Auditor Labs

Zeitls

Protocol

SMART CONTRACT AUDIT

31.01.2023

Made by Auditor Labs

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1. Disclaimer

The audit makes no statements or warrantees about utility of the code, safety of the code, suitability of the business model, investment advice, endorsement of the platform or its products, regulatory regime for the business model, or any other statements about fitness of the contracts to purpose, or their bug free status. The audit documentation is for discussion purposes only.

The information presented in this report is confidential and privileged. If you are reading this report, you agree to keep it confidential, not to copy, disclose or disseminate without the agreement of Zeitls AG. If you are not the intended receptor of this document, remember that any disclosure, copying or dissemination of it is forbidden.

Major Versions / Date	Description
0.1 (16.12.2022)	Layout
0.4 (19.12.2022)	Automated Security Testing Manual Security Testing
0.5 (20.12.2022)	Verify Claims and Test Deployment
0.6 (21.12.2022)	Testing SWC Checks
0.9 (22.12.2022)	Summary and Recommendation
1.0 (22.12.2022)	Final document
1.1 (02.01.2023)	Re-check commit 911026a171f9f80a97a773d4ce095b514f0f36bc
1.2 (31.01.2023)	Added deployed contracts

2. About the Project and Company

Company address:
Zeitls AG
Hungerstrasse 52
8832 Wilen b. Wollerau
Switzerland

Website: https://zeitls.ch

Twitter: https://twitter.com/ZeitlsAG

Facebook: https://www.facebook.com/Zeitls-115685684451739

Instagram: https://www.instagram.com/zeitlsag

LinkedIn: https://www.linkedin.com/company/zeitls

Medium: https://zeitls.medium.com

Discord: https://discord.gg/NUVGzpFnhk

2.1 Project Overview

In the age of digitalization and rapid technological development, Zeitls recognized the importance of preserving historically important pieces of art for years to come by transferring them into the digital world. More practically, converting rare and historically valuable pieces of art into interactive, non-degradable crypto assets that can be owned or traded by claiming their non-physical rights. Zeitls aim to preserve historical pieces in their digital form for all eternity, while accumulating funding and liquidity for their preservation in the real world.

Zeitls are striving to provide museums and art collectors with the means to keep their collections pristine, or even expand their collection. For that reason, Zeitls, are an agent that bridges not only museums and collectors, but also the real world with the digital one, and the past with the future. They believe art and history should be accessible to everyone, in a decentralized environment.

A marker of human achievement, a timeless testament to the power of imagination, and the expression of the highest order of skills. Zeitls, is giving everyone the possibility of owning unique historical objects as authentic digital collectibles, because they believe pieces of human history should be available to everyone.

3. Vulnerability & Risk Level

Risk represents the probability that a certain source-threat will exploit vulnerability, and the impact of that event on the organization or system. Risk Level is computed based on CVSS version 3.0.

Level	Value	Vulnerability	Risk (Required Action)
Critical	9 – 10	A vulnerability that can disrupt the contract functioning in a number of scenarios, or creates a risk that the contract may be broken.	Immediate action to reduce risk level.
High	7 – 8.9	A vulnerability that affects the desired outcome when using a contract, or provides the opportunity to use a contract in an unintended way.	Implementation of corrective actions as soon as possible.
Medium	4 – 6.9	A vulnerability that could affect the desired outcome of executing the contract in a specific scenario.	Implementation of corrective actions in a certain period.
Low	2 – 3.9	A vulnerability that does not have a significant impact on possible scenarios for the use of the contract and is probably subjective.	Implementation of certain corrective actions or accepting the risk.
Informational	0 – 1.9	A vulnerability that have informational character but is not effecting any of the code.	An observation that does not determine a level of risk

4. Auditing Strategy and Techniques Applied

Throughout the review process, care was taken to evaluate the repository for security-related issues, code quality, and adherence to specification and best practices. To do so, reviewed line-by-line by our team of expert pentesters and smart contract developers, documenting any issues as there were discovered.

4.1 Methodology

The auditing process follows a routine series of steps:

1. Code review that includes the following:
   i. Review of the specifications, sources, and instructions provided to Auditor Labs to make sure we understand the size, scope, and functionality of the smart contract.
   ii. Manual review of code, which is the process of reading source code line-by-line in an attempt to identify potential vulnerabilities.
   iii. Comparison to specification, which is the process of checking whether the code does what the specifications, sources, and instructions provided to Auditor Labs describe.
2. Testing and automated analysis that includes the following:
   i. Test coverage analysis, which is the process of determining whether the test cases are actually covering the code and how much code is exercised when we run those test cases.
   ii. Symbolic execution, which is analysing a program to determine what inputs causes each part of a program to execute.
3. Best practices review, which is a review of the smart contracts to improve efficiency, effectiveness, clarify, maintainability, security, and control based on the established industry and academic practices, recommendations, and research.
4. Specific, itemized, actionable recommendations to help you take steps to secure your smart contracts.

5. Metrics

The metrics section should give the reader an overview on the size, quality, flows and capabilities of the codebase, without the knowledge to understand the actual code.

5.1 Tested Contract Files

The following are the MD5 hashes of the reviewed files. A file with a different MD5 hash has been modified, intentionally or otherwise, after the security review. You are cautioned that a different MD5 hash could be (but is not necessarily) an indication of a changed condition or potential vulnerability that was not within the scope of the review

File	Fingerprint (MD5)
./contracts/opensea/IProxyRegistry.sol	b459aa8a1cafa4e2541bda8020081fbc
./contracts/weth/IWETH.sol	838a63817a55eeb814236b0051f6ff51
./contracts/IZtlDevilsTreasury.sol	d517ec06b1548d2fcd26e7fd120e83ef
./contracts/IZtlDevils.sol	ffa0fda278bcec83cef0908009f8b089
./contracts/ZtlDevilsWhitelist.sol	7c8d062be4940c279171b1e7bbb44246
./contracts/ZtlDevilsTreasury.sol	68b1f9a1a06cde9cd7bffe550fba22cd
./contracts/ZtlDevilsAuctionHouse.sol	b748ecac94e8857bc2098b3b377b8505
./contracts/ZtlDevils.sol	9a15a8c75ccd4dda5870c2708b2a18dc

Update 02.01.2023 (commit 911026a171f9f80a97a773d4ce095b514f0f36bc)

File	Fingerprint (MD5)
./contracts/opensea/IProxyRegistry.sol	4e24af9c60d832afe3bc7d23d141b79a
./contracts/weth/IWETH.sol	5d429d0157581c31de763a3cfbb15011
./contracts/IZtlDevilsTreasury.sol	e827d4480e483807e531c784fb7a15d9
./contracts/IZtlDevils.sol	d0dfe08233c06d9bec32fa13b031c55e
./contracts/ZtlDevilsWhitelist.sol	9e7bb73694fb9ea74ff508a08eb4ebf2
./contracts/ZtlDevilsTreasury.sol	e827d4480e483807e531c784fb7a15d9

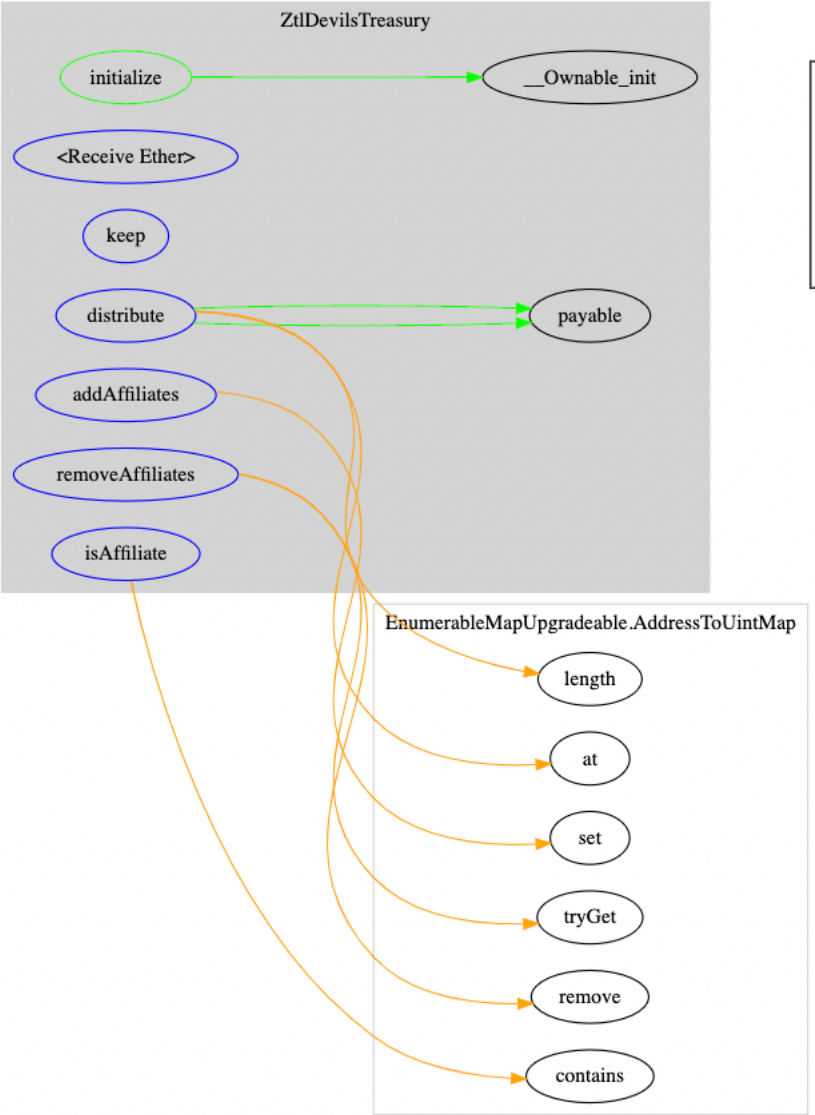
./contracts/ZtlDevilsAuctionHouse.sol	812d9ff423db6436190c711b142e42b1
./contracts/ZtlDevils.sol	73a7044f70e63e7eccfdbbe2f1fe2b2c

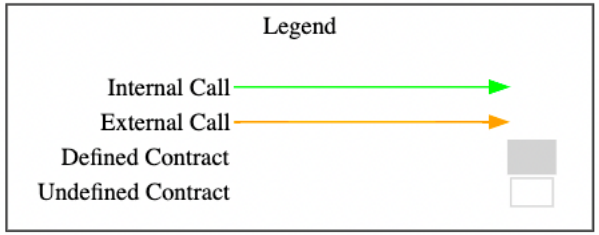
5.2 Used Code from other Frameworks/Smart Contracts (direct imports)

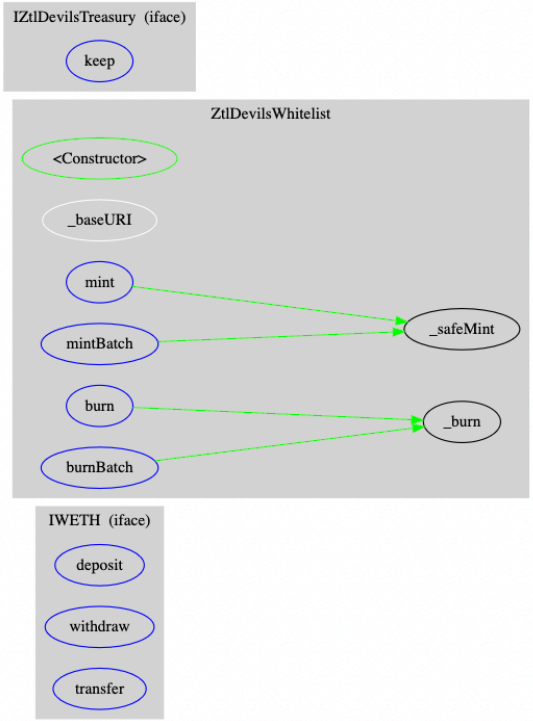
Dependency / Import Path	Source
@openzeppelin/contracts-upgradeable/access/OwnableUpgradeable.sol	https://github.com/OpenZeppelin/openzeppelin-contracts-upgradeable/tree/v4.7.3/contracts/access/OwnableUpgradeable.sol
@openzeppelin/contracts-upgradeable/security/PausableUpgradeable.sol	https://github.com/OpenZeppelin/openzeppelin-contracts-upgradeable/tree/v4.7.3/contracts/security/PausableUpgradeable.sol
@openzeppelin/contracts-upgradeable/security/ReentrancyGuardUpgradeable.sol	https://github.com/OpenZeppelin/openzeppelin-contracts-upgradeable/tree/v4.7.3/contracts/security/ReentrancyGuardUpgradeable.sol
@openzeppelin/contracts-upgradeable/utils/cryptography/ECDSAUpgradeable.sol	https://github.com/OpenZeppelin/openzeppelin-contracts-upgradeable/tree/v4.7.3/contracts/utils/cryptography/ECDSAUpgradeable.sol
@openzeppelin/contracts-upgradeable/utils/structs/EnumerableMapUpgradeable.sol	https://github.com/OpenZeppelin/openzeppelin-contracts-upgradeable/tree/v4.7.3/contracts/utils/structs/EnumerableMapUpgradeable.sol
@openzeppelin/contracts/access/Ownable.sol	https://github.com/OpenZeppelin/openzeppelin-contracts/tree/v4.7.3/contracts/access/Ownable.sol

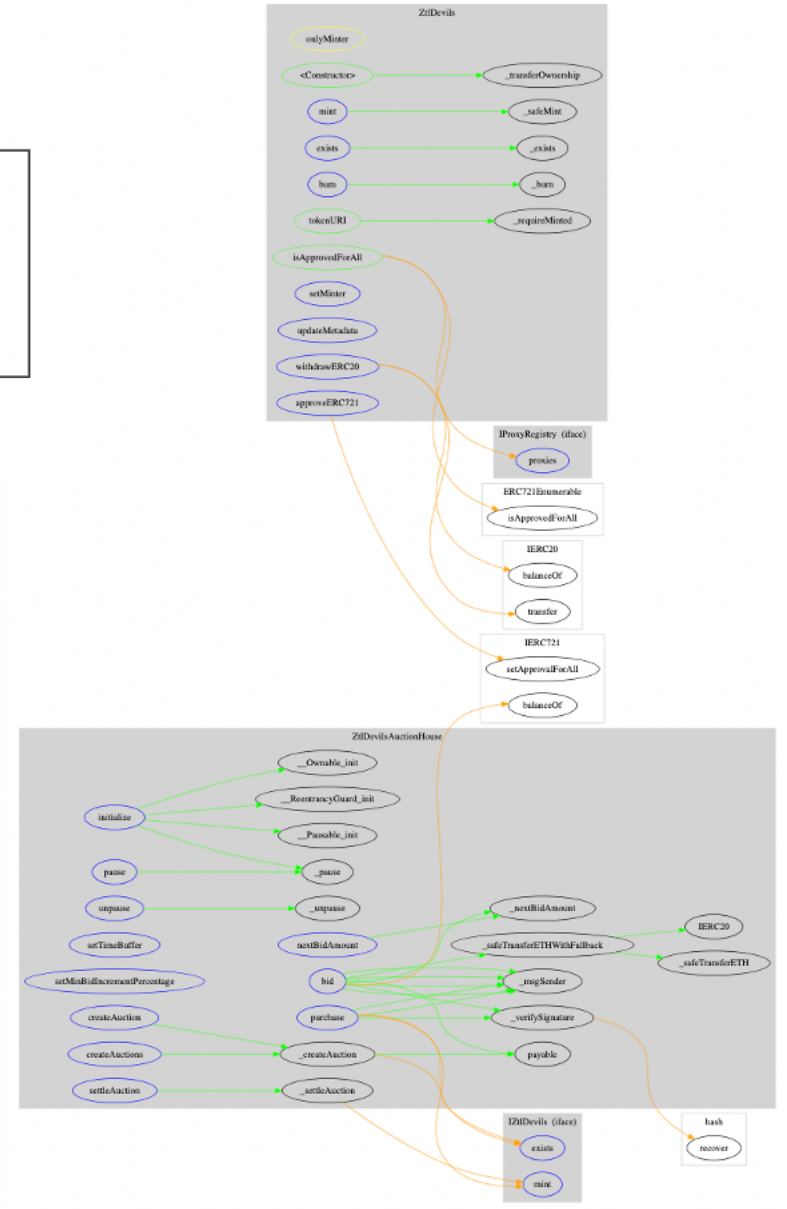
Dependency / Import Path	Source
@openzeppelin/contracts/token/ERC20/IERC20.sol	https://github.com/OpenZeppelin/openzeppelin-contracts/tree/v4.7.3/contracts/token/ERC20/IERC20.sol
@openzeppelin/contracts/token/ERC721/ERC721.sol	https://github.com/OpenZeppelin/openzeppelin-contracts/tree/v4.7.3/contracts/token/ERC721/ERC721.sol
@openzeppelin/contracts/token/ERC721/IERC721.sol	https://github.com/OpenZeppelin/openzeppelin-contracts/tree/v4.7.3/contracts/token/ERC721/IERC721.sol
@openzeppelin/contracts/token/ERC721/extensions/ERC721Enumerable.sol	https://github.com/OpenZeppelin/openzeppelin-contracts/tree/v4.7.3/contracts/token/ERC721/extensions/ERC721Enumerable.sol

5.3 CallGraph

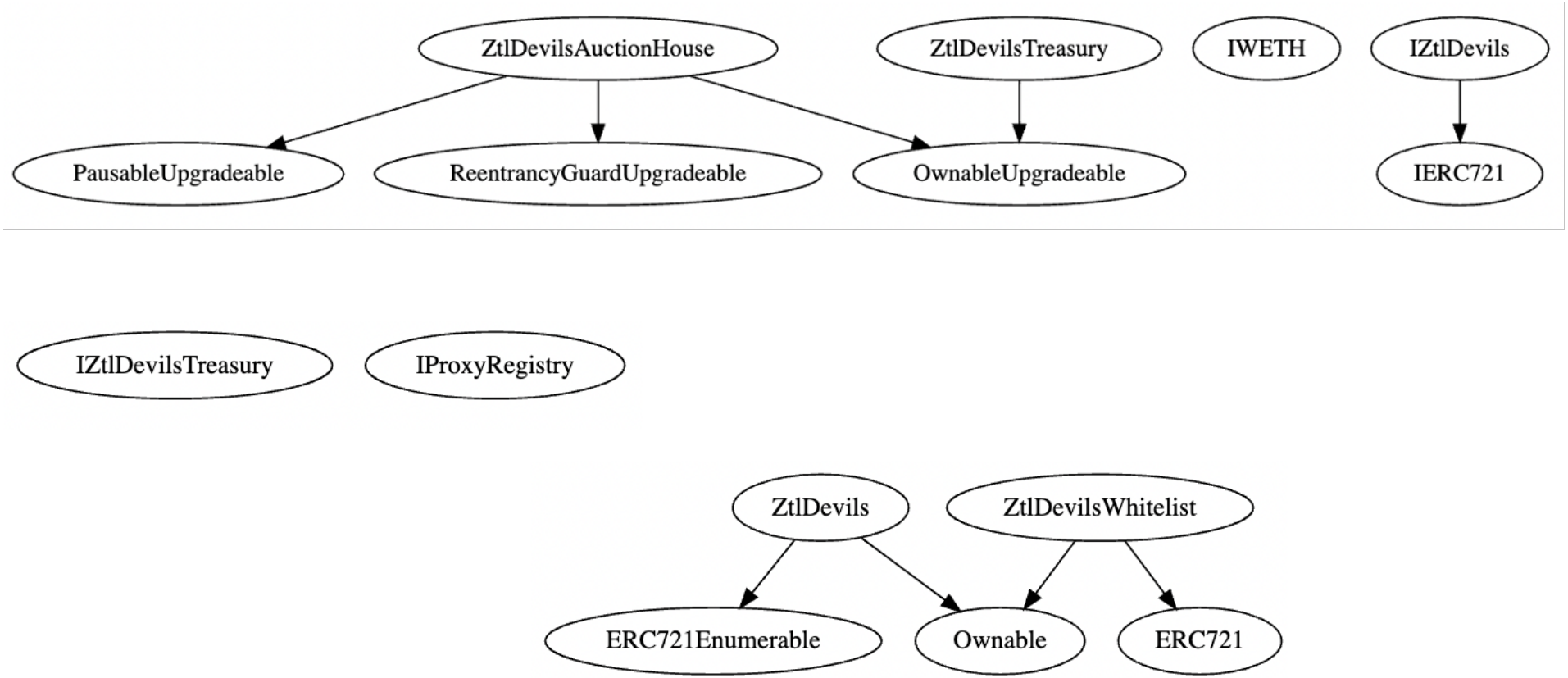




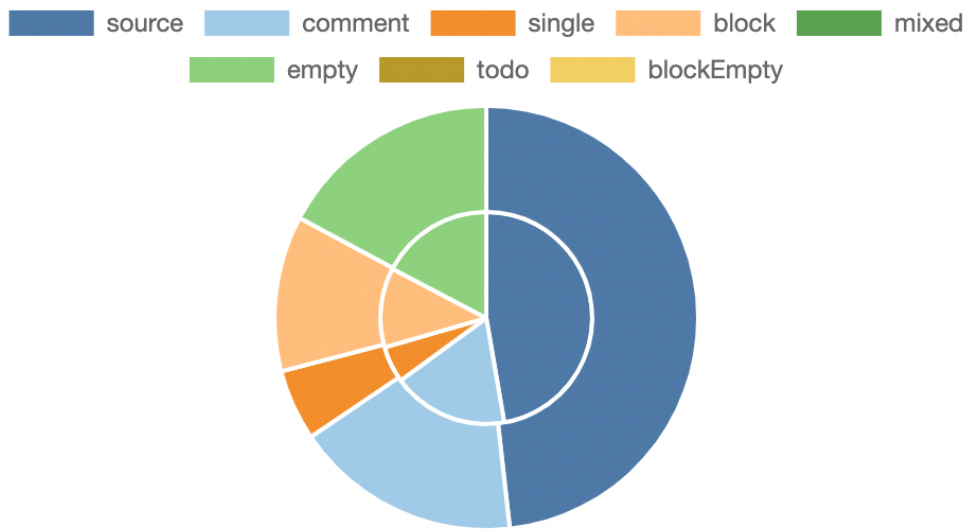


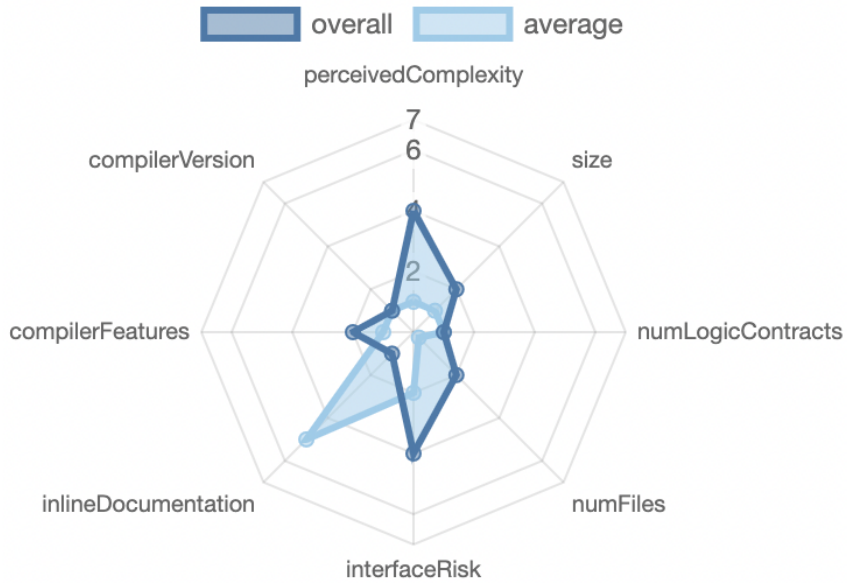


5.4 Inheritance Graph



5.5 Source Lines & Risk





5.6 Capabilities

Solidity Versions observed	🧪 Experimental Features	💰 Can Receive Funds	🖥️ Uses Assembly	💣 Has Destroyable Contracts
`^0.8.16`		`yes`		

📩 Transfers ETH	⚡ Low-Level Calls	👥 DelegateCall	🧮 Uses Hash Functions	🏷️ ECRecover	🌀 New/Create/Create2
`yes`			`yes`		

Exposed Functions
This section lists functions that are explicitly declared public or payable. Please note that getter methods for public stateVars are not included.

🌐Public	💰Payable
38	6

External	Internal	Private	Pure	View
35	38	0	0	10

StateVariables

Total	🌐Public
20	17

5.7 Source Unites in Scope

Source: https://github.com/hooy/zeitls-devils-museum-kaunas
Commit: a355deb099f82992efef421e161bad148e1fb79c
Branch: main

Type	File	Logic Contracts	Interfaces	Lines	nLines	nSLOC	Comment Lines	Complex. Score	Capabilities
📝	contracts/ZtlDevils.sol	1		142	142	77	40	72	🔷
📝	contracts/ZtlDevilsAuctionHouse.sol	1		317	308	172	75	151	💰🔷🧱
📝	contracts/ZtlDevilsTreasury.sol	1		113	113	70	17	68	💰🔷
🔍	contracts/weth/IWETH.sol		1	11	6	3	1	10	💰
📝	contracts/ZtlDevilsWhitelist.sol	1		46	46	33	1	34	
🔍	contracts/IZtlDevils.sol		1	10	8	4	1	7	
🔍	contracts/IZtlDevilsTreasury.sol		1	9	8	4	1	6	💰
🔍	contracts/opensea/IProxyRegistry.sol		1	7	6	3	1	3	
📝🔍	**Totals**	**4**	**4**	**655**	**637**	**366**	**137**	**351**	💰🔷🧱

Legend:

- **Lines**: total lines of the source unit
- **nLines**: normalized lines of the source unit (e.g. normalizes functions spanning multiple lines)
- **nSLOC**: normalized source lines of code (only source-code lines; no comments, no blank lines)
- **Comment Lines**: lines containing single or block comments
- **Complexity Score**: a custom complexity score derived from code statements that are known to introduce code complexity (branches, loops, calls, external interfaces, ...)

6. Scope of Work

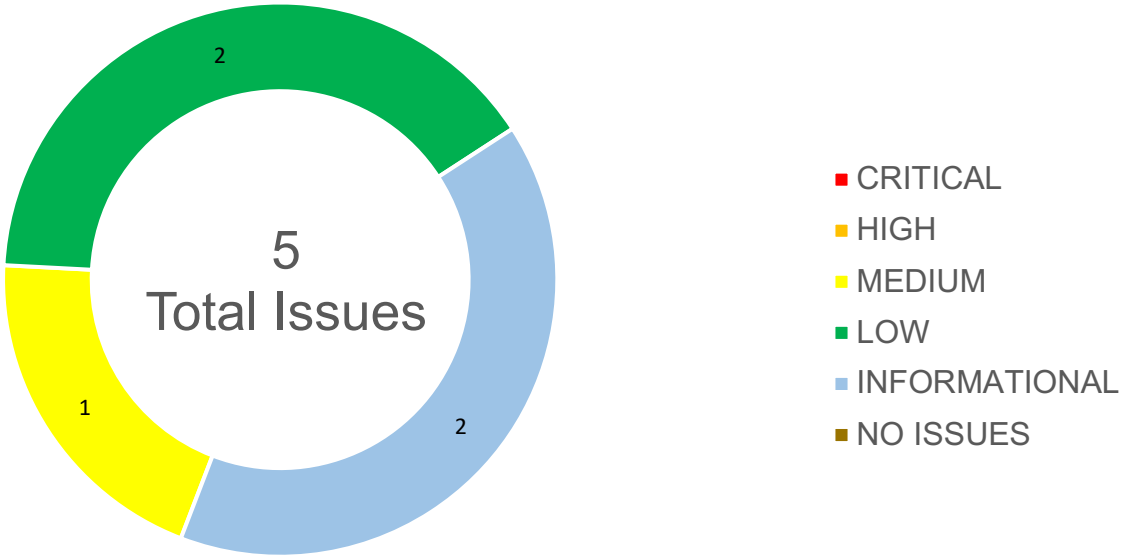
The Zeitls Team provided us with the files that needs to be tested. The scope of the audit is the Zeitls Protocol contract.

The team put forward the following assumptions regarding the security, usage of the contracts:

- The ERC-721 token standard is correctly implemented
- The Whitelist is working as expected
- The Treasury is working as expected
- Auctions are working as expected
- The smart contract is coded according to the newest standards and in a secure way

The main goal of this audit was to verify these claims. The auditors can provide additional feedback on the code upon the client's request.

6.1 Findings Overview



No	Title	Severity	Status
6.2.1	Overpowered Owner rights	MEDIUM	ACKNOWLEDGED
6.2.2	Missing Zero Address Checks	LOW	FIXED
6.2.3	Misleading In-Line Comment	LOW	FIXED
6.2.4	Floating Pragma Version Identified	INFORMATIONAL	FIXED
6.2.5	Storing Metadata via tokenURI	INFORMATIONAL	ACKNOWLEDGED

6.2 Manual and Automated Vulnerability Test

CRITICAL ISSUES

During the audit, experts found **0 Critical issues** in the code of the smart contract.

HIGH ISSUES

During the audit, experts found **0 High issues** in the code of the smart contract.

MEDIUM ISSUES

During the audit, experts found **1 Medium issue** in the code of the smart contract.

6.2.1 Overpowered Owner rights
Severity: MEDIUM
Status: ACKNOWLEDGED
Code: NA
File(s) affected: ZtlDevils.sol, ZtlDevilsAutionHouse.sol, ZtlDevilsTreasury.sol, ZtlDevilsWhitelist.sol
Update: Zeitls Team is aware of the potential risks of losing a single key, therefore their intention is to leverage Gnosis Safe (Multisig)

Attack / Description	Code Snippet	Result/Recommendation
The owner has extensive rights. The auditor has not recognized any roles, governance or multi-sig structure.	Line 104 (ZtlDevils.sol) `function setMinter(address _minter) external onlyOwner {` Line 114 (ZtlDevils.sol)	The owner has rights to distribute royalties, set the Minter, Pause the auction, and burn token. If the owner wallet/private key gets into the wrong hands, caused by a leak or hack, then it's easily

	`function updateMetadata(uint[] calldata ids, string[] calldata uris) external onlyOwner`
	
	Line 132 (ZtlDevils.sol)
	`function withdrawERC20(IERC20 _tokenContract) external onlyOwner`
	
	Line 139 (ZtlDevils.sol)
	`function approveERC721(IERC721 _tokenContract) external onlyOwner {`
	
	Line 113 (ZtlDevilsAutionHouse.sol)
	`function pause() external onlyOwner`
	
	Line 121 (ZtlDevilsAutionHouse.sol)
	`function unpause() external onlyOwner {`
	
	Line 129 (ZtlDevilsAutionHouse.sol)
	`function setTimeBuffer(uint40 _timeBuffer) external onlyOwner {`
	
	Line 138 (ZtlDevilsAutionHouse.sol)
	`function setMinBidIncrementPercentage(uint8 _minBidIncrementPercentage) external onlyOwner {`
	
	And within ZtlDevilsTreasury.sol, ZtlDevilsWhitelist.sol
		possible to harm the project. We recommend protecting the owner wallet with a multi-signature structure such as gnosis safe or add on-chain governance.

LOW ISSUES

During the audit, experts found **2 Low issues** in the code of the smart contract.

6.2.2 Missing Zero Address Checks

Severity: LOW
Status: FIXED
Code: NA
File(s) affected: ZtlDevils.sol, ZtlDevilsAuctionHouse.sol
Update: https://github.com/hooy/zeitls-devils-museum-kaunas/commit/911026a171f9f80a97a773d4ce095b514f0f36bc

Attack / Description	In the current implementation, there are several addresses set without checking for the zero address. This can lead to unintended behaviour.

Code	Line 104 - 107 (ZtlDevils.sol)
	`function setMinter(address _minter) external onlyOwner {`
	`  minter = _minter;`
	`  emit MinterUpdated(_minter);`
	`}`
	
	Line 55 - 62 (ZtlDevilsAuctionHouse.sol)
	`// The ERC721 whitelist token contract for community members`
	`IERC721 public whitelist;`
	
	`// The address of the WETH contract`
	`address public weth;`
	
	`// The address of the signer for auction participation`
	`address public signer;`

Result/Recommendation	It is recommended to check address values for correctness. This can be done by checking for zero address or exclude in a require.

6.2.3 Misleading In-Line Comment

Severity: LOW
Status: FIXED
Code: NA
File(s) affected: ZtlDevilsAuctionHouse.sol
Update: https://github.com/hooy/zeitls-devils-museum-kaunas/commit/911026a171f9f80a97a773d4ce095b514f0f36bc

Attack / Description	In the current codebase are some comments not matching with the current project. This could lead to misleading understanding and usage of the code.

Code	Line 108 (ZtlDevilsAuctionHouse.sol)
	`* @notice Pause the Nouns auction house.`
	
	Line 118 (ZtlDevilsAuctionHouse.sol)
	`* @notice Unpause the Nouns auction house.`
	
	Line 271 (ZtlDevilsAuctionHouse.sol)
	`* @dev If there are no bids, the Noun is burned.`

Result/Recommendation	It is recommended to correct the misleading comments and replace Nouns with Devils or Zeitls

INFORMATIONAL ISSUES

During the audit, experts found **2 Informational issues** in the code of the smart contract.

6.2.4 Floating Pragma Version Identified

Severity: INFORMATIONAL
Status: FIXED
Code: SWC-103
File(s) affected: ALL
Update: https://github.com/hooy/zeitls-devils-museum-kaunas/commit/911026a171f9f80a97a773d4ce095b514f0f36bc

Attack / Description	It is recommended to specify a fixed compiler version to ensure that the bytecode produced does not vary between builds. This is especially important if you rely on bytecode-level verification of the code.
Code	e.g. Line 3 `pragma solidity ^0.8.16;`
Result/Recommendation	It is recommended to follow the latter example, as future compiler versions may handle certain language constructions in a way the developer did not foresee. It is advised that floating pragma should not be used in production. Both truffle-config.js and hardhat.config.js support locking the pragma version. i.e. pragma solidity 0.8.16

6.2.5 Storing Metadata via tokenURI

Severity: INFORMATIONAL
Status: ACKNOWLEDGED
Code: NA
File(s) affected: ZtlDevils.sol
Update: Functionality exists only because business expectations are to share the token contract across different physical collections, thus metadata update feature is mandatory.

Attack / Description	In the current implementation the tokenURI is not hardcoded, means the owner/creator is free to choose the way how the metadata file is stored.

Code	Line 86 - 95 (ZtlDevils.sol)
	`function tokenURI(uint256 tokenId) public view override returns (string memory) {`
	`  _requireMinted(tokenId);`
	
	`  uint ipfsIndex = metadataIds.length - 1;`
	`  for (uint i = 1; i < metadataIds.length; i++) {`
	`  if (tokenId < metadataIds[i]) {`
	`  ipfsIndex = i - 1;`
	`  break;`
	`  }`
	`  }`

Result/Recommendation	We recommend using IPFS and pinning services to make the metadata behind the tokenURI permanently stored. To ensure that data persists on IPFS, and is not deleted during garbage collection, data can be pinned to one or more IPFS nodes. Pinning gives you control over disk space and data retention. As such, you should use that control to pin any content you wish to keep on IPFS indefinitely. Check more information here: https://docs.ipfs.io/concepts/persistence/#persistence-versus-permanence Keep in mind even if you use an IPFS Service, the file will only exist as long if it is “pinned”. And you still may need a dedicated gateway to serve your files with a decent speed, which may lead to your metadata requests timing out in the future. Please investigate SVG generated on-chain visuals and on-chain stored metadata, for persistent storage.

6.3 SWC Attacks

ID	Title	Relationships	Test Result
SWC-131	Presence of unused variables	CWE-1164: Irrelevant Code	✅
SWC-130	Right-To-Left-Override control character (U+202E)	CWE-451: User Interface (UI) Misrepresentation of Critical Information	✅
SWC-129	Typographical Error	CWE-480: Use of Incorrect Operator	✅
SWC-128	DoS With Block Gas Limit	CWE-400: Uncontrolled Resource Consumption	✅
SWC-127	Arbitrary Jump with Function Type Variable	CWE-695: Use of Low-Level Functionality	✅
SWC-125	Incorrect Inheritance Order	CWE-696: Incorrect Behavior Order	✅
SWC-124	Write to Arbitrary Storage Location	CWE-123: Write-what-where Condition	✅
SWC-123	Requirement Violation	CWE-573: Improper Following of Specification by Caller	✅

ID	Title	Relationships	Test Result
SWC-122	Lack of Proper Signature Verification	CWE-345: Insufficient Verification of Data Authenticity	✅
SWC-121	Missing Protection against Signature Replay Attacks	CWE-347: Improper Verification of Cryptographic Signature	✅
SWC-120	Weak Sources of Randomness from Chain Attributes	CWE-330: Use of Insufficiently Random Values	✅
SWC-119	Shadowing State Variables	CWE-710: Improper Adherence to Coding Standards	✅
SWC-118	Incorrect Constructor Name	CWE-665: Improper Initialization	✅
SWC-117	Signature Malleability	CWE-347: Improper Verification of Cryptographic Signature	✅
SWC-116	Timestamp Dependence	CWE-829: Inclusion of Functionality from Untrusted Control Sphere	✅
SWC-115	Authorization through tx.origin	CWE-477: Use of Obsolete Function	✅
SWC-114	Transaction Order Dependence	CWE-362: Concurrent Execution using Shared Resource with Improper Synchronization ('Race Condition')	✅

ID	Title	Relationships	Test Result
SWC-113	DoS with Failed Call	CWE-703: Improper Check or Handling of Exceptional Conditions	✅
SWC-112	Delegatecall to Untrusted Callee	CWE-829: Inclusion of Functionality from Untrusted Control Sphere	✅
SWC-111	Use of Deprecated Solidity Functions	CWE-477: Use of Obsolete Function	✅
SWC-110	Assert Violation	CWE-670: Always-Incorrect Control Flow Implementation	✅
SWC-109	Uninitialized Storage Pointer	CWE-824: Access of Uninitialized Pointer	✅
SWC-108	State Variable Default Visibility	CWE-710: Improper Adherence to Coding Standards	✅
SWC-107	Reentrancy	CWE-841: Improper Enforcement of Behavioral Workflow	✅
SWC-106	Unprotected SELFDESTRUCT Instruction	CWE-284: Improper Access Control	✅
SWC-105	Unprotected Ether Withdrawal	CWE-284: Improper Access Control	✅
SWC-104	Unchecked Call Return Value	CWE-252: Unchecked Return Value	✅

ID	Title	Relationships	Test Result
SWC-103	Floating Pragma	CWE-664: Improper Control of a Resource Through its Lifetime	✅
SWC-102	Outdated Compiler Version	CWE-937: Using Components with Known Vulnerabilities	✅
SWC-101	Integer Overflow and Underflow	CWE-682: Incorrect Calculation	✅
SWC-100	Function Default Visibility	CWE-710: Improper Adherence to Coding Standards	✅

6.4. Verify Claims

6.4.1 The ERC-721 token standard is correctly implemented
Status: tested and verified ✅

6.4.2 The Whitelist is working as expected
Status: tested and verified ✅

6.4.3 The Treasury is working as expected
Status: tested and verified ✅

6.4.4 Auctions are working as expected
Status: tested and verified ✅

6.4.5 The smart contract is coded according to the newest standards and in a secure way.
Status: tested and verified ✅

6.5 Unit Tests

```
ZtlDevilsAuctionHouse
  deployment
    ✔ should set contract owner address contract from constructor args (539ms)
    ✔ should set time buffer
    ✔ should set min increment percentage
  listing
    ✔ list single auction
    ✔ list many auctions
    forbid listing
      ✔ should forbid not permitted listing
      ✔ should forbid with zero reserve price
      ✔ should forbid secondary listing
      ✔ should forbid listing on existing token
  bidding
    ✔ should activate auction timer with the first bid
    ✔ should calculate next bid amount (98ms)
    ✔ should refund the previous bidder when the following user creates a bid
    ✔ should extend auction when bid made in buffer time
  settle
    ✔ should allow auction settle and token claim after release time (45ms)
  direct purchase
    ✔ should permit purchase
    ✔ should forbid expired signature
    ✔ should forbid underpaid transaction
    ✔ should forbid purchase for existing auction
    ✔ should forbid purchase for existing token
    ✔ should forbid invalid signature
  whitelist
    ✔ should allow bid when sender is whitelisted
    ✔ should forbid bid on limited auction without whitelist

ZtlDevils
```

```
  deployment
    ✔ should set contract owner address contract from constructor args
  management
    ✔ should change minter
    ✔ should change owner
  token
    ✔ should mint token
    ✔ should burn token
  metadata
    ✔ should update metadata and return correct link according to token id (41ms)
    ✔ should expand metadata links (87ms)
  marketplace
    ✔ should bypass approved for all for a marketplace (45ms)
    ✔ should forbid approved for all for a stranger

ZtlDevilsTreasury
  ✔ auction sale (59ms)
  ✔ royalty (48ms)
  affiliates
    ✔ add affiliates
    ✔ remove affiliates (38ms)
    ✔ forbid share limit exceeding (42ms)
    ✔ forbid share overwrite
  distribution
    ✔ distribute auction income (72ms)

ZtlDevilsWhitelist
  whitelist management
    ✔ add (42ms)
    ✔ add batch

ERC165
  ✔ supportsInterface uses less than 30k gas
  ✔ all interfaces are reported as supported
  ✔ all interface functions are in ABI
```

```
with minted tokens
  balanceOf
    when the given address owns some tokens
      ✔ returns the amount of tokens owned by the given address
    when the given address does not own any tokens
      ✔ returns 0
    when querying the zero address
      ✔ throws
  ownerOf
    when the given token ID was tracked by this token
      ✔ returns the owner of the given token ID
    when the given token ID was not tracked by this token
      ✔ reverts
  transfers
    via transferFrom
      when called by the owner
        ✔ transfers the ownership of the given token ID to the given address
        ✔ emits a Transfer event
        ✔ clears the approval for the token ID
        ✔ adjusts owners balances
        ✔ adjusts owners tokens by index
      when called by the approved individual
        ✔ transfers the ownership of the given token ID to the given address
        ✔ emits a Transfer event
        ✔ clears the approval for the token ID
        ✔ adjusts owners balances
        ✔ adjusts owners tokens by index
      when called by the operator
        ✔ transfers the ownership of the given token ID to the given address
        ✔ emits a Transfer event
        ✔ clears the approval for the token ID
        ✔ adjusts owners balances
        ✔ adjusts owners tokens by index
      when called by the owner without an approved user
```

```
      ✔ transfers the ownership of the given token ID to the given address
      ✔ emits a Transfer event
      ✔ clears the approval for the token ID
      ✔ adjusts owners balances
      ✔ adjusts owners tokens by index
    when sent to the owner
      ✔ keeps ownership of the token
      ✔ clears the approval for the token ID
      ✔ emits only a transfer event
      ✔ keeps the owner balance
      ✔ keeps same tokens by index
    when the address of the previous owner is incorrect
      ✔ reverts
    when the sender is not authorized for the token id
      ✔ reverts
    when the given token ID does not exist
      ✔ reverts
    when the address to transfer the token to is the zero address
      ✔ reverts
  via safeTransferFrom
    with data
      to a user account
        when called by the owner
          ✔ transfers the ownership of the given token ID to the given address
          ✔ emits a Transfer event
          ✔ clears the approval for the token ID
          ✔ adjusts owners balances
          ✔ adjusts owners tokens by index
        when called by the approved individual
          ✔ transfers the ownership of the given token ID to the given address
          ✔ emits a Transfer event
          ✔ clears the approval for the token ID
          ✔ adjusts owners balances
          ✔ adjusts owners tokens by index
        when called by the operator
```

```
      ✔ transfers the ownership of the given token ID to the given address
      ✔ emits a Transfer event
      ✔ clears the approval for the token ID
      ✔ adjusts owners balances
      ✔ adjusts owners tokens by index
    when called by the owner without an approved user
      ✔ transfers the ownership of the given token ID to the given address
      ✔ emits a Transfer event
      ✔ clears the approval for the token ID
      ✔ adjusts owners balances
      ✔ adjusts owners tokens by index
    when sent to the owner
      ✔ keeps ownership of the token
      ✔ clears the approval for the token ID
      ✔ emits only a transfer event
      ✔ keeps the owner balance
      ✔ keeps same tokens by index
    when the address of the previous owner is incorrect
      ✔ reverts
    when the sender is not authorized for the token id
      ✔ reverts
    when the given token ID does not exist
      ✔ reverts
    when the address to transfer the token to is the zero address
      ✔ reverts
  to a valid receiver contract
    ✔ calls onERC721Received
    ✔ calls onERC721Received from approved
    when called by the owner
      ✔ transfers the ownership of the given token ID to the given address
      ✔ emits a Transfer event
      ✔ clears the approval for the token ID
      ✔ adjusts owners balances
      ✔ adjusts owners tokens by index
    when called by the approved individual
```

```
      ✔ transfers the ownership of the given token ID to the given address
      ✔ emits a Transfer event
      ✔ clears the approval for the token ID
      ✔ adjusts owners balances
      ✔ adjusts owners tokens by index
    when called by the operator
      ✔ transfers the ownership of the given token ID to the given address
      ✔ emits a Transfer event
      ✔ clears the approval for the token ID
      ✔ adjusts owners balances
      ✔ adjusts owners tokens by index
    when called by the owner without an approved user
      ✔ transfers the ownership of the given token ID to the given address
      ✔ emits a Transfer event
      ✔ clears the approval for the token ID
      ✔ adjusts owners balances
      ✔ adjusts owners tokens by index
    when sent to the owner
      ✔ keeps ownership of the token
      ✔ clears the approval for the token ID
      ✔ emits only a transfer event
      ✔ keeps the owner balance
      ✔ keeps same tokens by index
    when the address of the previous owner is incorrect
      ✔ reverts
    when the sender is not authorized for the token id
      ✔ reverts
    when the given token ID does not exist
      ✔ reverts
    when the address to transfer the token to is the zero address
      ✔ reverts
    with an invalid token id
      ✔ reverts
  without data
    to a user account
```

```
when called by the owner
  ✔ transfers the ownership of the given token ID to the given address
  ✔ emits a Transfer event
  ✔ clears the approval for the token ID
  ✔ adjusts owners balances
  ✔ adjusts owners tokens by index
when called by the approved individual
  ✔ transfers the ownership of the given token ID to the given address
  ✔ emits a Transfer event
  ✔ clears the approval for the token ID
  ✔ adjusts owners balances
  ✔ adjusts owners tokens by index
when called by the operator
  ✔ transfers the ownership of the given token ID to the given address
  ✔ emits a Transfer event
  ✔ clears the approval for the token ID
  ✔ adjusts owners balances
  ✔ adjusts owners tokens by index
when called by the owner without an approved user
  ✔ transfers the ownership of the given token ID to the given address
  ✔ emits a Transfer event
  ✔ clears the approval for the token ID
  ✔ adjusts owners balances
  ✔ adjusts owners tokens by index
when sent to the owner
  ✔ keeps ownership of the token
  ✔ clears the approval for the token ID
  ✔ emits only a transfer event
  ✔ keeps the owner balance
  ✔ keeps same tokens by index
when the address of the previous owner is incorrect
  ✔ reverts
when the sender is not authorized for the token id
  ✔ reverts
when the given token ID does not exist
```

```
    ✔ reverts
  when the address to transfer the token to is the zero address
    ✔ reverts
to a valid receiver contract
  ✔ calls onERC721Received
  ✔ calls onERC721Received from approved
  when called by the owner
    ✔ transfers the ownership of the given token ID to the given address
    ✔ emits a Transfer event
    ✔ clears the approval for the token ID
    ✔ adjusts owners balances
    ✔ adjusts owners tokens by index
  when called by the approved individual
    ✔ transfers the ownership of the given token ID to the given address
    ✔ emits a Transfer event
    ✔ clears the approval for the token ID
    ✔ adjusts owners balances
    ✔ adjusts owners tokens by index
  when called by the operator
    ✔ transfers the ownership of the given token ID to the given address
    ✔ emits a Transfer event
    ✔ clears the approval for the token ID
    ✔ adjusts owners balances
    ✔ adjusts owners tokens by index
  when called by the owner without an approved user
    ✔ transfers the ownership of the given token ID to the given address
    ✔ emits a Transfer event
    ✔ clears the approval for the token ID
    ✔ adjusts owners balances
    ✔ adjusts owners tokens by index
  when sent to the owner
    ✔ keeps ownership of the token
    ✔ clears the approval for the token ID
    ✔ emits only a transfer event
    ✔ keeps the owner balance
```

```
          ✔ keeps same tokens by index
        when the address of the previous owner is incorrect
          ✔ reverts
        when the sender is not authorized for the token id
          ✔ reverts
        when the given token ID does not exist
          ✔ reverts
        when the address to transfer the token to is the zero address
          ✔ reverts
        with an invalid token id
          ✔ reverts
    to a receiver contract returning unexpected value
      ✔ reverts (41ms)
    to a receiver contract that reverts with message
      ✔ reverts (53ms)
    to a receiver contract that reverts without message
      ✔ reverts (41ms)
    to a receiver contract that panics
      ✔ reverts
    to a contract that does not implement the required function
      ✔ reverts
safe mint
  via safeMint
    - calls onERC721Received — with data
    - calls onERC721Received — without data
    to a receiver contract returning unexpected value
      - reverts
    to a receiver contract that reverts with message
      - reverts
    to a receiver contract that reverts without message
      - reverts
    to a receiver contract that panics
      - reverts
    to a contract that does not implement the required function
      - reverts
```

```
approve
  when clearing approval
    when there was no prior approval
      ✔ clears approval for the token
      ✔ emits an approval event
    when there was a prior approval
      ✔ clears approval for the token
      ✔ emits an approval event
  when approving a non-zero address
    when there was no prior approval
      ✔ sets the approval for the target address
      ✔ emits an approval event
    when there was a prior approval to the same address
      ✔ sets the approval for the target address
      ✔ emits an approval event
    when there was a prior approval to a different address
      ✔ sets the approval for the target address
      ✔ emits an approval event
  when the address that receives the approval is the owner
    ✔ reverts
  when the sender does not own the given token ID
    ✔ reverts
  when the sender is approved for the given token ID
    ✔ reverts
  when the sender is an operator
    ✔ sets the approval for the target address
    ✔ emits an approval event
  when the given token ID does not exist
    ✔ reverts
setApprovalForAll
  when the operator willing to approve is not the owner
    when there is no operator approval set by the sender
      ✔ approves the operator
      ✔ emits an approval event
    when the operator was set as not approved
```

```
        ✔ approves the operator
        ✔ emits an approval event
        ✔ can unset the operator approval
      when the operator was already approved
        ✔ keeps the approval to the given address
        ✔ emits an approval event
    when the operator is the owner
      ✔ reverts
  getApproved
    when token is not minted
      ✔ reverts
    when token has been minted
      ✔ should return the zero address
      when account has been approved
        ✔ returns approved account

_mint(address, uint256)
  ✔ reverts with a null destination address (64ms)
  with minted token
    ✔ emits a Transfer event
    ✔ creates the token
    ✔ reverts when adding a token id that already exists

_burn
  ✔ reverts when burning a non-existent token id (59ms)
  with minted tokens
    with burnt token
      ✔ emits a Transfer event
      ✔ deletes the token
      ✔ reverts when burning a token id that has been deleted

ERC165
  ✔ supportsInterface uses less than 30k gas
  ✔ all interfaces are reported as supported
  ✔ all interface functions are in ABI
```

```
with minted tokens
  totalSupply
    ✔ returns total token supply
  tokenOfOwnerByIndex
    when the given index is lower than the amount of tokens owned by the given address
      ✔ returns the token ID placed at the given index
    when the index is greater than or equal to the total tokens owned by the given address
      ✔ reverts
    when the given address does not own any token
      ✔ reverts
    after transferring all tokens to another user
      ✔ returns correct token IDs for target
      ✔ returns empty collection for original owner
  tokenByIndex
    ✔ returns all tokens
    ✔ reverts if index is greater than supply
    ✔ returns all tokens after burning token 5042 and minting new tokens
    ✔ returns all tokens after burning token 79217 and minting new tokens

_mint(address, uint256)
  ✔ reverts with a null destination address
  with minted token
    ✔ adjusts owner tokens by index
    ✔ adjusts all tokens list

_burn
  ✔ reverts when burning a non-existent token id
  with minted tokens
    with burnt token
      ✔ removes that token from the token list of the owner
      ✔ adjusts all tokens list
      ✔ burns all tokens
```

```
259 passing (27s)
7 pending
```

7. Executive Summary

Two (2) independent Auditor Labs experts performed an unbiased and isolated audit of the smart contract codebase.

The main goal of the audit was to verify the claims regarding the security and functions of the smart contract. During the audit, no critical, no high, one medium, two low and two informational issues have been found, after the manual and automated security testing.

We advise the Zeitls team to implement the recommendations to further enhance the code's security and readability.

Update (02.01.2023): The Zeitls Team addressed all issues and fixed them.

8. Deployed Contracts

Zeitls Devils (DEVILS): https://etherscan.io/address/0xf0b8b1F6685a5a2E95E922D0d45D89efFa7a0cc6#code

Zeitls Key (ZTL-KEY): https://etherscan.io/address/0x8EB199D3620759ada6C3377AC6e5d71B3521eA21#code

ZtlDevilsTreasury: https://etherscan.io/address/0x907583c591A85A3C8dc3E29294836D9034CF82F4#code

ZtlDevilsAuctionHouse: https://etherscan.io/address/0x56cE7EFFa21c995C5fB2E29FFf18Cdf6FC2fe8d2#code

9. About the Auditor

Auditor Labs is a professional software development firm, founded in 2017 and based in Germany. They show ways, opportunities, risks and offer comprehensive Web3 solutions. Their services include web3 development, security and consulting.

Auditor Labs conducts code audits on market-leading blockchains such as Solana, Tezos, Ethereum, Binance Smart Chain, and Polygon to mitigate risk and instil trust and transparency into the vibrant crypto community. They have also reviewed and secure the smart contracts of many top DeFi projects.

Auditor Labs currently secures $100 billion in user funds locked in multiple DeFi protocols. The team behind the leading audit firm relies on their robust technical know-how in the web3 sector to deliver top-notch smart contract audit solutions, tailored to the clients' evolving business needs.

Check our website for further information: https://auditorlabs.com