

The Dark Arts

Contract Runtime Mutability

0age

(Defense Against) The Dark Arts

Contract Runtime Mutability

0age

tl;dr

Deployed contract code is no longer immutable

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github.com/0age/devcon5-contract-runtime-mutability

Summary

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Key Concepts

Creation Code + Runtime Code

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Creation Code + Runtime Code

Contract Storage + Runtime Code

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Contract Storage + Runtime Code

Create + Create2

 Create + Create2

👨 Create + Create2 👩

Selfdestruct



Selfdestruct

⚠—Selfdestruct—⚠

⚠️ Selfdestruct 💣

Redeployment

Redeployment

What happens when you:

Redeployment

What happens when you:

- try to deploy to an account with a contract?

Redeployment

What happens when you:

- try to deploy to an account with a contract? **INVALID**

Redeployment

What happens when you:

- try to deploy to an account with a contract? **INVALID**
- selfdestruct a contract?

Redeployment

What happens when you:

- try to deploy to an account with a contract? **INVALID**
- selfdestruct a contract? **WIPED**

Redeployment

What happens when you:

- try to deploy to an account with a contract? **INVALID**
- selfdestruct a contract? **WIPED**
- deploy to the account after it's been wiped?

Redeployment

What happens when you:

- try to deploy to an account with a contract? **INVALID**
- selfdestruct a contract? **WIPED**
- deploy to the account after it's been wiped? **OK!**

Redeployment

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- try to deploy to an account with a contract? **INVALID**
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- were counting on the nonce or state of the contract?

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- selfdestruct a contract? **WIPED**
- deploy to the account after it's been wiped? **OK!**
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YOU JUST GOT PWNED, PAL!

Exhibit A: ERC20 Approval exploit



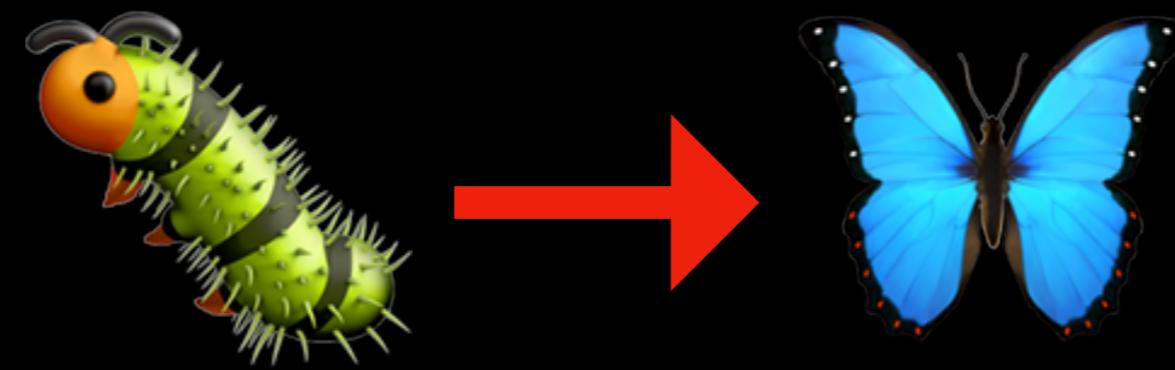
Exhibit B: ERC20 Approval exploit v2

Good thing the code can't change!



Spoiler alert: the code can change.





Metamorphism

The trick:

The trick: non-deterministic creation code

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Deployer + creation code + salt can't change

Other than that, **anything's** fair game

Metamorphism

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 - Get creation code from storage + Create2 → Create
 - Supports a constructor, but requires an "extra hop"
- Metamorphic Delegator
 - Put creation code in runtime code of another contract
 - During deployment, DELEGATECALL into that contract

Cloner

Cloner (standard)

0x73<address>3d803b3d3d82943cf3

pc	op	name	[stack] + <memory> + *runtime!*
--	--	-----	-----
00	73	PUSH20 <address>	[address]
21	3d	RETURNDATASIZE	[address, 0]
22	80	DUP1	[address, 0, address]
23	3b	EXTCODESIZE	[address, 0, size]
24	3d	RETURNDATASIZE	[address, 0, size, 0]
25	3d	RETURNDATASIZE	[address, 0, size, 0, 0]
26	82	DUP3	[address, 0, size, 0, 0, size]
27	94	SWAP5	[size, 0, size, 0, 0, address]
28	3c	EXTCODECOPY	[size, 0] <code_to_clone>
29	f3	RETURN	[] *code_to_clone*

Cloner (metamorphic)

0x5860203d593d335afa1551803b80928080933cf3

pc	op	name	[stack] + <memory> + *runtime!*
00	58	PC	[0]
00	60	PUSH1 0x20	[0, 32]
02	3d	RETURNDATASIZE	[0, 32, 0]
03	59	MSIZE	[0, 32, 0, 0]
04	3d	RETURNDATASIZE	[0, 32, 0, 0, 0]
05	33	CALLER	[0, 32, 0, 0, 0, caller]
06	5a	GAS	[0, 32, 0, 0, 0, caller, gas]
07	fa	STATICCALL	[0, 1 (if successful)] <address>
08	15	ISZERO	[0, 0]
10	51	MLEAD	[0, address]
11	80	DUP1	[0, address, address]
12	3b	EXTCODESIZE	[0, address, size]
13	80	DUP1	[0, address, size, size]
14	92	SWAP3	[size, address, size, 0]
15	80	DUP1	[size, address, size, 0, 0]
16	80	DUP1	[size, address, size, 0, 0, 0]
17	93	SWAP4	[size, 0, size, 0, 0, address]
18	3c	EXTCODECOPY	[size, 0] <code_to_clone>
19	f3	RETURN	[] *code_to_clone*

```
contract MetamorphicCloner {
    // We'll store the address to clone (temporarily).
    address private _addressToCloneInStorageSlotZero;

    // The fallback function will return this address when called.
    function () external {
        assembly {
            mstore(0, sload(0)) // Get the target address from storage slot 0.
            return(0, 32)       // Return the target address.
        }
    }

    function deployClone(address target) external returns (address clone) {
        // Set the target to clone in storage slot zero.
        _addressToCloneInStorageSlotZero = target;

        // Deploy the contract with fixed, non-deterministic creation code.
        assembly {
            mstore(
                0,
                0x5860203d593d335afa1551803b80928080933cf30000000000000000000000000000000
            )

            clone := create2(0, 0, 20, 0)
        }

        // Clear out the storage slot once we're done.
        delete _addressToCloneInStorageSlotZero;
    }
}
```

Transient Deployer

0x58593d59335afa3d59343d59593ef080601a573d81ed81803efd5bff

pc	op	name	[stack] + <memory> + {return_buffer} + -contract- + *return*
00	58	PC	[0]
01	59	MSIZE	[0, 0]
02	3d	RETURNDATASIZE	[0, 0, 0]
03	59	MSIZE	[0, 0, 0, 0]
04	33	CALLER	[0, 0, 0, 0, caller]
05	5a	GAS	[0, 0, 0, 0, caller, gas]
06	fa	STATICCALL	[1 (if successful)] {creation_code}
07	3d	RETURNDATASIZE	[x, size]
08	59	MSIZE	[x, size, 0]
09	34	CALLVALUE	[x, size, 0, ⊿]
10	3d	RETURNDATASIZE	[x, size, 0, ⊿, size]
11	59	MSIZE	[x, size, 0, ⊿, size, 0]
12	59	MSIZE	[x, size, 0, ⊿, size, 0, 0]
13	3e	RETURNDATACOPY	[x, size, 0, ⊿] <creation_code>
14	f0	CREATE	[x, address (if successful)] -contract- or {revert_reason}
15	80	DUP1	[x, address, address]
16	60	PUSH1 0x1a	[x, address, address, 26]
18	57	JUMPI	[x, 0]
19	3d	RETURNDATASIZE	[x, 0, size]
20	81	DUP2	[x, 0, size, 0]
21	3d	RETURNDATASIZE	[x, 0, size, 0, size]
22	81	DUP2	[x, 0, size, 0, size, 0]
23	80	DUP1	[x, 0, size, 0, size, 0, 0]
24	3e	RETURNDATACOPY	[x, 0, size, 0 <revert_reason>]
25	fd	REVERT	[x, 0] *revert_reason*
26	5b	JUMPDEST	[x, address]
27	ff	SELFDESTRUCT	[x] 🙌 さよなら 🙌

Metamorphic Delegator

Arbitrary runtime prelude

0x600b5981380380925939f3...

pc	op	name	[stack] + <memory> + *runtime!*
-- -- ----- -----			
00	60	PUSH1 0x0b	[11 -> offset]
02	59	MSIZE	[offset, 0]
03	81	DUP2	[offset, 0, offset]
04	38	CODESIZE	[offset, 0, offset, codesize]
05	03	SUB	[offset, 0, codesize - offset => runtime_size]
06	80	DUP1	[offset, 0, runtime_size, runtime_size]
07	92	SWAP3	[runtime_size, 0, runtime_size, offset]
08	59	MSIZE	[runtime_size, 0, runtime_size, offset, 0]
09	39	CODECOPY	[runtime_size, 0] <arbitrary_runtime>
10	f3	RETURN	[] *arbitrary_runtime*
... arbitrary_runtime			

0x58593d593d5960203d593d335afa15515af43d3d93833e601b57fd5bf3

pc	op	name	[stack] + <memory> + {return_buffer} + *runtime!*
00	58	PC	[0]
01	59	MSIZE	[0, 0]
02	3d	RETURNDATASIZE	[0, 0, 0]
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04	3d	RETURNDATASIZE	[0, 0, 0, 0, 0]
05	59	MSIZE	[0, 0, 0, 0, 0, 0]
06	60	PUSH1 0x20	[0, 0, 0, 0, 0, 0, 32]
08	3d	RETURNDATASIZE	[0, 0, 0, 0, 0, 0, 32, 0]
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11	33	CALLER	[0, 0, 0, 0, 0, 0, 32, 0, 0, 0, caller]
12	5a	GAS	[0, 0, 0, 0, 0, 0, 32, 0, 0, 0, caller, gas]
13	fa	STATICCALL	[0, 0, 0, 0, 0, 0, 1] <creation_in_runtime>
14	15	ISZERO	[0, 0, 0, 0, 0, 0, 0]
15	51	MLOAD	[0, 0, 0, 0, 0, 0, creation_in_runtime]
16	5a	GAS	[0, 0, 0, 0, 0, 0, creation_in_runtime, gas]
17	f4	DELEGATECALL	[0, 0, 1 or 0] {runtime_code or revert_reason}
18	3d	RETURNDATASIZE	[0, 0, 1 or 0, size]
19	3d	RETURNDATASIZE	[0, 0, 1 or 0, size, size]
20	93	SWAP4	[size, 0, 1 or 0, size, 0]
21	83	DUP4	[size, 0, 1 or 0, size, 0, 0]
22	3e	RETURNDATACOPY	[size, 0, 1 or 0] <runtime_code or revert_reason>
23	60	PUSH1 0x1b	[size, 0, 1 or 0, 27]
25	57	JUMPI	[size, 0]
26	fd	REVERT	[] *revert_reason*
27	5b	JUMPDEST	[size, 0]
28	f3	RETURN	[] *runtime_code*

```
contract MetamorphicDelegator {
    // We'll store the address where the target creation code is located (temporarily).
    address private _addressOfContractWithCreationCodeInRuntimeCode;

    // The fallback function will return this address when called.
    function () external {
        assembly {
            mstore(0, sload(0)) // Get the target address from storage slot 0.
            return(0, 32)       // Return the target address.
        }
    }

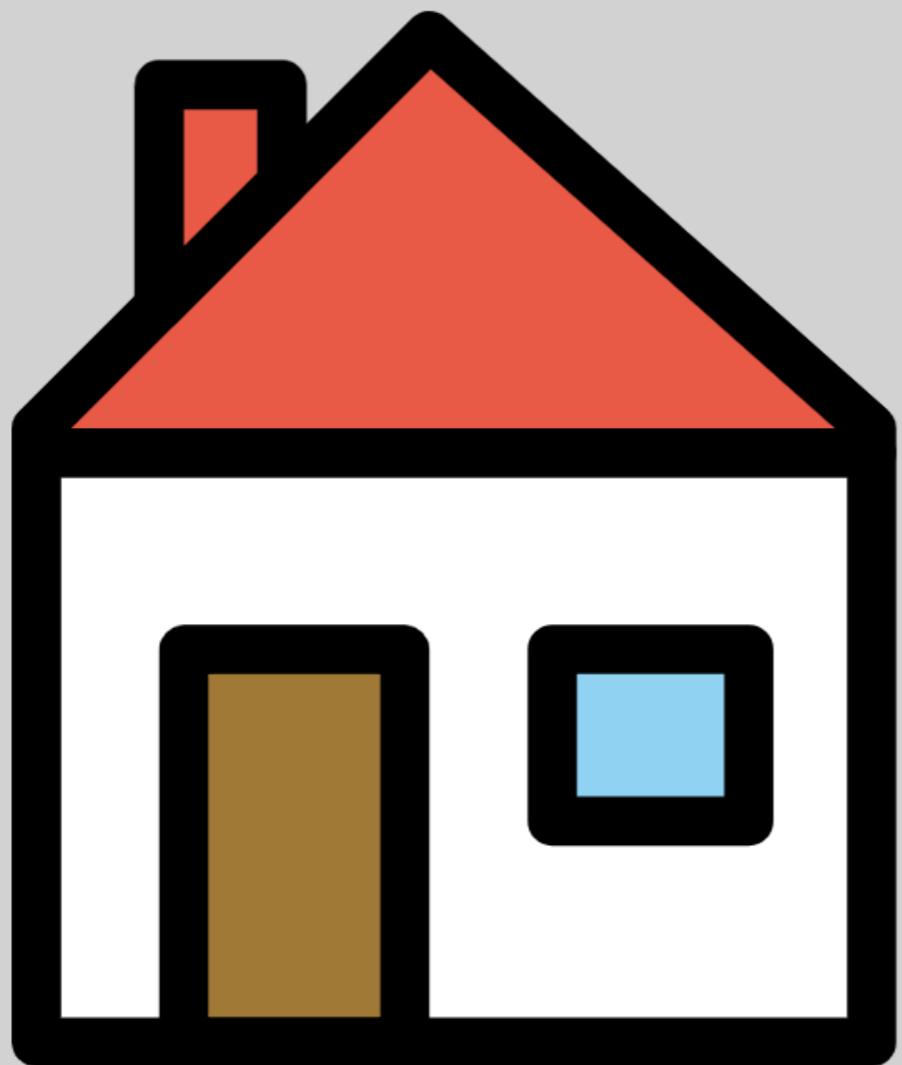
    function deployMetamorphicDelegator(
        bytes calldata creationCode
    ) external returns (address metamorphic) {
        // Construct creation code for the creation-in-runtime contract using the prelude.
        bytes memory targetCreationCode = abi.encodePacked(
            bytes11(0x600b5981380380925939f3), creationCode
        );

        assembly {
            // Deploy creation-in-runtime contract via `CREATE` and set the address in storage.
            sstore(0, create(0, add(32, targetCreationCode), mload(targetCreationCode)))

            // Deploy the contract with fixed, non-deterministic creation code.
            mstore(0, 0x58593d593d5960203d593d335afa15515af43d3d93833e601b57fd5bf3000000)
            metamorphic := create2(0, 0, 29, 0)
            if iszero(metamorphic) { // "bubble up" any revert and pass along reason.
                returndatcopy(0, 0, returndatasize)
                revert(0, returndatasize)
            }
        }

        // Clear out the storage slot once we're done.
        delete _addressOfContractWithCreationCodeInRuntimeCode;
    }
}
```





github.com/0age/HomeWork

...is all this making you nervous?



PROTECT YO' SELF!

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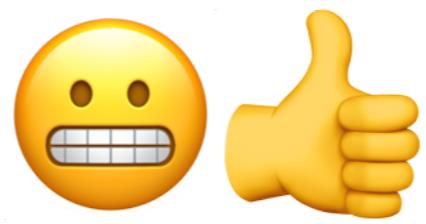
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 - Register runtime code hash → [codehashcache.eth](#)

And most of all...

EDUCATE PEOPLE ABOUT THIS!





...is all this getting you psyched?

Shiny New Things!

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1. Contract Deployments

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- Efficient: find contract addresses that cost less gas to interact with.

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- Coordinated: deploy interconnected groups of contracts that refer to one another as constants.

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1. Contract Deployments

- Efficient: find contract addresses that cost less gas to interact with.
- Coordinated: deploy interconnected groups of contracts that refer to one another as constants.
- Universal: easily refer to local, testnet, and mainnet contracts at the same addresses.

Shiny New Things!

2. Runtime Storage

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- Accessible: let anyone read any section of storage on their own terms.

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- Transferrable: give ownership over a "region" of storage to another account.

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2. Runtime Storage

- Accessible: let anyone read any section of storage on their own terms.
- Transferrable: give ownership over a "region" of storage to another account.
- Economical: save big on initial storage writes and practically **all** reads (*tradeoff: more expensive updates*).

Shiny New Things!

3. Smart Wallets

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- Versatile: add new functionality on-the-fly using arbitrary “transaction scripts” that SELFDESTRUCT.

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- Secure: keep your funds at an empty address with no code to hack.

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- Versatile: add new functionality on-the-fly using arbitrary “transaction scripts” that SELFDESTRUCT.
- Secure: keep your funds at an empty address with no code to hack.
- User-friendly: perform multiple actions (*conditional, atomic, multifaceted, etc.*) in one adaptable transaction.

Shiny New Things!

4. Tokenized Accounts

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- Portable: reassign control over arbitrary deployments and redeployments using NFTs.

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4. Tokenized Accounts

- Portable: reassign control over arbitrary deployments and redeployments using NFTs.
- Combinatorial: create baskets of diverse assets, permissions, and reputation.
- Reliable: safely reserve, manage, and transfer accounts.

Yeah, this stuff is definitely weird...

...but isn't that what Ethereum's all about?



"The Dark Arts are many, varied, ever-changing and eternal. Fighting them is like fighting a many-headed monster, which, each time a neck is severed, sprouts a head even fiercer and cleverer than before. You are fighting that which is unfixed, mutating, indestructible."

"Your defenses must therefore be as flexible and inventive as the Arts you seek to undo."

- Severus Snape

"The Dark Arts are many, varied, ever-changing and eternal. Fighting them is like fighting a many-headed monster, which, each time a neck is severed, sprouts a head even fiercer and cleverer than before. You are fighting that which is unfixed, mutating, SELFDESTRUCT-ible."

"Your defenses must therefore be as flexible and inventive as the Arts you seek to undo - or better yet, use this crypto voodoo to go do something new and epic!"

- Øage

🙏 どうもありがとう 🙏

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