50    address _src,
51    uint256 _srcAmount,
52    address _dest,
53    uint256 _minDestAmount,
54    uint256 _learnedId
55  )
56    external
```

```

57   view
58   returns(
59     bytes32 _compressedData
60   )
61 {
62   require(_srcAmount <= type(uint96).max,
63 "WardenDataSerialize:tradeWithLearnedSerialize _srcAmount is too large, uint96
64 support only.");
65   require(_minDestAmount <= type(uint96).max,
66 "WardenDataSerialize:tradeWithLearnedSerialize _minDestAmount is too large,
67 uint96 support only.");
68   require(_learnedId <= type(uint16).max,
69 "WardenDataSerialize:tradeWithLearnedSerialize _learnedId is too large, uint16
70 support only.");
71
72   // tokenLookup
73   uint256 srcIndex = addressTable.lookup(_src);
74   uint256 destIndex = addressTable.lookup(_dest);
75
76   require(srcIndex <= type(uint24).max,
77 "WardenDataSerialize:tradeWithLearnedSerialize srcIndex is too large, uint24
78 support only.");
79   require(destIndex <= type(uint24).max,
80 "WardenDataSerialize:tradeWithLearnedSerialize destIndex is too large, uint24
81 support only.");
82
83   bytes memory _bytes = abi.encodePacked(
84     uint24(srcIndex),
85     uint24(destIndex),
86     uint96(_srcAmount),
87     uint96(_minDestAmount),
88     uint16(_learnedId)
89   );
90
91   require(_bytes.length == 32, "WardenDataSerialize:toBytes32 length is not
92 32");
93
94   return toBytes32(_bytes, 0);
95 }
```

Listing 17.2 The *tradeWithLearnedSerialize* function

Recommendations

The mentioned `toBytes32` function can be removed, and we can use the function in the imported `BytesLib` library instead, as shown below.

WardenDataSerialize.sol

```

49  function tradeWithLearnedSerialize(
50      address _src,
51      uint256 _srcAmount,
52      address _dest,
53      uint256 _minDestAmount,
54      uint256 _learnedId
55  )
56      external
57      view
58      returns(
59          bytes32 _compressedData
60      )
61  {
62      require(_srcAmount <= type(uint96).max,
63          "WardenDataSerialize:tradeWithLearnedSerialize _srcAmount is too large, uint96
64          support only.");
65      require(_minDestAmount <= type(uint96).max,
66          "WardenDataSerialize:tradeWithLearnedSerialize _minDestAmount is too large,
67          uint96 support only.");
68      require(_learnedId <= type(uint16).max,
69          "WardenDataSerialize:tradeWithLearnedSerialize _learnedId is too large, uint16
70          support only.");
71
72      // tokenLookup
73      uint256 srcIndex = addressTable.lookup(_src);
74      uint256 destIndex = addressTable.lookup(_dest);
75
76      require(srcIndex <= type(uint24).max,
77          "WardenDataSerialize:tradeWithLearnedSerialize srcIndex is too large, uint24
78          support only.");
79      require(destIndex <= type(uint24).max,
80          "WardenDataSerialize:tradeWithLearnedSerialize destIndex is too large, uint24
81          support only.");
82
83      bytes memory _bytes = abi.encodePacked(
84          uint24(srcIndex),
85          uint24(destIndex),
86          uint96(_srcAmount),
87          uint96(_minDestAmount),
88          uint16(_learnedId)
89      );
90
91      require(_bytes.length == 32, "WardenDataSerialize:toBytes32 length is not
92          32");

```

```
32");
82
83     return _bytes.toBytes32(0);
84 }
```

Listing 17.3 The improved `tradeWithLearnedSerialize` function

Using the standard `BytesLib` library function will benefit an aspect of code maintenance and bug fixes.

Reassessment

The developer updated the associated source code as per our recommendation.

No. 18	Generic Typographic Error		
Risk	Informational	Likelihood	Low
Functionality is in use	In use	Impact	Low
Associated Files	<i>WardenSwap1_5_L2.sol</i>		
Locations	For example: <code>_split2(uint256[],uint256[],address,uint256,address,address) L:368</code> <code>_splitTradesWithSafeGuard(uint256[],uint256[],address,uint256,address) L:411</code>		

Detailed Issue

Some variables and comments contain typos which may lead to the name confusion, or slightly increase the time when debugging or maintaining the source code.

For example, the `_voLumns` or `_voLumn` is misspelled in several locations.

WardenSwap1_5_L2.sol	
409	<code>function _splitTradesWithSafeGuard(</code>
410	<code> uint256[] memory _learnedIds,</code>
411	<code> uint256[] memory _volumns,</code>
412	<code> IERC20 _src,</code>
413	<code> uint256 _totalSrcAmount,</code>
414	<code> IERC20 _dest</code>
415	<code>)</code>
416	<code> private</code>
417	<code> returns(uint256 _destAmount)</code>
418	<code>{</code>
419	<code>... (SNIP) ...</code>
420	<code> _destAmount = _split2(</code>
421	<code> _learnedIds,</code>
422	<code> _volumns,</code>
423	<code> adjustedSrc,</code>
424	<code> _totalSrcAmount,</code>
425	<code> adjustedDest,</code>
426	<code> fromAddress</code>
427	<code>);</code>

Listing 18.1 An example variable that is misspelled

Recommendations

Review the variables and comments and revise the incorrect or typographical words. In the example case, consider renaming the variable from “`_voLumns`” to “`_volumes`” instead.

Reassessment

The misspelled variables were renamed to “volume” or “volumes”.

WardenSwap1_5_L2.sol

```
419 function _splitTradesWithSafeGuard(
420     uint256[] memory _learnedIds,
421     uint256[] memory _volumes,
422     IERC20 _src,
423     uint256 _totalSrcAmount,
424     IERC20 _dest
425 )
426     private
427     returns(uint256 _destAmount)
428 {
... (SNIP)...
449     _destAmount = _loopSplit(
450         _learnedIds,
451         _volumes,
452         adjustedSrc,
453         _totalSrcAmount,
454         adjustedDest,
455         fromAddress
456 );
```

Listing 18.2 An example variable that was renamed

No. 19	Misleading Function Name		
Risk	Informational	Likelihood	Low
Functionality is in use	In use	Impact	Low
Associated Files	<i>WardenSwap1_5_L2.sol</i>		
Locations	<i>_split2(uint256[], uint256[], IERC20, uint256, IERC20, address) L: 366 - 407</i>		

Detailed Issue

The `_split2` function splits trading into multiple trading routes according to the length of the `_LearnedIds` variable (line no. 381). The function actually supports multiple trading routes, which can be more than two routes. At this point, it comes to our attention that the function name, `_split2`, is misleading. The misleading function name may hinder the source code maintenance process as well as the understanding of the source code.

WardenSwap1_5_L2.sol

```

366 function _split2(
367     uint256[] memory _learnedIds,
368     uint256[] memory _volumns,
369     IERC20 _src,
370     uint256 _totalSrcAmount,
371     IERC20 _dest,
372     address _fromAddress
373 )
374     private
375     returns (
376         uint256 _destAmount
377     )
378 {
379     // Trade with routes
380     uint256 amountRemain = _totalSrcAmount;
381     for (uint i = 0; i < _learnedIds.length; i++) {
382         uint256 amountForThisRound;
383         if (i == _learnedIds.length - 1) {
384             amountForThisRound = amountRemain;
385         } else {
386             amountForThisRound = _totalSrcAmount * _volumns[i] / 100;
387             amountRemain = amountRemain - amountForThisRound;
388         }
389         bytes32 learnedHash = cosmicBrain.learnedHashes(_learnedIds[i]);

```

```

391      (
392          uint256[] memory subRoutes,
393          IERC20[] memory correspondentTokens
394      ) = cosmicBrain.fetchRoutesAndTokens(learnedHash);
395
396      _destAmount = _destAmount +
397          _tradeStrategies(
398              _src,
399              amountForThisRound,
400              _dest,
401              subRoutes,
402              correspondentTokens,
403              _fromAddress
404          )
405      ;
406  }
407 }
```

Listing 19.1 The *_split2* function

Recommendations

We recommend renaming the *_split2* function to reflect its functionality to improve the source code maintenance process as well as the understanding of the source code.

Reassessment

The *_split2* function was renamed to *_LoopSplit* to describe its functionality better.

WardenSwap1_5_L2.sol

```

375  function _loopSplit(
376      uint256[] memory _learnedIds,
377      uint256[] memory _volumes,
378      IERC20 _src,
379      uint256 _totalSrcAmount,
380      IERC20 _dest,
381      address _fromAddress
382  )
383  private
384  returns (
385      uint256 _destAmount
386  )
387 {
```

... (SNIP) ...

Listing 19.2 The renamed function, *_LoopSplit*

Appendix

About Us

Founded in 2020, Valix Consulting is a blockchain and smart contract security firm offering a wide range of cybersecurity consulting services such as blockchain and smart contract security consulting, smart contract security review, and smart contract security audit.

Our team members are passionate cybersecurity professionals and researchers in areas of private and public blockchain technology, smart contract, and decentralized application (DApp).

We provide a service for assessing and certifying the security of smart contracts. Our service also includes recommendations on smart contracts' security and gas optimization to bring the most benefit to users and platform creators.

Contact Information



info@valix.io



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References

Title	Link
OWASP Risk Rating Methodology	https://owasp.org/www-community/OWASP_Risk_Rating_Methodology
Smart Contract Weakness Classification and Test Cases	https://swcregistry.io/



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