OST
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Blockchain (BlCh)

Solidity

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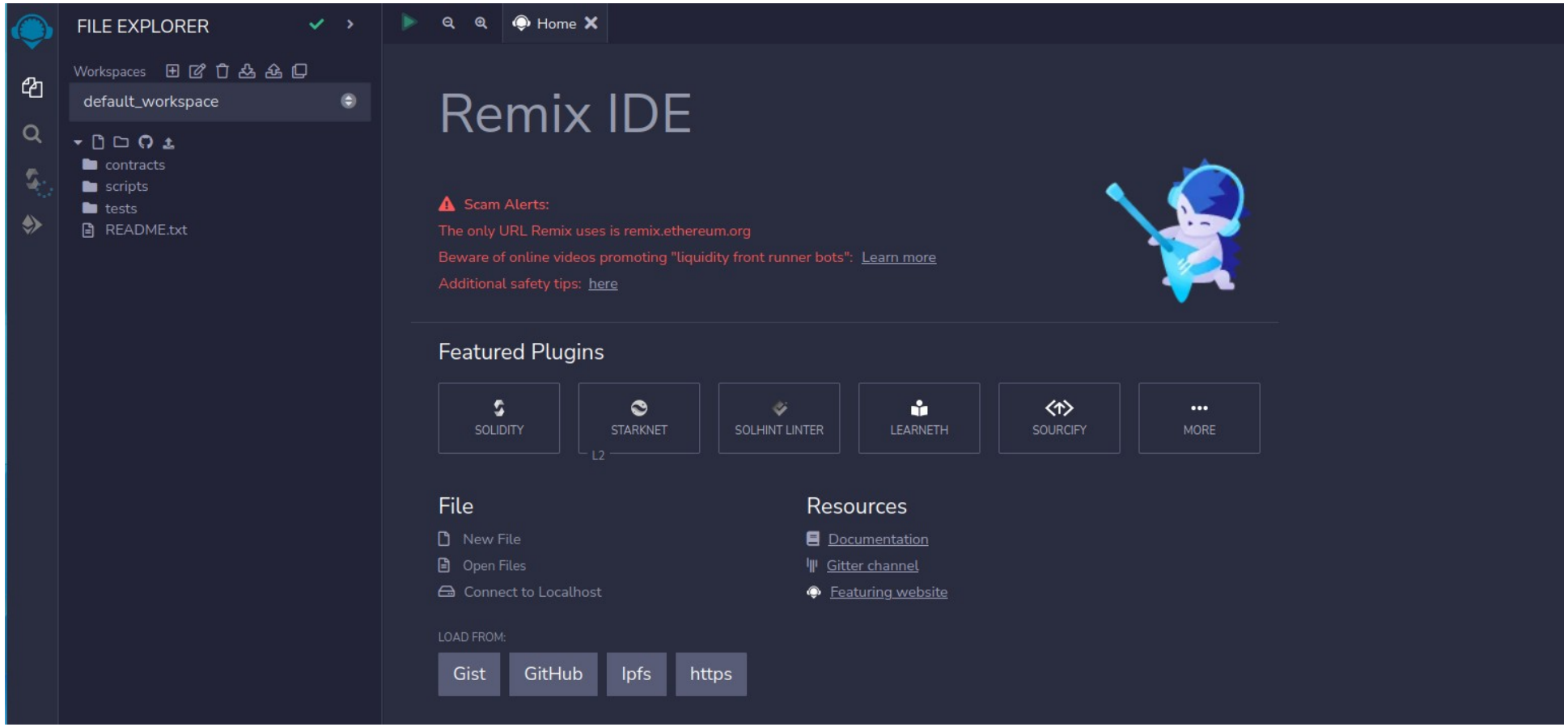
08.10.2023

Solidity IDE

- https://remix.ethereum.org
  - IDE e.g., in combination with Solidity Intellij plugin (not ideal)



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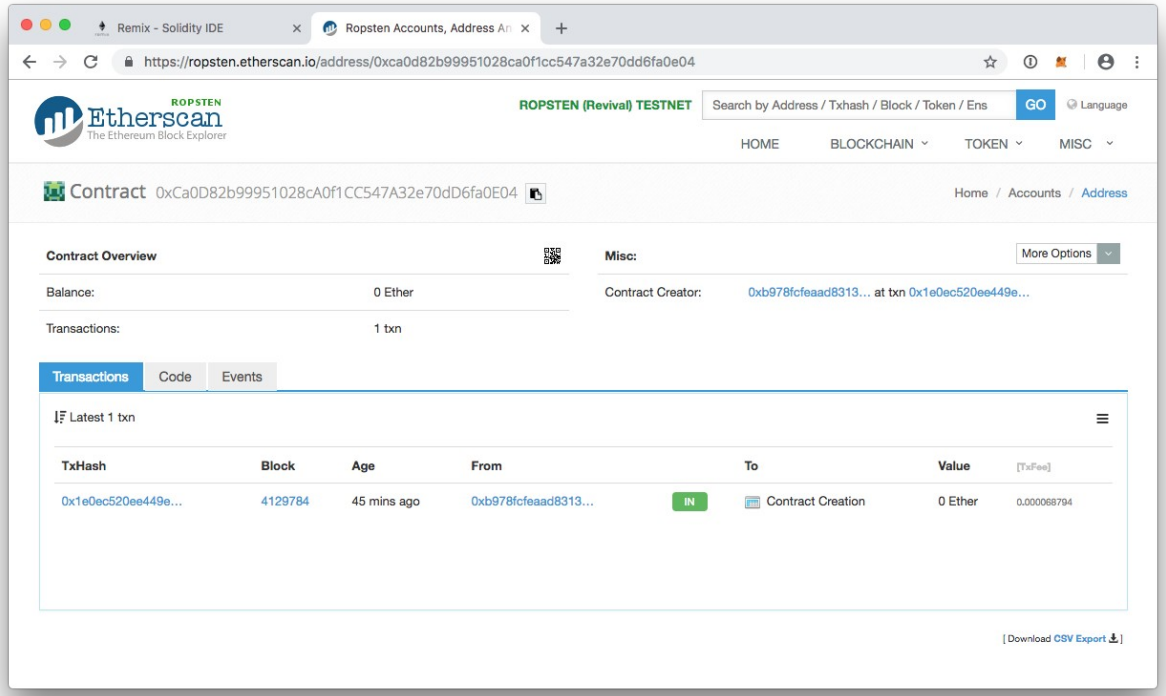
Check Deployment

- Etherscan is a public blockchain explorer
  - Shows all transactions, blocks, understands tokens, also works for testnets
  - Mine you first contract! 🎉



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Gas: Ethereum's Fuel

- Price that is paid for running a transaction or a contract in the Ethereum VM (EVM)
- EVM: can execute instructions (opcodes) → yellow paper (on the right)
- Unit of measuring computational work
- Every instruction needs to be paid for
- If you run out of gas, state is reverted, ETH gone

APPENDIX G. FEE SCHEDULE

The fee schedule G is a tuple of 31 scalar values corresponding to the relative costs, in gas, of a number of abstract operations that a transaction may effect.

Name	Value	Description*
G_{zero}	0	Nothing paid for operations of the set W_{zero}.
G_{base}	2	Amount of gas to pay for operations of the set W_{base}.
$G_{verylow}$	3	Amount of gas to pay for operations of the set $W_{verylow}$.
G_{low}	5	Amount of gas to pay for operations of the set W_{low}.
G_{mid}	8	Amount of gas to pay for operations of the set W_{mid}.
G_{high}	10	Amount of gas to pay for operations of the set W_{high}.
$G_{extcode}$	700	Amount of gas to pay for operations of the set $W_{extcode}$.
$G_{balance}$	400	Amount of gas to pay for a BALANCE operation.
G_{sload}	200	Paid for a SLOAD operation.
$G_{jumpdest}$	1	Paid for a JUMPDEST operation.
G_{sset}	20000	Paid for an SSTORE operation when the storage value is set to non-zero from zero.
G_{sreset}	5000	Paid for an SSTORE operation when the storage value's zeroness remains unchanged or is set to zero.
R_{sclear}	15000	Refund given (added into refund counter) when the storage value is set to zero from non-zero.
$R_{suicide}$	24000	Refund given (added into refund counter) for suiciding an account.
$G_{suicide}$	5000	Amount of gas to pay for a SUICIDE operation.
G_{create}	32000	Paid for a CREATE operation.
$G_{codedeposit}$	200	Paid per byte for a CREATE operation to succeed in placing code into state.
G_{call}	700	Paid for a CALL operation.
$G_{callvalue}$	9000	Paid for a non-zero value transfer as part of the CALL operation.
$G_{callstipend}$	2300	A stipend for the called contract subtracted from $G_{callvalue}$ for a non-zero value transfer.
$G_{newaccount}$	25000	Paid for a CALL or SUICIDE operation which creates an account.
G_{exp}	10	Partial payment for an EXP operation.
$G_{expbyte}$	10	Partial payment when multiplied by $\lceil \log_{256}(exponent) \rceil$ for the EXP operation.
G_{memory}	3	Paid for every additional word when expanding memory.
$G_{txcreate}$	32000	Paid by all contract-creating transactions after the *Homestead transition*.
$G_{txdatazero}$	4	Paid for every zero byte of data or code for a transaction.
$G_{txdatanonzero}$	68	Paid for every non-zero byte of data or code for a transaction.
$G_{transaction}$	21000	Paid for every transaction.
G_{log}	375	Partial payment for a LOG operation.
$G_{logdata}$	8	Paid for each byte in a LOG operation's data.
$G_{logtopic}$	375	Paid for each topic of a LOG operation.
G_{sha3}	30	Paid for each SHA3 operation.
$G_{sha3word}$	6	Paid for each word (rounded up) for input data to a SHA3 operation.
G_{copy}	3	Partial payment for *COPY operations, multiplied by words copied, rounded up.
$G_{blockhash}$	20	Payment for BLOCKHASH operation.

$W_{zero} = \{\text{STOP, RETURN}\}$
$W_{base} = \{\text{ADDRESS, ORIGIN, CALLER, CALLVALUE, CALLDATASIZE, CODESIZE, GASPRICE, COINBASE, TIMESTAMP, NUMBER, DIFFICULTY, GASLIMIT, POP, PC, MSIZE, GAS}\}$
$W_{verylow} = \{\text{ADD, SUB, NOT, LT, GT, SLT, SGT, EQ, ISZERO, AND, OR, XOR, BYTE, CALLDATALOAD, MLOAD, MSTORE, MSTORE8, PUSH*, DUP*, SWAP*}\}$
$W_{low} = \{\text{MUL, DIV, SDIV, MOD, SMOD, SIGNEXTEND}\}$
$W_{mid} = \{\text{ADDMOD, MULMOD, JUMP}\}$
$W_{high} = \{\text{JUMPI}\}$
$W_{extcode} = \{\text{EXTCODESIZE}\}$

Solidity Source File

- SPDX License Identifier
  - List, example: // SPDX-License-Identifier: MIT
  - Private code: UNLICENSED
- Version Pragma
  - ```
    pragma solidity ^0.4.24;
    // not before 0.4.24, before 0.5.0
    ```
  - ```
    pragma solidity >=0.4.22 <0.9.0;
    // not before 0.4.22, before 0.9.0
    ```
- Importing
  - ```
    import "filename";
    //into the current global scope
    ```
- Comments
  - ```
    // This is a single-line
    comment.
    ```
  - ```
    /*
    This is a
    multi-line comment.
    */
    ```

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    ```

Solidity Structure

- State variables
  - Stores state persistently, expensive to write!

```
contract SimpleStorage {
    uint256 storedData;
    // state variable
}
```

- Functions
  - Internal or external calls
  - `function bid() public {`

```
  // ...
}
```

- Visibility
  - Specify from where functions can be called
    - Internal / private: only callable internally
      - Internal: can be overridden, private not
    - External: only callable from outside
    - Public: callable from internally / outside
- Types
  - pure
    - No state read or write
  - view
    - No state write but state read
  - payable
    - Can send or receive ETH

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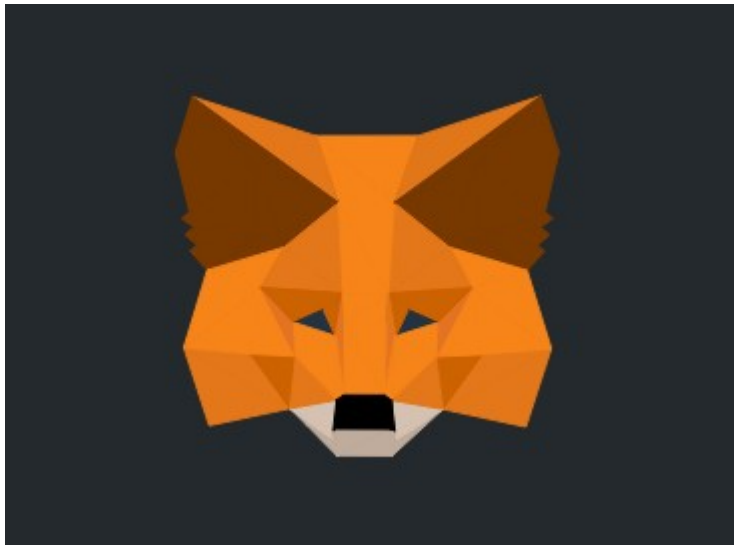
Solidity IDE

- Create a first contract

```
pragma solidity ^0.8.21;
// Minimal contract example
contract SimpleStorage {
    uint256 storedData; // State variable
}
```



- Install MetaMask
- Compile
- Compile and push «Deploy»

Solidity Structure

- Modifiers (e.g., OpenZeppelin)
  - Called before the function, e.g.,
  - ```
    modifier onlyOwner() {
      require(
        msg.sender == owner, "Only
    owner allowed");
      _;
    }
    ```
  - ```
    function abort() public view
    onlyOwner{
            // …
    }
    ```
- Modifier / Function Overriding
  - Functions can be overridden → virtual
  - Function that overrides → override
- Example
  - function test() public view virtual returns (bool)

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Solidity Structure

- Events
  - Communicate to (not from!) the outside
  - `event HighestBidIncreased(string msg);`

```
function bid() public payable {
  // ...
  emit HighestBidIncreased(“hallo”);
}
```

  - Sometimes misused for debugging (hint: use Hardhat, console.log)

- Errors, use with revert
  - `error NotEnoughFunds(uint requested);`

```
function transfer(address to) public {
if (balance < amount)
  revert NotEnoughFunds(amount);
}
```

  - Often require is used, but more expensive
  - `require(balance >= amount, "Not enough");`
  - Not used that often: `assert`
    - For catching bugs in your contract
  - `try/catch` also supported, not for assert, but for require/revert

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Solidity – Events/Notifications

- Events are a way for smart contracts written in Solidity to log that something has occurred
- Interested observers, notably JavaScript front ends for decentralized apps, can watch for events and react accordingly.

Solidity Structure

- Struct
  - Define custom types
  - ```
    contract Ballot {
        struct Voter {
            uint weight;
            bool voted;
            address delegate;
            uint vote;
        }
    }
    ```
- Enum
  - Custom types with a set of ‘constant values’
  - ```
    contract Purchase {
        enum State { Created, Locked, Inactive }
    }
    ```

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Solidity Types and Operators

- Boolean
  - ! (logical negation)
  - && (logical conjunction, “and”)
  - || (logical disjunction, “or”)
  - == (equality)
  - != (inequality)
  - No short-circuit evaluation
    - Probably you should not use it in other languages as well (my opinion)
- Integers
  - int/uint from 8 to 256 bit → e.g, uint256
    - Comparisons: <=, <, ==, !=, >=, >
    - Bit operators: &, |, ^ (exclusive or), ~ (negation)
    - Shift operators: << (left shift), >> (right shift)
    - Arithmetic operators: +, -, unary - (only for signed integers), *, /, % (modulo), ** (exponentiation)
  - Not yet ready: fixed / ufixed → ufixed128x18 (18 decimal points)
- Address
  - `address / address payable`
    - `balance`
    - `transfer`
    - `send`
    - `call, delegatecall and staticcall` - typically use: `ERC721(address).balanceOf(...)`

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Solidity Types and Operators

- Arrays
  - Fixed size or dynamic (slices :)
  - `bytes1 … bytes32`
  - `pop/push/length`
- User-defined Value Types
  - Rarely used in simple contracts
- Data Location
  - storage: often copy
  - memory: references

- Mapping ~hash table (without iteration)
  - ```
    mapping(address => uint) public balances;

    function update(uint newBalance) public {
      balances[msg.sender] = newBalance;
    }
    ```
- Ternary Operator: ?
- Constant / immutable
- Using statement
  - used often before Solidity 0.8 in SafeMath
  - `uint256 amount1 = amount1.sub(amount2);`
  - Now: `uint256 amount1 -= amount2;`

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    ```

Units and Builtin Variables / Control Structures

- Complete list [link]
  - wei, gwei or ether
  - seconds, minutes, hours, days and weeks
  - blockhash, blocknumber
  - block.prevrandao (**new**)
  - block.timestamp
  - msg.data
  - **msg.sender**
  - **msg.value**

- `if, else, while, do, for, break, continue, return`
- Creating Contracts
  - `new` within contract, `web3.eth.Contract` from outside
  - Constructor
- Inheritance
  - Base contracts from OpenZeppelin
  - `contract ERC721 is Context, ERC165, IERC721, IERC721Metadata`
  - `abstract contract / interface`

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Control Structures

- Can a contract deploy another contract?
  - Yes
  - ```
    contract ChildContract {
        string public data;
        constructor(string memory _data) {
            data = _data;
        }
    }

    contract FactoryContract {
        // address of the last deployed ChildContract
        address public lastDeployedAddress;
        function deployChild(string memory _data) public {
            // Deploy a new instance of ChildContract
            ChildContract child = new ChildContract(_data);
            // Store the address of the deployed contract
            lastDeployedAddress = address(child);
        }
    }
    ```

- You probably don't need this: Inline Assembly
  - ```
    assembly {
      // retrieve the size of
      //the code, this needs
      //assembly

      let size :=
        extcodesize(addr)

    }
    ```
- `unchecked{}` → make variables under/overflow
  - Used to optimize gas usage

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Many References / Tutorials

- https://consensys.github.io/smart-contract-best-practices/
- https://learnxinyminutes.com/docs/solidity/
- https://consensys.net/blog/developers/solidity-best-practices-for-smart-contract-security/
- https://www.tutorialspoint.com/solidity/solidity_basic_syntax.htm
- https://docs.soliditylang.org/en/v0.8.21/
- https://www.dappuniversity.com/articles/solidity-tutorial
- https://www.w3schools.io/blockchain/solidity-tutorials/

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