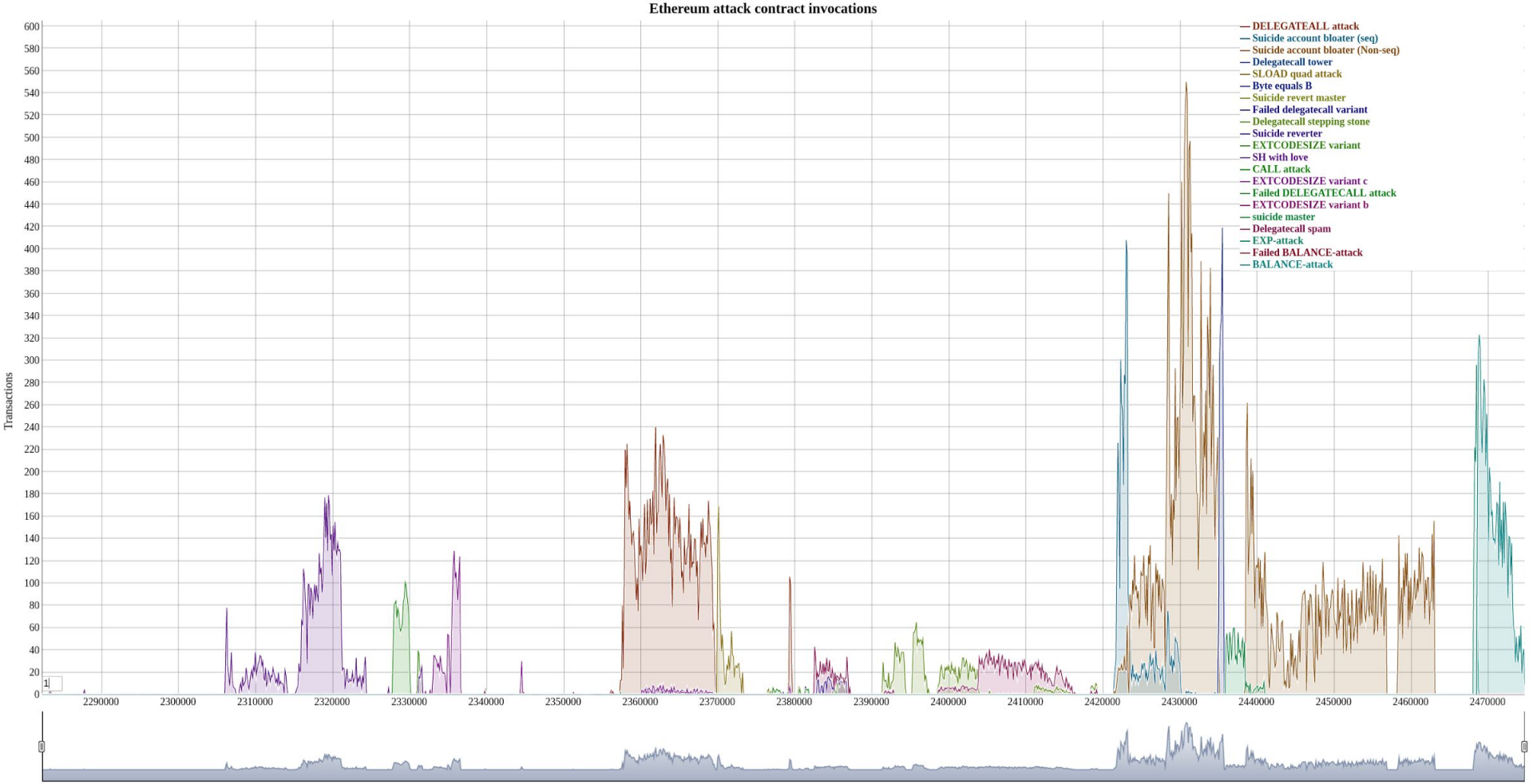
The Shanghai Attacks

From a technical perspective

Martin Holst Swende - EDCON 2017


Ethereum attack contract invocations
Transactions
DELEGATEALL attack
Suicide account bloater (seq)
Suicide account bloater (Non-seq)
Delegatecall tower
SLOAD quad attack
Byte equals B
Suicide revert master
Failed delegatecall variant
Delegatecall stepping stone
Suicide reverter
EXTCODESIZE variant
SH with love
CALL attack
EXTCODESIZE variant c
Failed DELEGATECALL attack
EXTCODESIZE variant b
suicide master
Delegatecall spam
EXP-attack
Failed BALANCE-attack
BALANCE-attack
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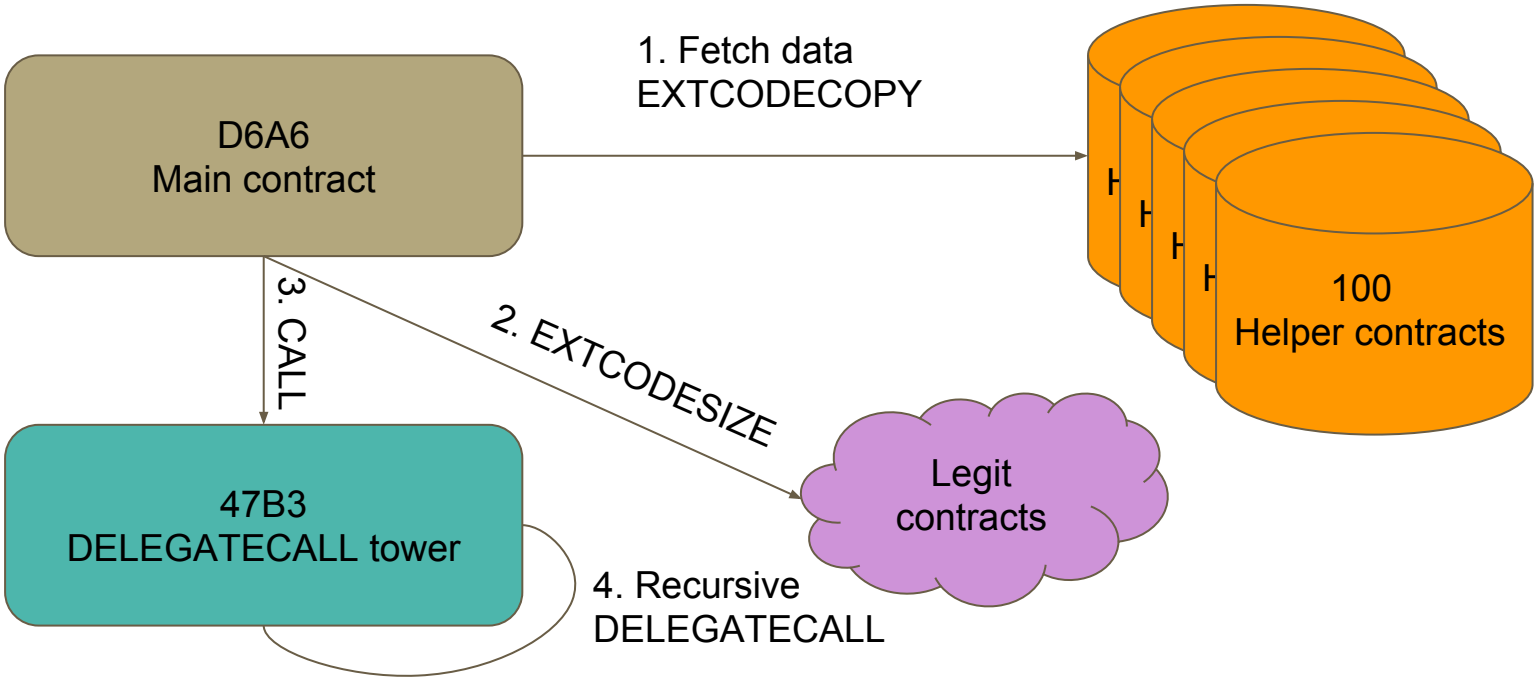
September 18: From shanghai with love



Helpers

```
191c7da3941d55030ccf1738794ca36b4bf7f096 191ca3d1d47889dbc815e21509473400283cf875
592b557898080648e0ab45fbc147a789627be8a3 824804539b13b9cc3e4961ee8a45b71266aa6edd
7add626ef7c48df8debca5538d3d74a98ce354b1 51c6e9f300dfaf7ce3be314276c5f5bd6cda7452
14a6e26df1936e1166942a482138b83da74abe7f ed09d52418909d91398a809dfcf492a9915cec7f
199b55303d6bdd3e603abed3283b4c5ab01707a0 4124bdba90bc2dd4ceb4b3b620a0249a533deb77
d27f6c7fc9abe8c06d6d645957c3bc64fe5843ee 4c00c95155a1bcb15fee20b9180f8420cac4fdff
60152d8a48bfd55ee8a3c6af500c79cd2c63dd80 e2c9f65aad44367296cc3446bc64d67e276a695c
2b26d137119db89293d91d13c18ffc4aad2d9a0e e09e2af286e60766a3093d22436db48157d26e53
fddb712410853f75da945d4b60ead490988424a7 5d40fc74afdfb82e1460eb8abd25df3ecfef452c
```

XOR

```
fromshanghaiwithlove fromshanghaiwithlove
fromshanghaiwithlove fromshanghaiwithlove
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fromshanghaiwithlove fromshanghaiwithlove
fromshanghaiwithlove fromshanghaiwithlove
```

=

```
7f6e12cee775346d6ba776510e25d703279886f3 7f6eccbca710e8b5af7d837c7e2e406844538e10
3f593a15eb60672687c32492b62ed3e10e149ec6 e43a6b3ee87bd8a259210087fd2cc37a0ac518b8
1caf0d0384acec96b9d4c43afa5400c1e08c22d4 37b4869e73b7ce1284d6502b01ac81d500b50237
72d48d0082fb0f7f01fc4b215651cc55cb25c81a 8b7bba496bf8fcff5ee2e1f48b9de6c1fd339a1a
7fe93a5d4e03bc500752dfba5f523832dc7871c5 2756d2d7e3d44cbaa9dcd2df57c950f23f529d12
b40d0312bac389ae0a05053020aac80c9237358b 2a72a63c26c9dddf388641d06f66f048a6ab8b9a
066742e73bd7b4308fcba7c627650da5400cabe5 84bb9937de2c571cf1a4552fcb0da2164b051f39
4d54be5a62f5d9fcf4b17c7ab6e68822c142ec6b 86ec459ff58e6608c4615c4b3404c0e93bbd1836
9ba91e4963ed5e1bbdfc3c221783a0f8f4eb52c2 3b329319dcb7d94073088ae3ca4cab56a3803349
```

Amplification

0x47B3 : A recursive DELEGATECALL

```
# Stack: []
0x2    JUMP(:label0)

:label0
# Stack: []
0x4    PUSH(0x0)
0x6    DUP1
0x7    DUP1
0x8    DUP1
0xE    PUSH(DELEGATECALL(GAS() - 0x2B, ADDRESS(), POP(), POP(), POP(), POP()))
0xF    STOP()
```

Sidenote: About DELEGATECALL

The `DELEGATECALL` opcode can be thought of as borrowing code from another account. It means:

- I want to execute code at X, as if it was my code
  - within my own context and address

Whereas a CALL would execute within the callee-account, a DELEGATECALL executes within the caller-account.

Effect

- 100 x 512 contracts in memory
- Amplified by 1024

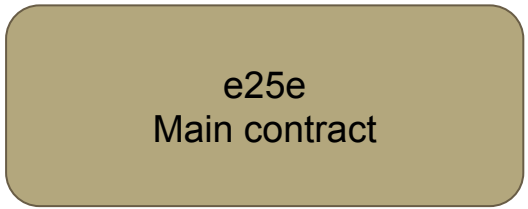
52 428 800 contracts in memory

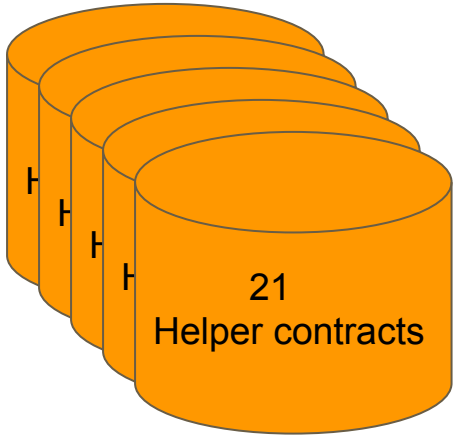
An attack against a client-specific caching mechanism

- Fix in 1.4.12 “From Shanghai, with love”
  - The new version only copied 'dirty' objects in the state cache

September 26: Variant #1

s/EXTCODESIZE/CALL





- Fetches data from helpers (21), XOR:s out addresses (21 * 256 = 5376)
- Performs a 0-value `CALL` to each one

Sidenote: About CALL

The `CALL` opcode is the mechanism used to transfer value in Ethereum, AND to invoke contract execution.

```
contract y{
    function bazonk(){ }
}
contract x{
    function baz(address bar){
        bar.send(1);      // Uses the CALL opcode
        y(bar).bazonk(); // Also uses the CALL opcode
    }
}
```

Effect

- CALL flagged an object as 'dirty'
- When it neared the end of the run, the `CALL` would necessitate a copying of 5000 objects into the new `state` cache.
- Since the dirtyness of the state is increased (linearly), the state copying becomes worse(linearly).

- Fix in 1.4.13 "Into the Woods"
  - Various fixes to state handling, as well as shortcutting transfers of `0`-value, to prevent setting ‘dirty’ flag on those objects.

September 27: Hitting the IO

- Very simple construct
- Fetch code size of ‘random’ addresses
- Causes heavy IO
- On 1.45MGas
  - POP: 2
  - GAS: 2
  - EXTCODESIZE: 20
- 60K lookups

7a30
Main contract

```
:label0
0x3     POP(EXTCODESIZE(GAS()))
0x6     POP(EXTCODESIZE(GAS()))
...
0x13EF     JUMP(:label0)
```

- Fix in prerelease 1.4.14 "What else should we rewrite?”
  - Among other things, this contained a codesize cache.

October 3: SLOAD quad attack

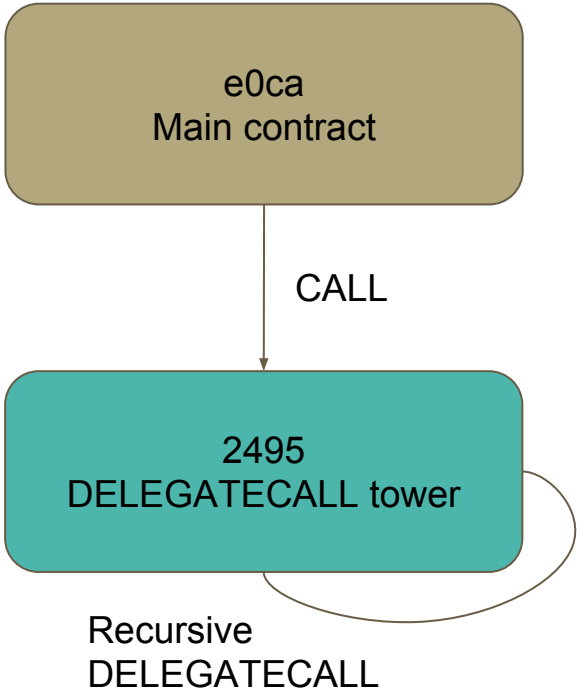
1. Setup section:

- While gas left, write '1' to next storage slot
- Update slot '0' with last slot
- Return

Called 457 times, filling 6754 slots

2. Execution section:

- Do 'SLOAD' on all storage slots 6,7K
- Call DELEGATECALL tower



Sidenote - What sources of data are there?

Storage: The persistent data-storage area where a contract can read/write data for later use. (**per-account**).

Memory: A temporary data area where, during execution, data can be placed. Memory is (**per-context**).

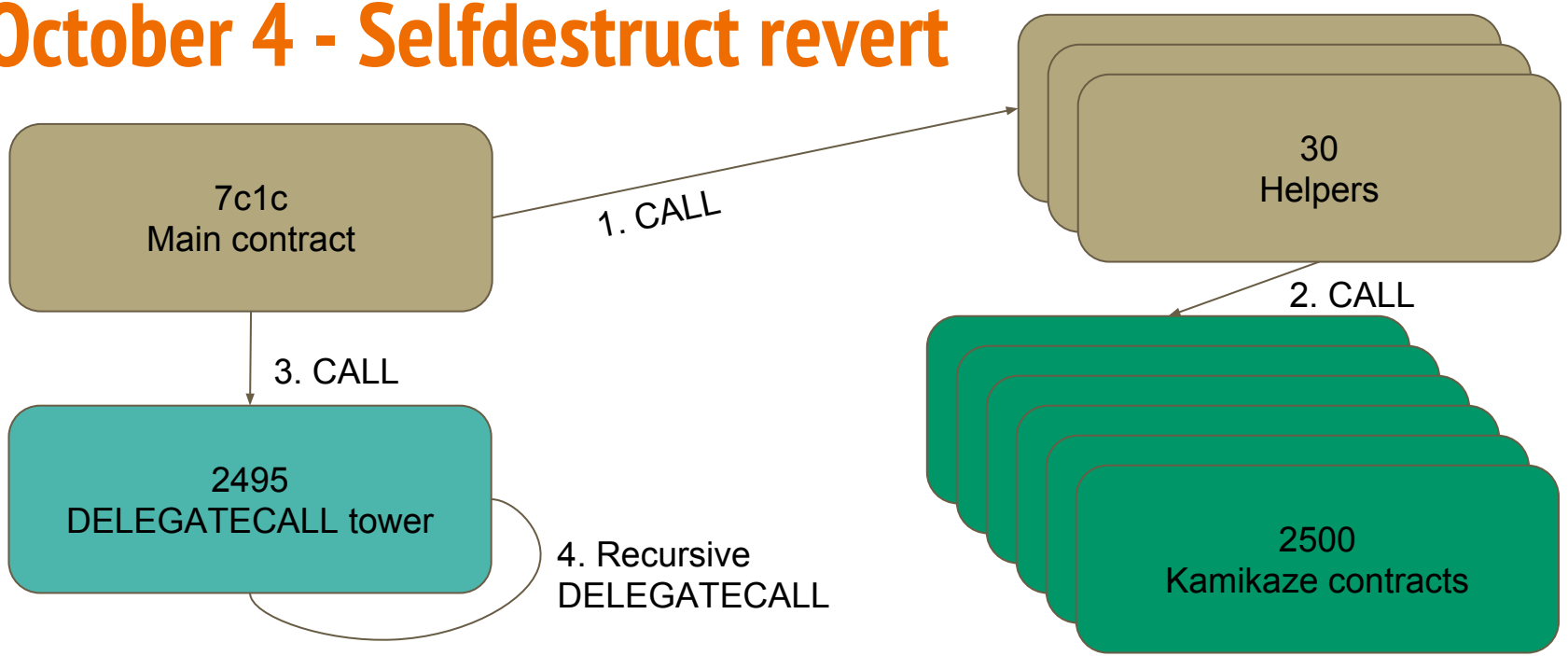
Other data-sources include:

- Calldata - data coming from the transaction (from the caller)
- Code - either own code (CODECOPY) or external (EXTCODECOPY)

Effect

- Very similar to “Shanghai with love” original attack
- Account storage was treated “as a whole”, causing a similar quadratic blowup of state cache during DELEGATECALL recursion
    - Caveat: 6K storage slots are takes less memory than 52M contracts. But quadratic effects are still bad
- Nodes at 100% CPU and 4G memory consumption
- Fix in 1.4.15 "Come at me Bro"
    - Track dirty state entries for each account object.

October 4 - Selfdestruct revert




```
0x1A    JUMPI(ADDRESS, !(0xD3E325.. == ORIGIN()))
0x30    SELFDESTRUCT(0x764D7849..)
```

Sidenote: SELFDESTRUCT

The SELFDESTRUCT opcode is a special snowflake

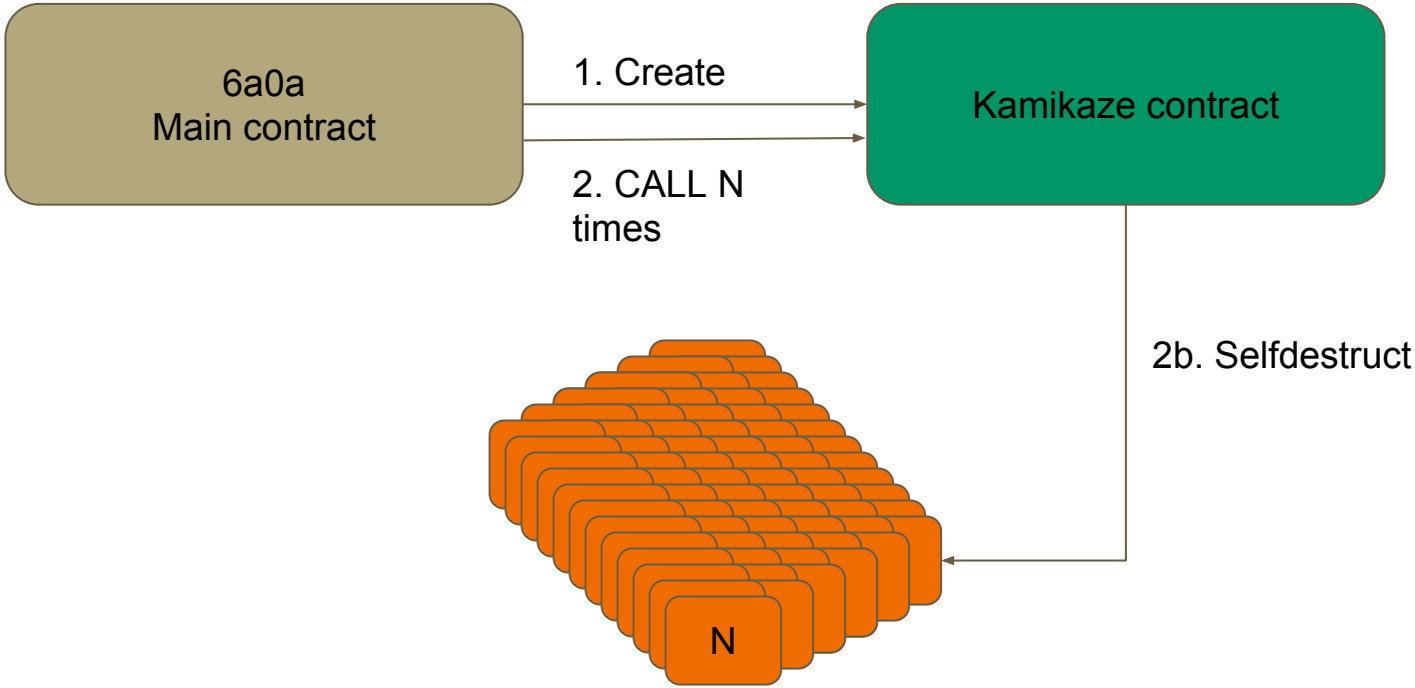
- An account is to be terminated, removing all state (code, storage) associated with the account.
- Very cheap, to incentivise clean-up of data
- Sends remaining funds to a beneficiary
- Terminates the current call
- Quirk: Can be called multiple times, even after selfdestruct has occurred
- … And all of this work is wasted/reverted in the case of OOG…

October 4 - Selfdestruct Revert (with a twist)

- Same as before, but also endowing each selfdestructor with 1 wei
  - (1 wei = smallest unit of ether)
- The attack(s) require quite a lot of set-up, in order to create the kamikaze contracts

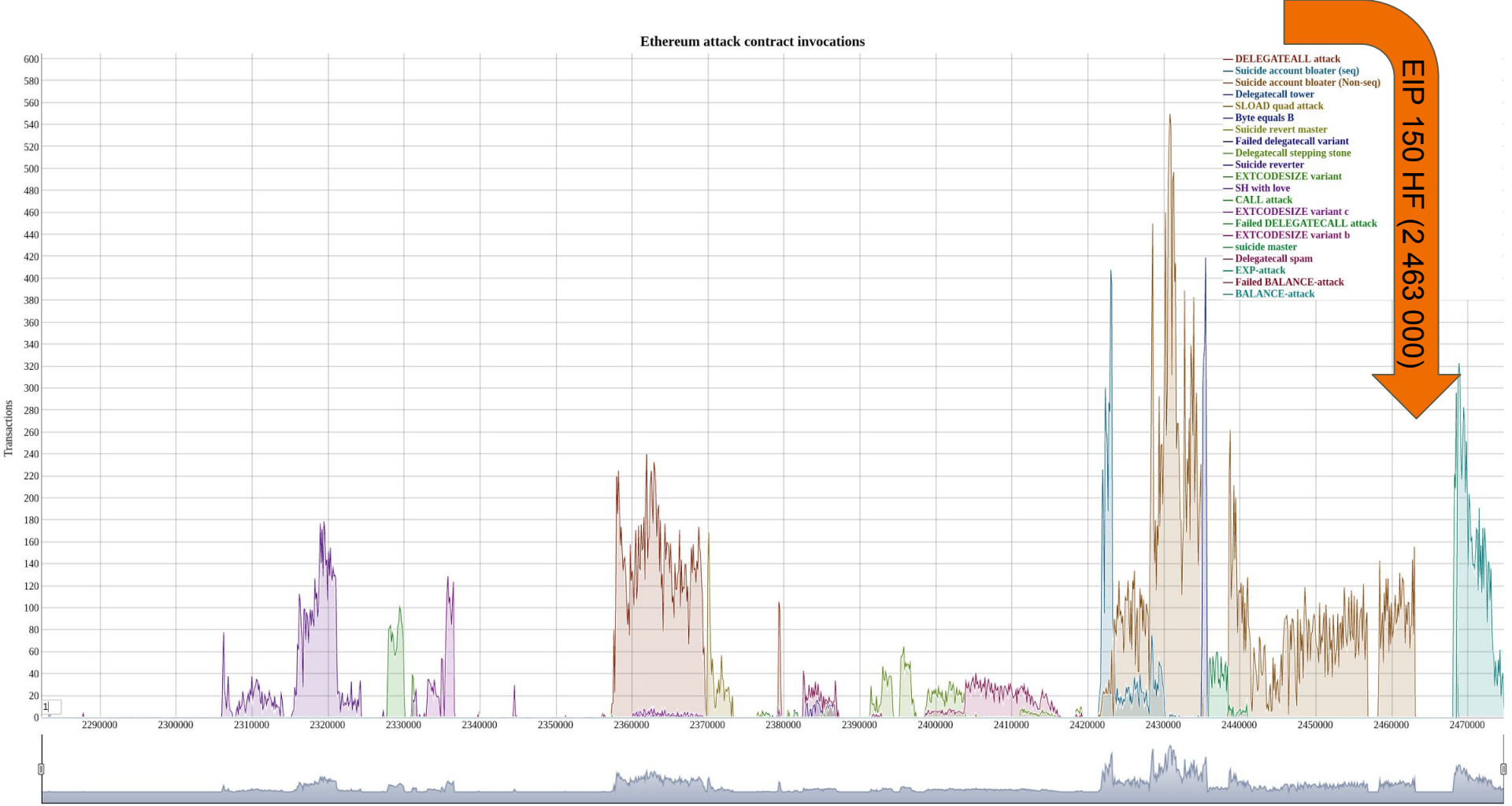
- Fix in 1.4.16 “Dear Diary” on October 6
  - Implemented state journaling, which makes state writing and reversion a linear operation.

October 11 : Kill-off and The Suicide State Bloat



Effects

- On October 13, the EIP150 HF was announced
- During the remaining time, the state bloat attack continued.
- Other attacks were also carried out:
  - EXP-attack
  - DELEGATECALL-spam
  - BALANCE-attack
- On October 18, EIP150 Rolled out at 2463000
- An estimated total of > 19M accounts were then created in the state
- Another HF (Spurious Dragon) facilitated cleanup of state
  - https://github.com/ethereum/statesweep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END

Questions?

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