Lecture 10

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Software Testing

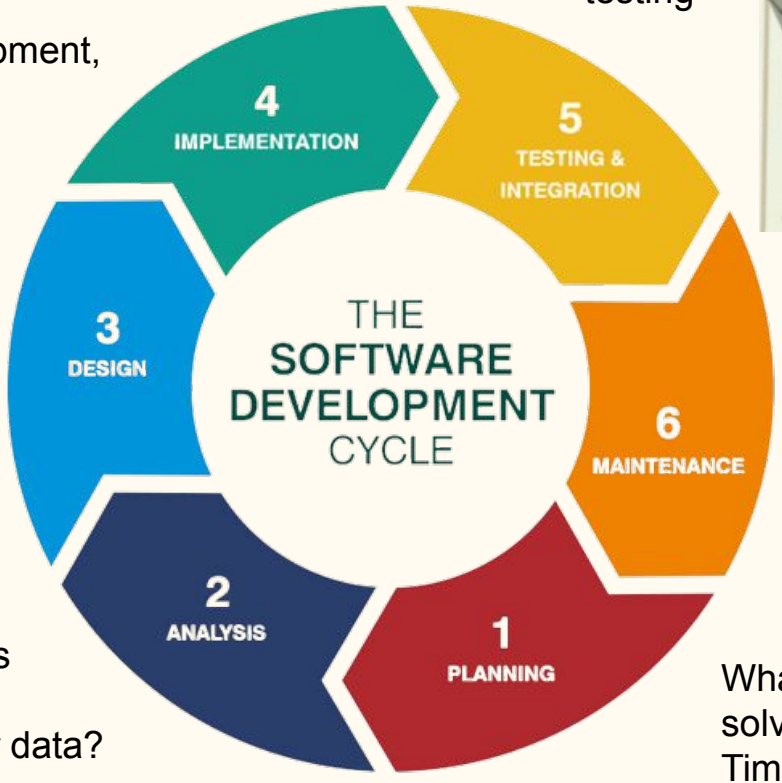
Software Development Lifecycle

Idea to prototype

6 Stages of SDLC

Actual code development, debugging

Security risks, edge case, stress testing



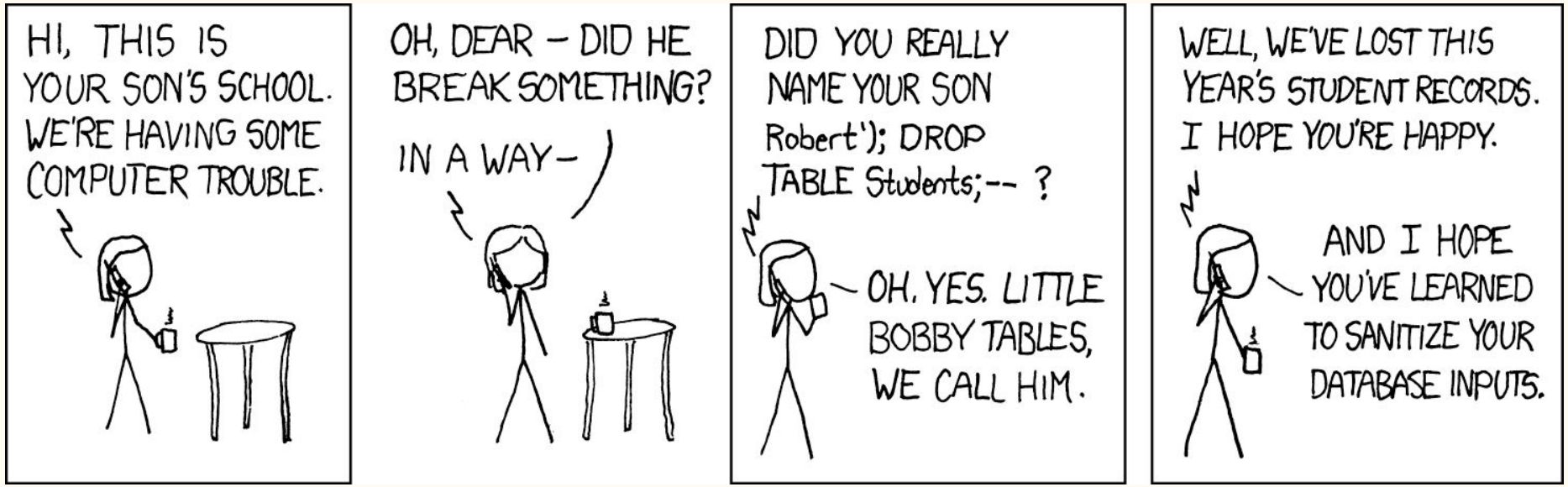
UI/UX, psychological factors
Product Architecture, libraries, licenses, etc

Continuous improvement, product competitive analysis, consumer feedback integration

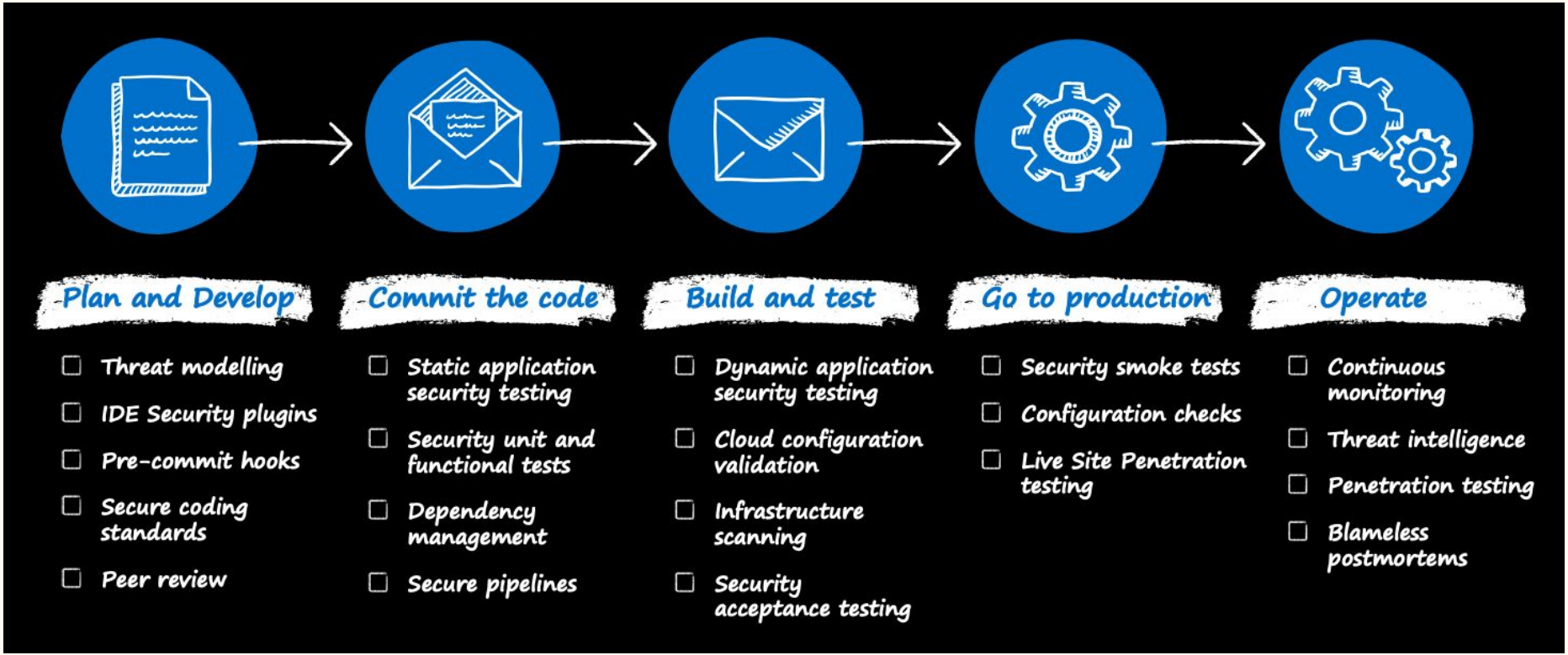
Requirements and Risks
Financial - users? gas?
Technical - faster, better data?

What problem is our software solving / market being captured?
Timeline, teams, budget.

Testing - protection against users



From DevOps to DevSecOps



Functional Tests

Unit Test

Test small chunks - units. Can be a function, interface, module.

Write tests as you code!

Test expected failures and event emissions.

Test edge cases.

Forge problem - cannot test private functions

Functional- works as expected?

Non-functional - can it handle simultaneous connections? Is it cheap?

Integration Test

Different modules tested as an entity.

Checks conditions unit testing cannot detect - code interaction

Either logical test suites or black box testing.

Integrated Foundry Test Suite

Fuzz Testing

Automatic input of extreme, malformed data into a function.

function testFuzz_name(uint x){}

assume();

runs: # attempts
μ - mean gas used
~ - median gas used

Invariant Testing

Project wide coverage instead of unit testing. Check for conditions which must always hold true. Eg. balance Mapping = total circulating supply

function invariant_name(){}

config - runs, depth

runs: # attempts
calls: # func called
revert: # revert triggered

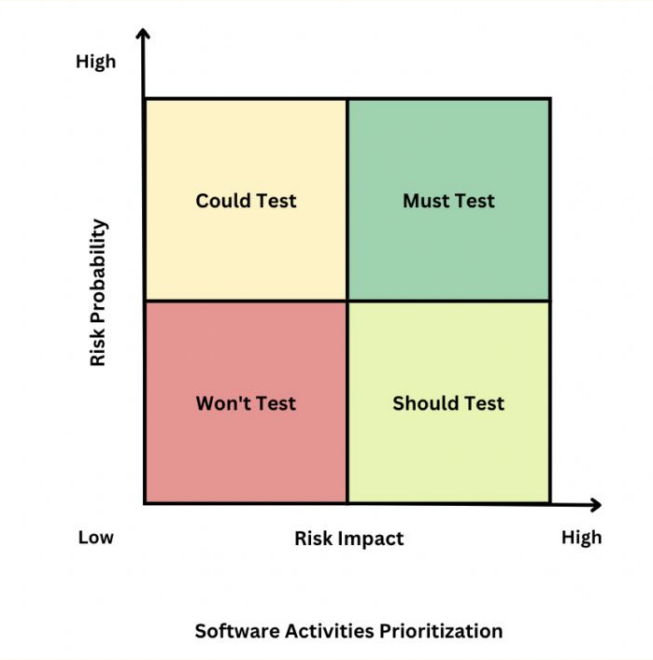
Differential Testing

Cross reference your implementation in another context.

This requires execution of non-Solidity code using the ffi command to compare against Solidity code

Test Coverage

Lines of code reached by test / total # of lines in project



- "debug" flag prints out which functions were not tested.
- Discover which functions are called the most frequent - increase security, decrease gas cost
- Remove redundant tests
- Refactor unused functions

Code Coverage vs Test Coverage
Quality vs Quantity
100% is NOT the ideal

1. View summarized coverage:

```
forge coverage
```

2. Create lcov file with coverage data:

```
forge coverage --report lcov
```

3. Output uncovered code locations:

```
forge coverage --report debug
```

Common Attacks

Reentrancy Attack

```
Contract Bank {

  function withdraw(uint amount){
        msg.sender.call(value: amount);
  }
}
```

1. Request withdraw

2. Bank sends, goes to fallback function

3. Fallback function calls withdraw again! Re-enters the Bank

```
Contract Attacker {

   function attack() external payable{
         withdraw();
   }
   fallback() external payable {
         Bank.call("withdraw()");
   }
}
```

- Uniswap/Lendf.Me hacks (April 2020) – $25 mln, attacked by a hacker using a reentrancy.
- The BurgerSwap hack (May 2021) – $7.2 million because of a fake token contract and a reentrancy exploit.
- The SURGEBNB hack (August 2021) – $4 million seems to be a reentrancy-based price manipulation attack.
- CREAM FINANCE hack (August 2021) – $18.8 million, reentrancy vulnerability allowed the exploiter for the second borrow.
- Siren protocol hack (September 2021) – $3.5 million, AMM pools were exploited through reentrancy attack.

Simulate in Remix!

Reentrancy Guards

Check-Effect-Interaction coding pattern

```
contract ChecksEffectsInteractions {

    mapping(address => uint) balances;

    function deposit() public payable {
        balances[msg.sender] = msg.value;
    }

    function withdraw(uint amount) public {
        require(balances[msg.sender] >= amount);

        balances[msg.sender] -= amount;

        msg.sender.transfer(amount);
    }
}
```

1. Reentrancy Modifier
   a. A modifier which contains a bool which turns true the first time a function is call in a transaction
   b. Prevent recursive calls from external contracts and itself.
2. Pull payments
   a. Do not allow direct push contract interactions
   b. To withdraw, users/contracts make a payment request and then call a separate withdraw pool themselves instead of the contract sending.
3. Pausable Contract
   a. Contract logic of what to do in an emergency

Denial of Service Attacks - Forced Revert

Very frequent on the internet, not just web3. Cause the service to fail from unexpected behaviour.

```
// INSECURE
contract Auction {
    address currentLeader;
    uint highestBid;

    function bid() payable {
        require(msg.value > highestBid);

        require(currentLeader.send(highestBid)); // Refund the old leader, if it fails then revert

        currentLeader = msg.sender;
        highestBid = msg.value;
    }
}
```

What if the current leader has a fallback function that rejects any attempt to send money?

Denial of Service Attacks - Gas Limit

Choke the contract with requests → Remember Black Thursday?

How about a bot contracts which floods the blockchain with useless blocks for a set period of time?

1. On May 1, 2022, a DDoS attack brought down the Solana network for seven hours due to a non-fungible token (NFT) minting tool, "Candy Machine." The downtime was reportedly caused by bots taking over the tool and flooding the network with over 4,000,000 transactions per second at its peak before it went down.
2. On September 14, 2021, Arbitrum One experienced a DDoS attack, one of Ethereum's largest layer 2 protocols. Sequencer — the entity which receives and reorders transactions on its network — was overwhelmed by a flood of transactions that brought down the network for nearly an hour.

The dangers of dynamic arrays - a payout for contributors example

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```
struct Payee {
    address addr;
    uint256 value;
}

Payee[] payees;
uint256 nextPayeeIndex;

function payOut() {
    uint256 i = nextPayeeIndex;
    while (i < payees.length && gasleft() > 200000) {
      payees[i].addr.send(payees[i].value);
      i++;
    }
    nextPayeeIndex = i;
}
```

Griefing - Business Logic Attack

1. Malicious but compliant attacks to disrupt business operations.

➔ A group staking contract which pays dividends 24 hours after last deposit.
➔ Attacker keeps on putting tiny deposit amount to ensure payouts keeps on getting delayed.

2. Insufficient Gas Griefing - Wallet and Relayers

➔ A malicious relayer can first pose as legitimate transaction handler, get wallets to send them transactions, then purposefully set a small gas limit, resulting in no transactions ever go through.

3. Self destructing contracts

➔ The self destruct command erases a smart contract and force sends the remaining ether to a target address. Deprecated by EIP-6049 in 2022.

Replay Attack - Importance of nonces

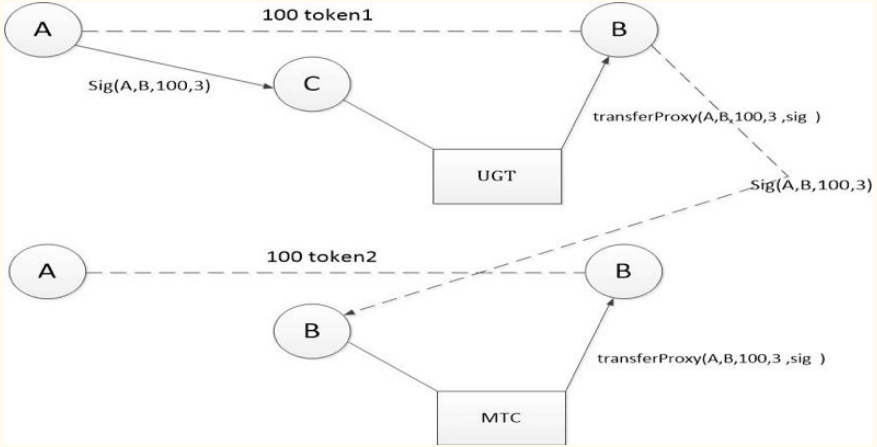
Signed Transaction


```
{
  nonce: "0x0",
  maxFeePerGas: "0x1234",
  maxPriorityFeePerGas: "0x1234",
  gas: "0x55555",
  to:"0x07a565b7ed7d7a695fe0",
  value: "0x1234",
  data: "0xabcd",
   v: "0x26",
   r: "0x223a7c9bcf20e",
   s: "0x28cc7704971491663",
   hash: "0xeb0d46df3870f8a30e"
}
```


```
function action(uint256 _param1, bytes32 _param2, bytes memory _sig) external {
    bytes32 hash = keccak256(abi.encodePacked(_param1, _param2));
    bytes32 signedHash = hash.toEthSignedMessageHash();
    address signer = signedHash.recover(_sig);

    require(signer == owner, "Invalid signature");

    // use `param1` and `param2` to perform authorized action
}
```



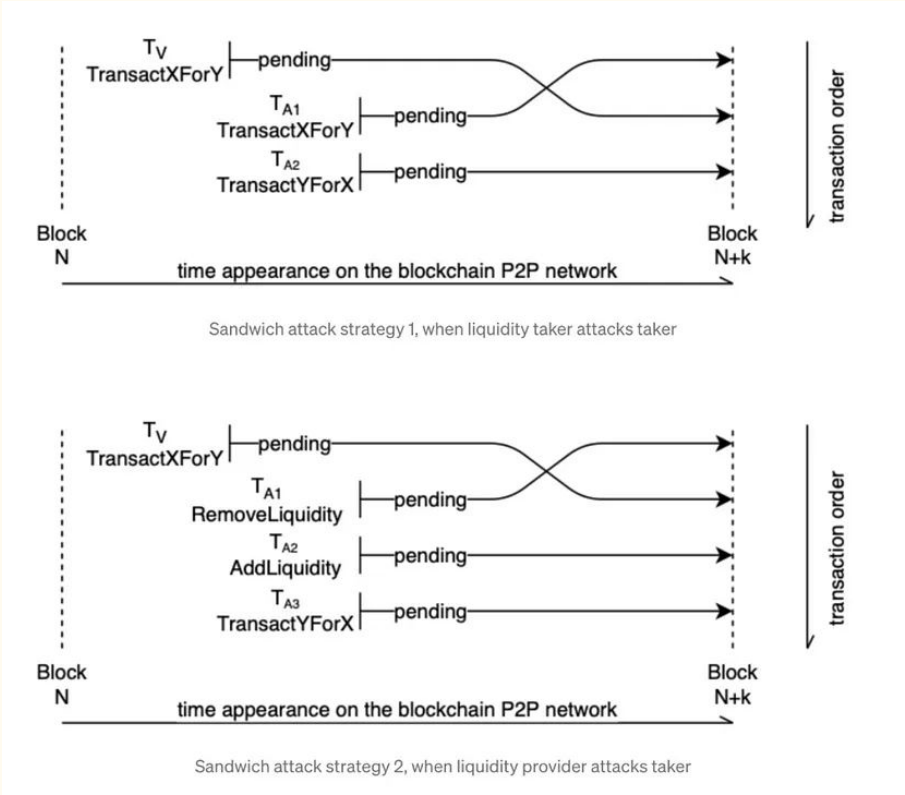
Toxic MEV - Front Running

- ➔ Scan for a winning transaction
- ➔ Simulate the transaction on a fork of the chain
- ➔ Submit your transaction with a much higher gas limit

```
function guess(uint256 number) public payable {
    require(msg.value == 1 ether, "Submission fee required");
    uint256 balance = address(this).balance;
    require(balance != 0, "Game has ended");

    bytes32 userChallenge = keccak256(abi.encode(number));
    if (userChallenge == challenge) {
        (bool success, ) = msg.sender.call{value: balance}("");
        require(success, "Transfer failed");
    }
}
```

Toxic MEV - Sandwich Attack



1. Victim identifies arbitrage opportunity
2. Copy the transaction and pay higher gas
3. victim suffers slippage
4. Two transactions lowers price of Y against X, trade all Y forX.

1. Provider sees large order for Y.
2. Remove all liquidity for Y in that pool.
3. Victim suddenly pays high X for little Y.
4. Provider refills pool with Y, normalizing price again.
5. Buys X with remaining Y.

Code level vulnerabilities

- Integer under and overflow, patched in Solidity 0.8.0 onwards
- Pseudo-random number generation
  - block level parameters can be deduced/calculated.
    - block.timestamp
    - block.number
- Incorrect parameter ordering
  - Solidity do not name parameter inputs. Make sure the ordering is correct for structs and functions with many inputs.

Defensive Programming

- Aim for simplicity
  - Less lines of code is cheaper
  - Less code = less room for mistakes
- Be as private as possible
  - Public functions and variables are expensive and potentially open to manipulation. Always try to keep things private.
  - Use external / internal above public.
- Reuse secure code
  - Copy code from the internet. But copy secure code. Openzeppelin, Safe, Eth, etc.
  - Refactor as much as possible. Aggregate similar features into a library.
- Write readable code
  - Natspec commenting as much as possible
  - Clear variable names, follow conventions
- Test! Test! Test!

Cyber Security
&
Smart Contract Auditing

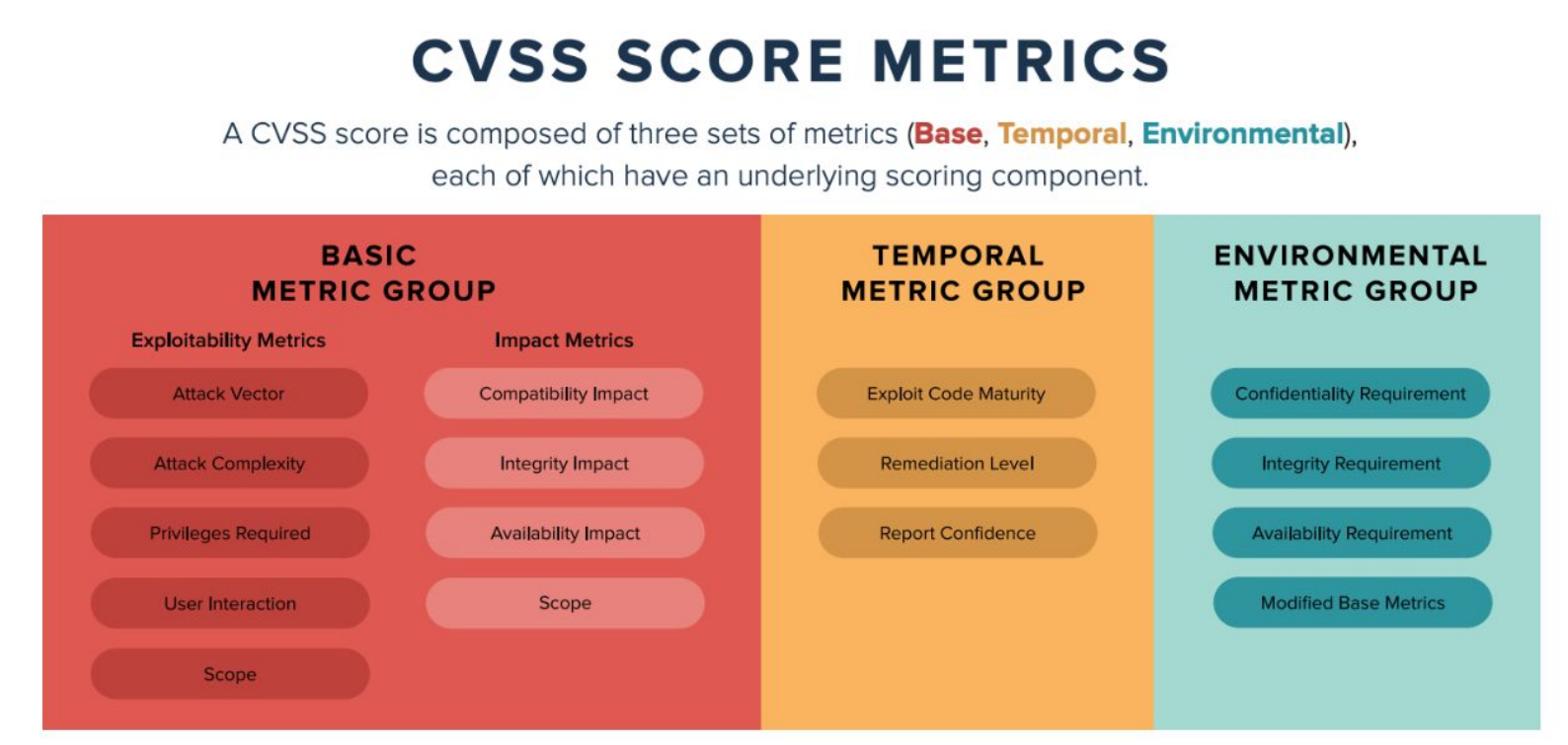
Vulnerability Registries

Cyber Security is a never ending race of discovering vulnerabilities. All vulnerabilities are tracked on registries.

- CWE, CVE, OWASP Top 10, NVD, SWC, SCSVS

Registries differ by area (OWASP is web), vulnerability approach (CWE - flaws/weakness pattern vs CVE - named vulnerability)

CVSS - Common Vulnerability Scoring System



Static / Dynamic Scanners

Static Scanning

- In depth code analysis
- Auto detection of vulnerable coding practices
- Building of intermediate execution flows and recognise attacks
- Taint analysis - detect injection attacks which corrupt data and memory

Dynamic Scanning

- User POV testing
- Send malicious requests
- Network attacks and stress testing
- User behaviour modelling. In the real world, perhaps your user fell victim to social engineering?

SLITHER

List of scanners

SolidityScan

No solution is perfect

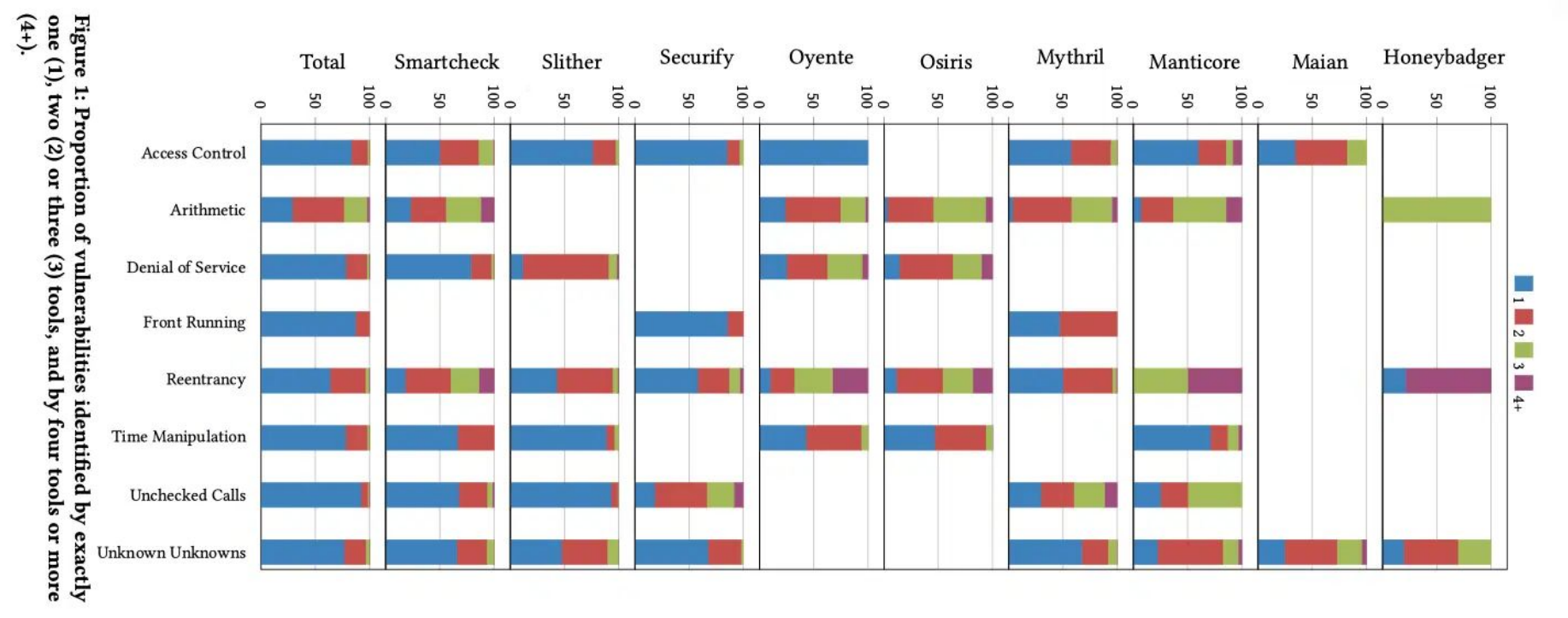


Figure 1: Proportion of vulnerabilities identified by exactly one (1), two (2) or three (3) tools, and by four tools or more (4+).

Source

Accuracy, speed, vulnerability type & age

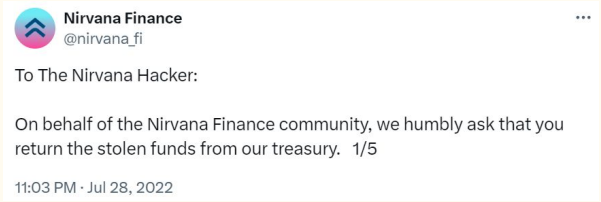
Audit Lifecycle

1. Documentation	2. Automated Testing	3. Manual Review	4. Vulnerability Classification	5. Reporting
Code freeze and scope agreement. Provide all specifications, system architecture and intended execution of system.	Dynamic and Static scanning. Formal Verification. Custom test suites.	Humans are better at detecting logic errors, poor coding patterns and business manipulations like gas attacks. Analysis of code with consultation to original goals and specifications.	A list of vulnerabilities with their risk levels. Provide recommended resolution techniques. **** Note:** From a business perspective, each vulnerability is a cost. Weigh it against the cost of the exploit.	Provide initial report with findings. Provide further consulting for the client. Most Web3 projects release their audits publicly to gain confidence from the public.

Cost: $5000 - $15000

Social Bug Finding

The "please give our money back" method



First account of Indictment

Payouts

There is a 2X bounty multiplier until September 30th, $50,000. The payouts vary according to severity. For ar

client through an on-chain data request, an additional

Severity	Payment in LINK
Low	$2,000
Medium	$4,000
High	$8,000
Critical	$16,000