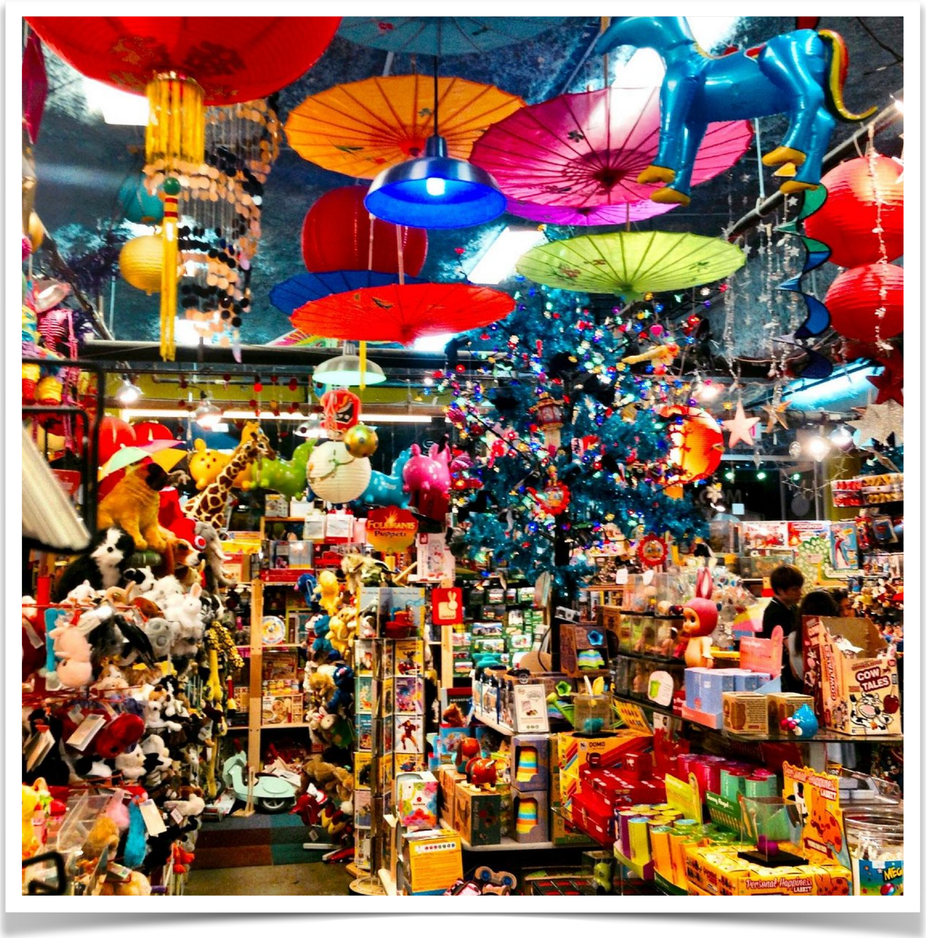

The Power of Toys

Lambda Days 2022

Vouch.io

- Clojurist

- Clojurist
  - Lead developer of ClojureScript ~11 years

- Clojurist
  - Lead developer of ClojureScript ~11 years
- Functional programming in anger for the last 8 years

1 year

5 years

10 years

10+ years

toy (n.)

c. 1300, "amorous playing, sport," later "piece of fun or entertainment" (c. 1500), "thing of little value, trifle" (1520s), and "thing for a child to play with" (1580s). Of uncertain origin, and there may be more than one word here. Compare Middle Dutch *toy*, Dutch *tuig* "tools, apparatus; stuff, trash," in *speeltuig* "play-toy, plaything;" German *Zeug* "stuff, matter, tools," *Spielzeug* "plaything, toy;" Danish *tøj*, Swedish *tyg* "stuff, gear." Applied as an adjective to things of diminutive size, especially dogs, from 1806. *Toy-boy* is from 1981.

toy model (n.)

a simplified set of objects and equations relating them so that they can nevertheless be used to understand a mechanism that is also useful in the full, non-simplified theory.


POST
1932

- Value Oriented Programming

- Value Oriented Programming
  - Including the databases!

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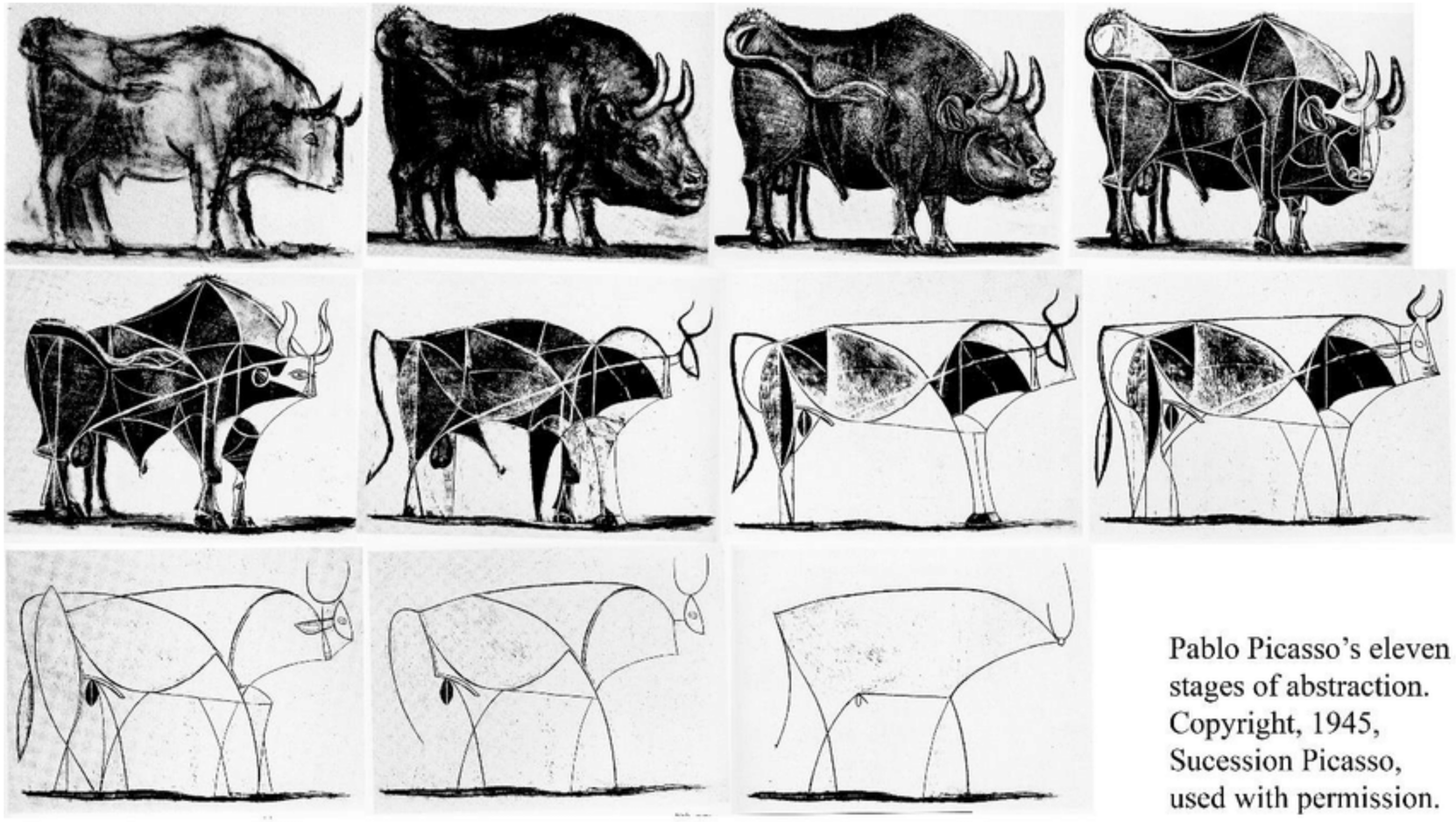
  - Including the databases!
- Symbolic representation / evaluators

- Value Oriented Programming
  - Including the databases!
- Symbolic representation / evaluators
- Stateful Property Based Testing



Pablo Picasso's eleven stages of abstraction. Copyright, 1945, Sucession Picasso, used with permission.

Abstraction - not as process of *generalization* (a risky endeavor) - but process of *toyification*

Value Oriented Programming

Value Oriented Programming

- Programming with values

Value Oriented Programming

- Programming with values
- Functions take state as value and return a new state

Value Oriented Programming

- Programming with values
- Functions take state as value and return a new state
- Make a toy. Everything of interest is in the state - no externals. A single "database"

Symbolic Commands

Symbolic Commands

- Toy model language - Do X, Do Y …

Symbolic Commands

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- No arguments other than *names*

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- No arguments other than *names*
  - `[:share-key :person-a :person-b]`

Symbolic Commands

- Toy model language - Do X, Do Y …
- No arguments other than *names*
  - `[:share-key :person-a :person-b]`
- No programmatic constructs of any kind

Stateful Property Based Testing

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- Verify properties of interest of the toy model by *generating* instructions

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- Verify properties of interest of the toy model by *generating* instructions
- Avoids implicit dependencies / constraints

Stateful Property Based Testing

- Verify properties of interest of the toy model by *generating* instructions
- Avoids implicit dependencies / constraints
- Toy-ify the search problem to avoid trivial scenarios.

PBT in a Nutshell

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- Instead of unit testing with hard coded values, *generate* values - with good distribution but also reproducibility (PRNG)

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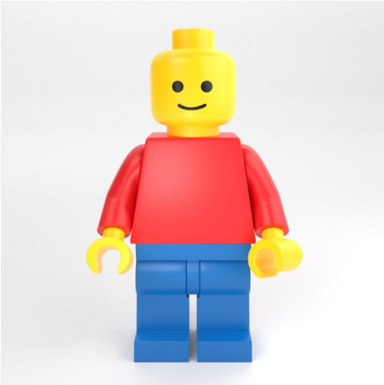
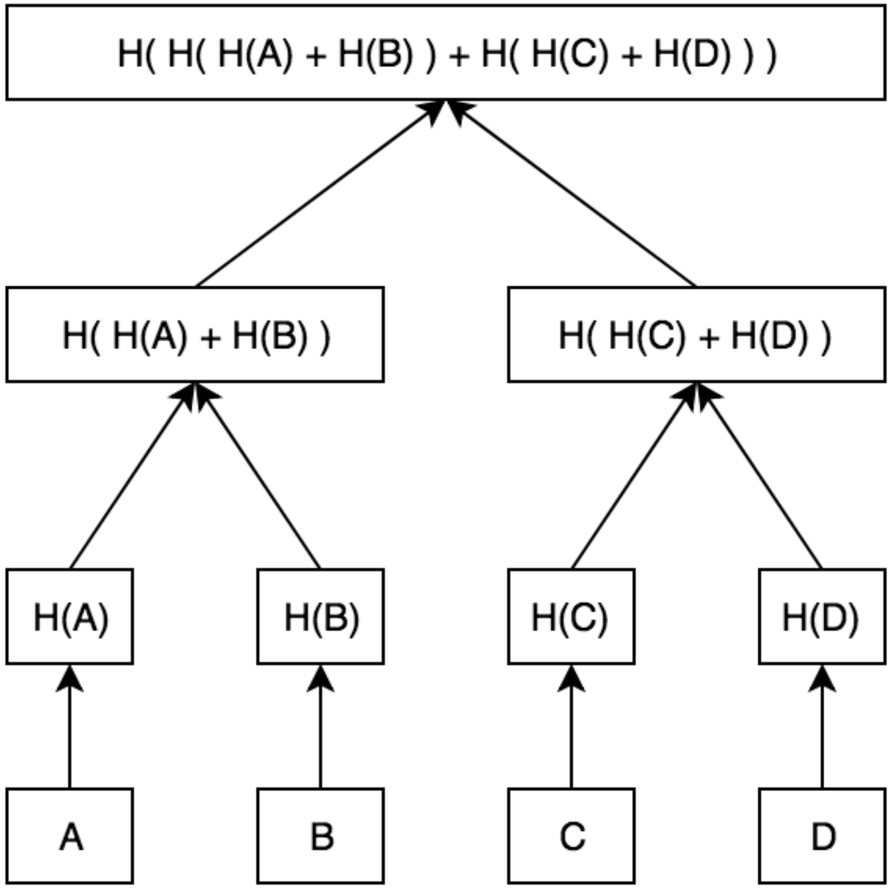
- Instead of unit testing with hard coded values, *generate* values - with good distribution but also reproducibility (PRNG)
- If a test fails - search for the “smallest” input that causes the failure - “shrinking”

Identities & Assets on the Blockchain

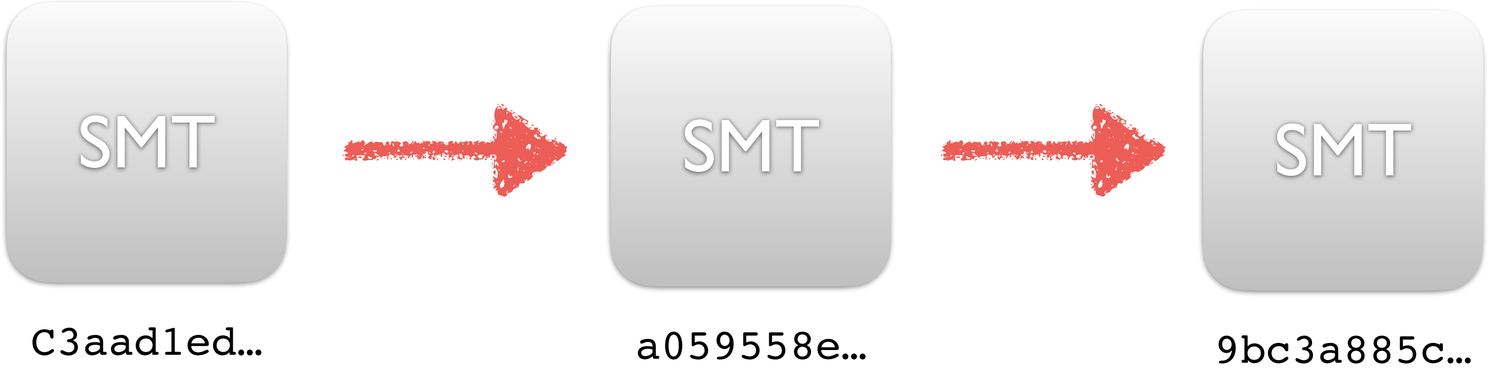


SMT

C3aad1ed…



Sparse Merkle Tree (SMT)


SMT
SMT
SMT
C3aad1ed...
a059558e...
9bc3a885c...

- Every transaction to the blockchain is recorded

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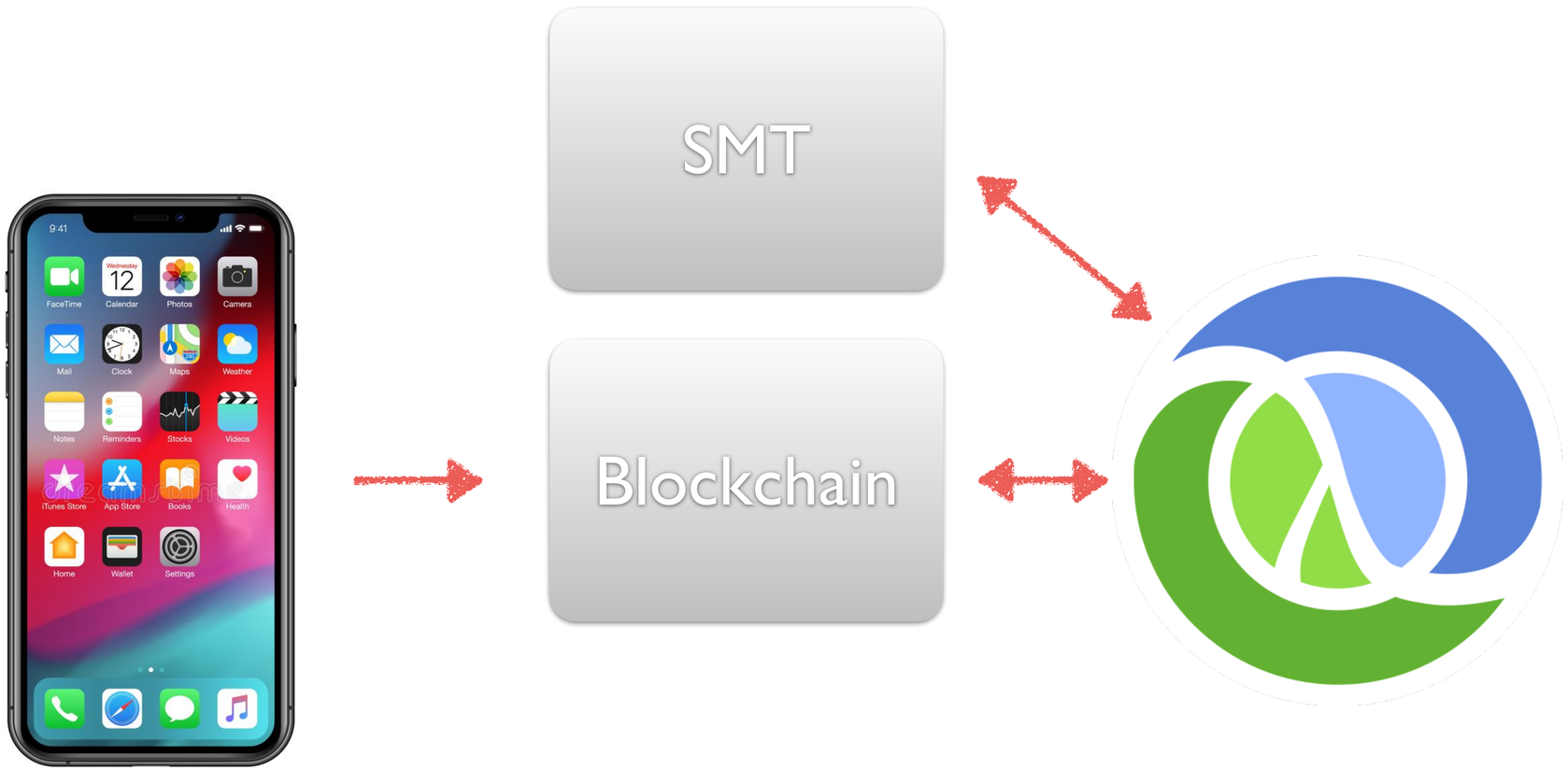
- Can bring up a new node to the same state as the others by playing back transactions

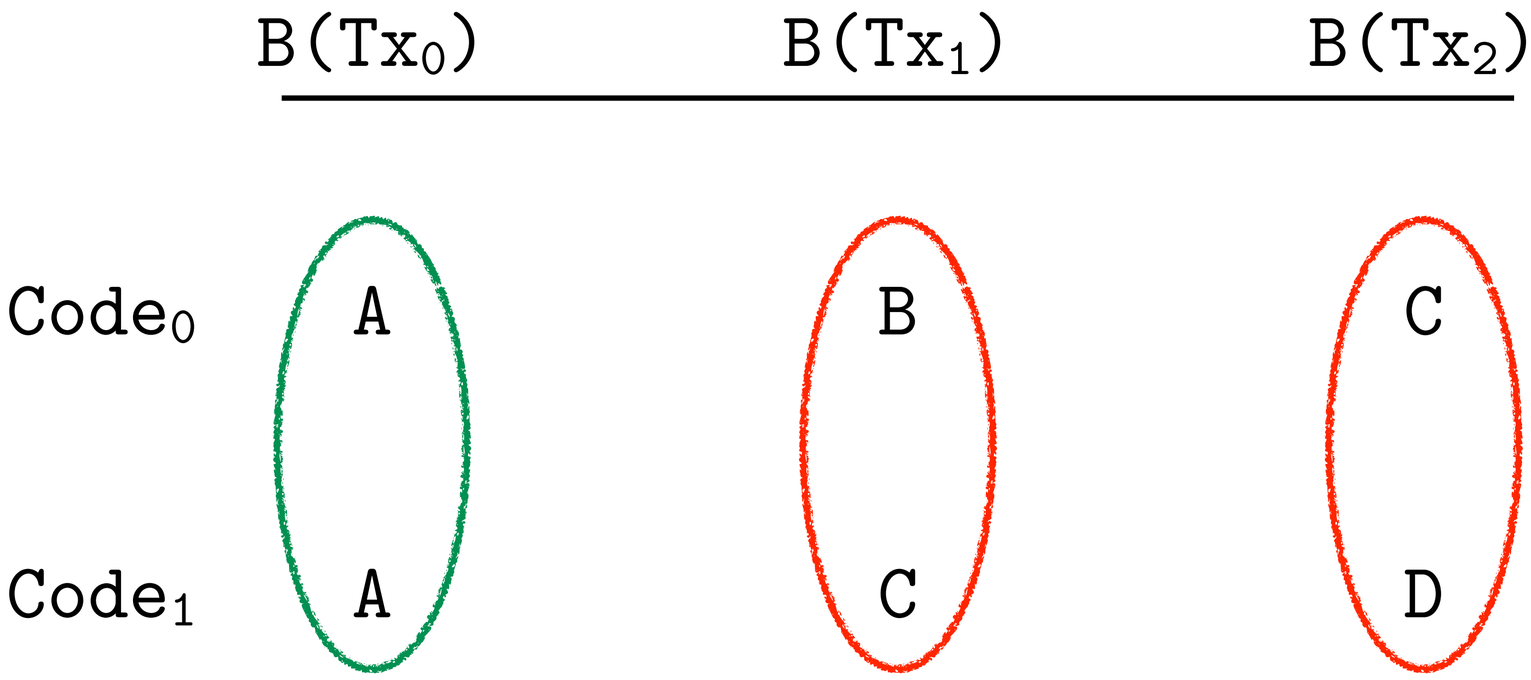

SMT
Blockchain

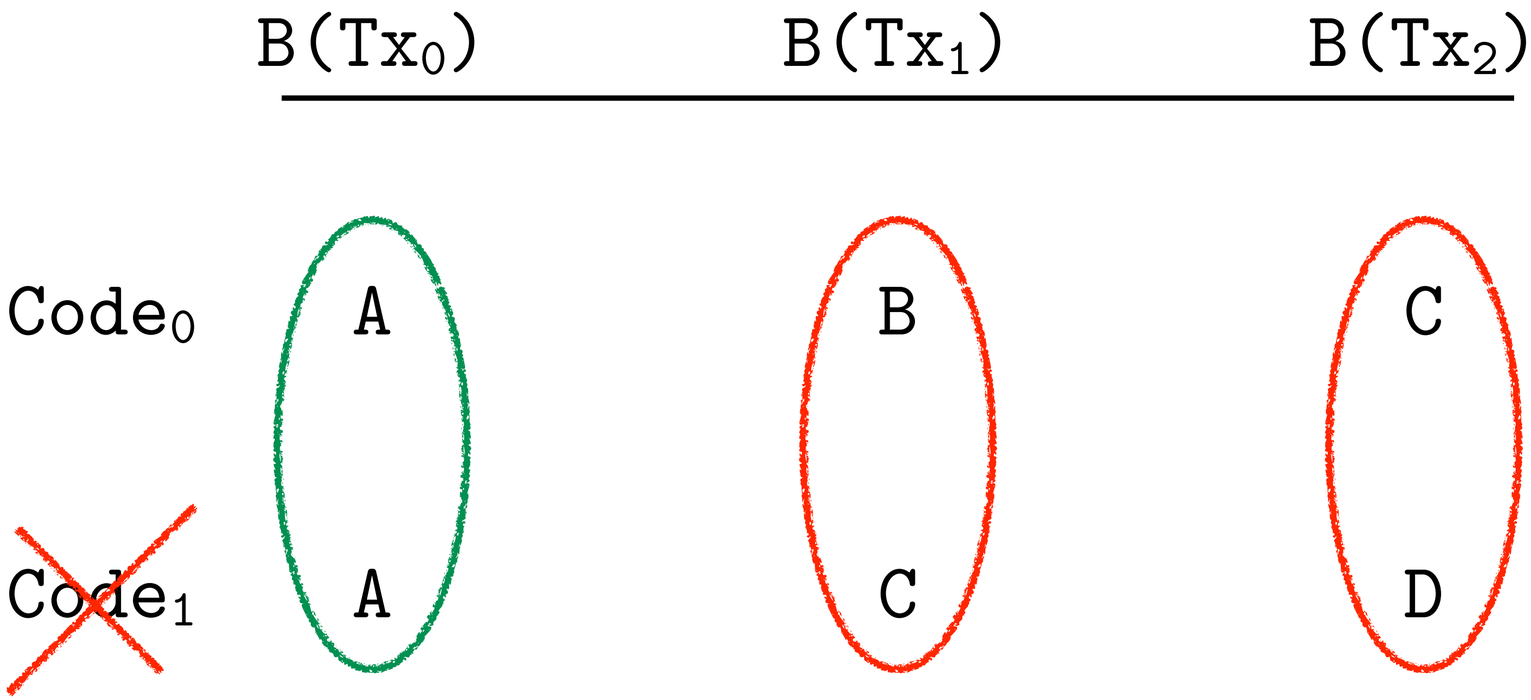
SMT

Blockchain

```
~/t/git-diff ❯❯❯ diff test.txt sample.txt
diff --git a/test.txt b/sample.txt
index ad01390..5629924 100644
--- a/test.txt
+++ b/sample.txt
@@ -1,3 +1,3 @@
-This is a test
-    * Hello
-    * world!
+This is a sample
+  * Hello
+  * universe!
~/t/git-diff ❯❯❯
```

	$B(Tx_0)$	$B(Tx_1)$	$B(Tx_2)$
$Code_0$	A	B	C
$Code_1$	A	C	D


B(Tx0)
B(Tx1)
B(Tx2)
Code0
Code1
A
A
B
C
C
D


B(Tx0)
B(Tx1)
B(Tx2)
Code0
Code1
A
A
B
C
C
D

- Feature flags - any new branch that might alter the SMT (even if it's a bug fix!) must be behind a feature flag

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- Feature flag toggling must be a blockchain transaction

- How can we increase confidence that old behavior is always supported?

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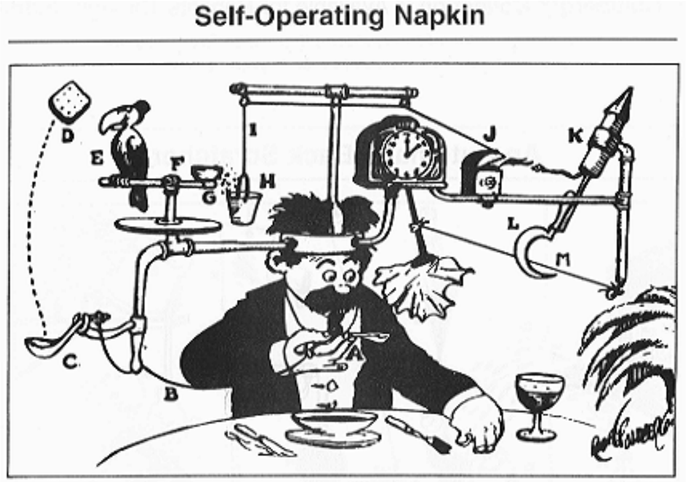
- How can we increase confidence that when a feature has an undesirable affect that we can downgrade?



Integration testing

- Implement a toy model of the clients and assets and their interactions

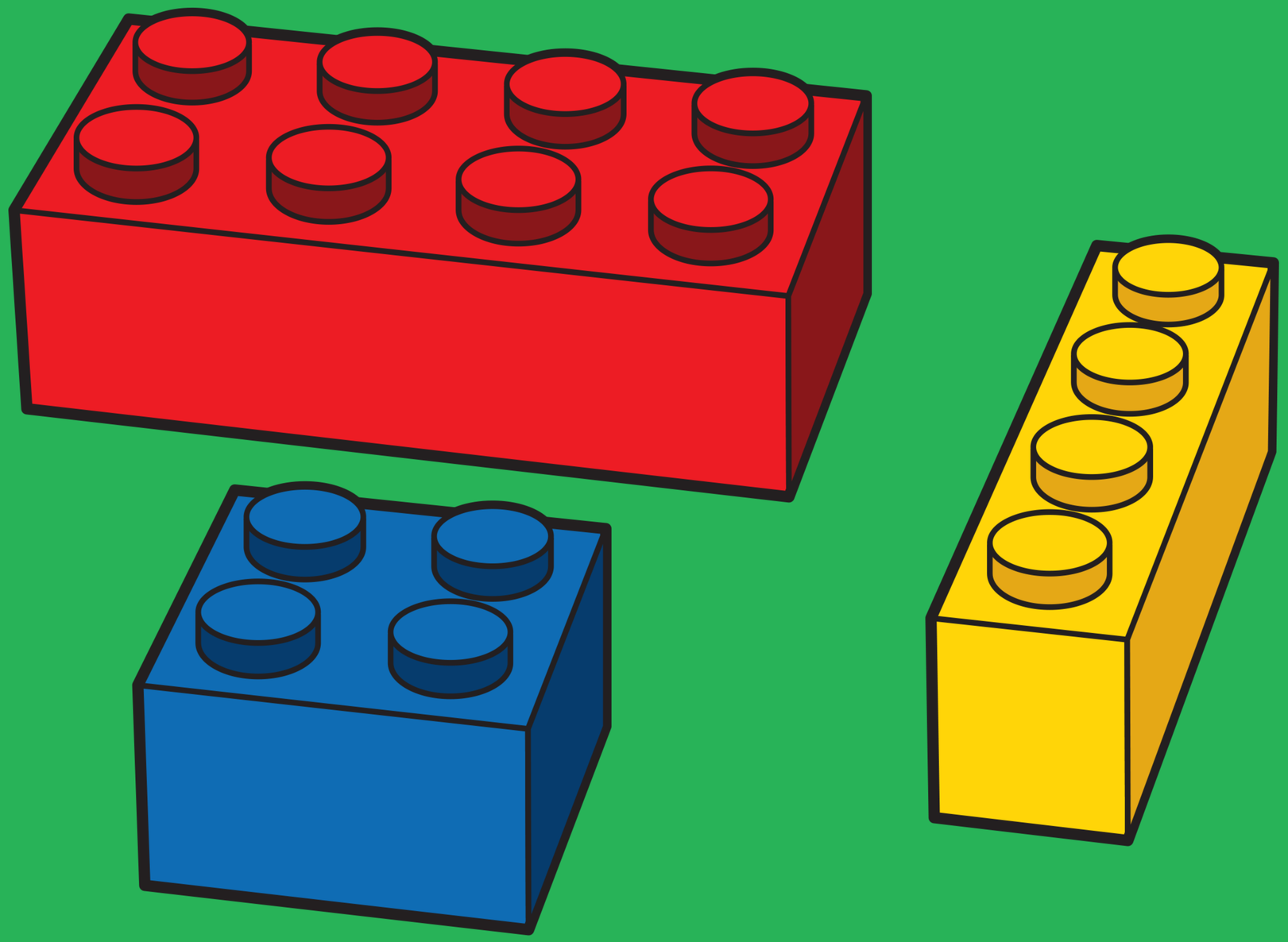
- Implement a toy model of the clients and assets and their interactions

- All toy model functions take toy model state (which is a value) as the first argument

$$f(\mathrm{A},\ \mathrm{B},\ \mathrm{C},\ \ldots) \rightarrow \mathrm{Z}$$

$$f(\mathrm{S}_0,\ \mathrm{A},\ \mathrm{B},\ \mathrm{C},\ \ldots) \rightarrow \mathrm{S}_1$$

```
{:db                DatomicDB
 :smt               VouchSMT
 :crypto-devices    {:customer-a …}
 :assets            {:vehicle-a …}}
```



```clojure
(defn installer+dealer+customer+one-asset
  "Return a state with one installer, one dealer, one customer, and one asset
  enrolled by the installer."
  [{:keys [org-data vin customer-mobile-number]}]
  (-> (test-org/persist (state/create tu/*conn*) org-data)
    (state/add-crypto-device :installer
      (test-org/add-token-data (crypto-device/create) org-data))
    (crypto-device/enroll-oidc :installer)
    (test-org/endorse-membership :installer [:enroll-asset-device])
    (test-assets/enroll-asset+device :installer
      (test-assets/create-asset {:asset-mfg-id vin}))
    (state/add-crypto-device :dealer
      (test-org/add-token-data (crypto-device/create) org-data))
    (state/add-crypto-device :customer
      (crypto-device/create {:token-data {:mobile-number customer-mobile-number}}))
    (crypto-device/enroll-oidc-all)
    (state/tag-state :all-enrolled)
    (test-org/endorse-membership :dealer [:operate :transfer-owner])))
```

Functional Scenarios

Functional Scenarios

- We now write scenarios close to the business language

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- We now write scenarios close to the business language
- SMT & Datomic functional storage - we can “run" a scenario - yet go to any step and make db assertions, run db queries, SMT queries, check transitions, etc.

- A significant improvement over previous unit tests - less ad-hoc.

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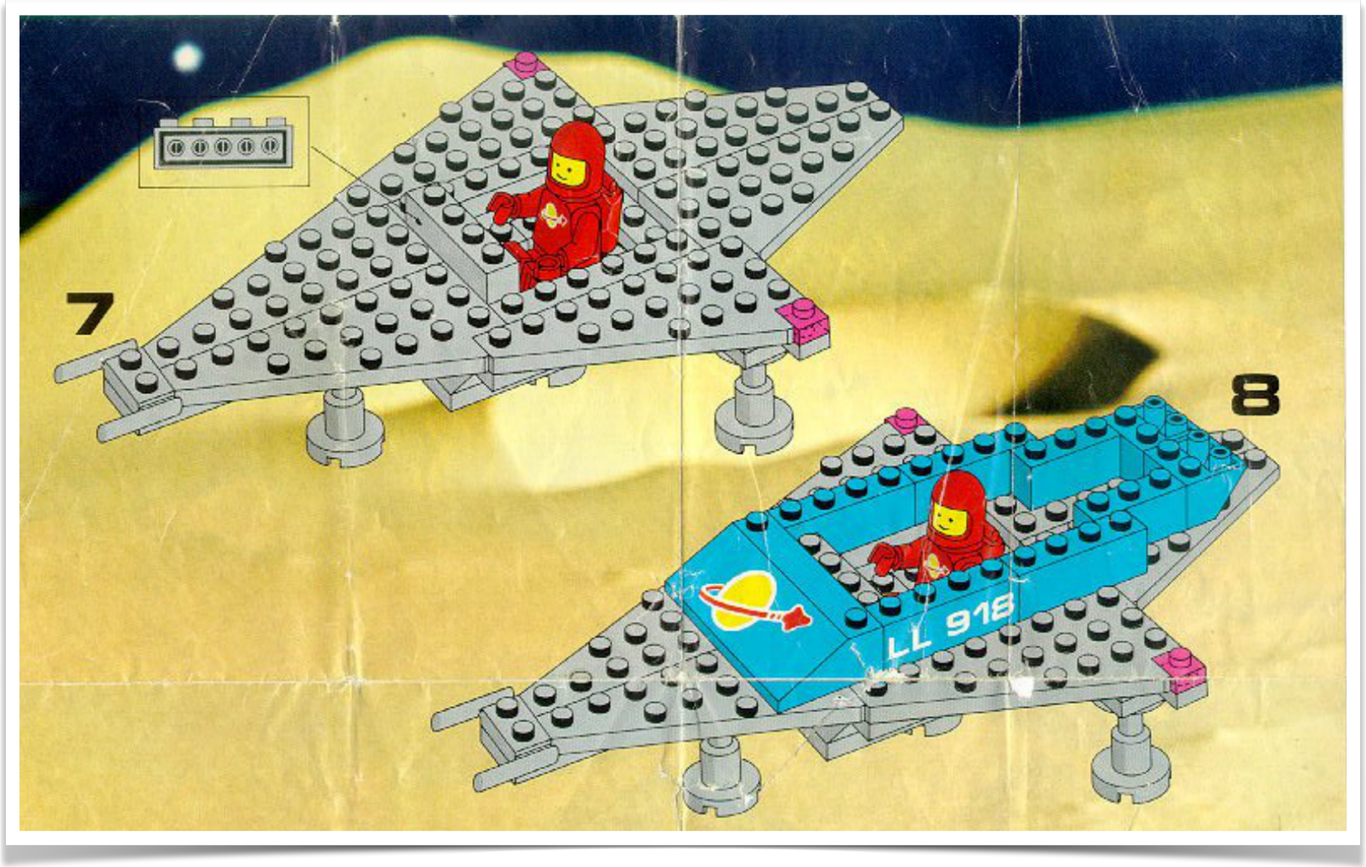
- For complex scenario, no need to build Android/iOS clients, no need to boot Docker, etc.

- A significant improvement over previous unit tests - less ad-hoc.
- For complex scenario, no need to build Android/iOS clients, no need to boot Docker, etc.
- Can often convert a good customer bug report to a matching test scenario in 15-30 minutes.



Generating Instructions

Stateful PBT

Stateful PBT

- The toy stateful model should be carefully considered - esp. granularity

Stateful PBT

- The toy stateful model should be carefully considered - esp. granularity
- While fuzzing is useful, we want sequences that do match our expectations - managing the search space is important

- Dealers can sell a vehicle to a customer

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- Vehicle operators can share keys

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- Vehicle operators can revoke keys

- Dealers can sell a vehicle to a customer
- Vehicle operators can share keys
- Vehicle operators can revoke keys
- System admins can enable a bugfix / feature

```
({:command :transfer, :args [:dealer-2 :customer-10 :asset-10]}
 {:command :share-key, :args [:dealer-1 :customer-7 :asset-11]}
 {:command :transfer, :args [:dealer-2 :customer-3 :asset-18]}
 {:command :revoke-key, :args [:dealer-1 :customer-7 :asset-11]}
 {:command :share-key, :args [:customer-10 :customer-4 :asset-10]}
 {:command :connect, :args [:dealer-1 :asset-11]}
 {:command :share-key, :args [:dealer-1 :customer-3 :asset-6]}
 {:command :share-key, :args [:dealer-1 :customer-5 :asset-9]}
 {:command :connect, :args [:dealer-1 :asset-3]}
 {:command :transfer, :args [:dealer-1 :customer-1 :asset-11]}
 {:command :transfer, :args [:dealer-2 :customer-6 :asset-16]}
 {:command :share-key, :args [:dealer-1 :customer-10 :asset-7]}
 {:command :share-key, :args [:dealer-2 :customer-8 :asset-15]}
 {:command :share-key, :args [:dealer-1 :customer-5 :asset-6]}
 {:command :transfer, :args [:dealer-2 :customer-4 :asset-6]}
 {:command :connect, :args [:dealer-1 :asset-8]}
 {:command :share-key, :args [:customer-3 :customer-6 :asset-18]}
 {:command :revoke-key, :args [:dealer-2 :customer-8 :asset-15]}
 {:command :share-key, :args [:dealer-1 :customer-8 :asset-20]}
 {:command :connect, :args [:dealer-2 :asset-14]}
 {:command :connect, :args [:dealer-2 :asset-17]}
 {:command :revoke-key, :args [:dealer-1 :customer-8 :asset-20]}
 {:command :share-key, :args [:dealer-2 :customer-8 :asset-17]}
 {:command :revoke-key, :args [:dealer-1 :customer-5 :asset-9]}
 {:command :revoke-key, :args [:customer-3 :customer-6 :asset-18]})
```

```
({:command :transfer, :args [:dealer-2 :customer-10 :asset-10]}
 {:command :share-key, :args [:dealer-1 :customer-7 :asset-11]}
 {:command :transfer, :args [:dealer-2 :customer-3 :asset-18]}
 {:command :revoke-key, :args [:dealer-1 :customer-7 :asset-11]}
 {:command :share-key, :args [:customer-10 :customer-4 :asset-10]}
 {:command :connect, :args [:dealer-1 :asset-11]}
 {:command :share-key, :args [:dealer-1 :customer-3 :asset-6]}
 {:command :share-key, :args [:dealer-1 :customer-5 :asset-9]}
 {:command :connect, :args [:dealer-1 :asset-3]}
 {:command :transfer, :args [:dealer-1 :customer-1 :asset-11]}
 {:command :transfer, :args [:dealer-2 :customer-6 :asset-16]}
 {:command :share-key, :args [:dealer-1 :customer-10 :asset-7]}
 {:command :share-key, :args [:dealer-2 :customer-8 :asset-15]}
 {:command :share-key, :args [:dealer-1 :customer-5 :asset-6]}
 {:command :transfer, :args [:dealer-2 :customer-4 :asset-6]}
 {:command :connect, :args [:dealer-1 :asset-8]}
 {:command :share-key, :args [:customer-3 :customer-6 :asset-18]}
 {:command :revoke-key, :args [:dealer-2 :customer-8 :asset-15]}
 {:command :share-key, :args [:dealer-1 :customer-8 :asset-20]}
 {:command :connect, :args [:dealer-2 :asset-14]}
 {:command :connect, :args [:dealer-2 :asset-17]}
 {:command :revoke-key, :args [:dealer-1 :customer-8 :asset-20]}
 {:command :share-key, :args [:dealer-2 :customer-8 :asset-17]}
 {:command :revoke-key, :args [:dealer-1 :customer-5 :asset-9]}
 {:command :revoke-key, :args [:customer-3 :customer-6 :asset-18]})
```

Initial State

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- Because the toy model puts everything into the state, we can take any unit test scenario already written and trivially derive an initial state to feed to the command generator

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- Because the toy model puts everything into the state, we can take any unit test scenario already written and trivially derive an initial state to feed to the command generator
- Jump start the generative test!

test.check

test.check

- We used test.check, an open source Clojure implementation of Quick Check with shrinking

test.check

- We used test.check, an open source Clojure implementation of Quick Check with shrinking
- We implemented a stateful generator with acceptable shrinking in ~130 LOC

Evaluator

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- An evaluator for the commands is trivial since all functions are of the same form: $f(\mathrm{S}_0, \ldots) \rightarrow \mathrm{S}_1$

Evaluator

- An evaluator for the commands is trivial since all functions are of the same form: $f(S_0, \ldots) \rightarrow S_1$
- Evaluate the commands and record the final hash. Rerun the transactions (not the commands) from fresh toy state and verify hash is equal.

Stateful PBT Generator

Stateful PBT Generator

- Can create a “gold file”, a file of SMT hash to series of commands to generate that hash. Checked in CI when source code is pushed.

Stateful PBT Generator

- Can create a “gold file”, a file of SMT hash to series of commands to generate that hash. Checked in CI when source code is pushed.
- Write property check to verify that a feature (or fix) can be enabled/disabled and always arrive at same hash

```
(defspec app-hash-playback-toggle 5
  (testing "App-hash test in the presence of feature toggling"
    (let [state      (base-scenario)
          init-state (-> state
                         big-step/state->gen-state
                         (update :features dissoc :abci.feature/short-retail-key-share))]
      (prop/for-all [commands (scen-gen/commands models/abci init-state 20 30)]
        (let [state1 (big-step/run state commands)
              state2 (ledger/playback (state/create tu/*conn*) (:txes state1))]
          (= (some-> state1 :smt :trie-root data-crypto/bytes->hex-str)
             (some-> state2 :smt :trie-root data-crypto/bytes->hex-str))))))
```

Takeaways

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- Creating a toy model allowed us to write better unit tests - customer bug reports are easily captured in domain

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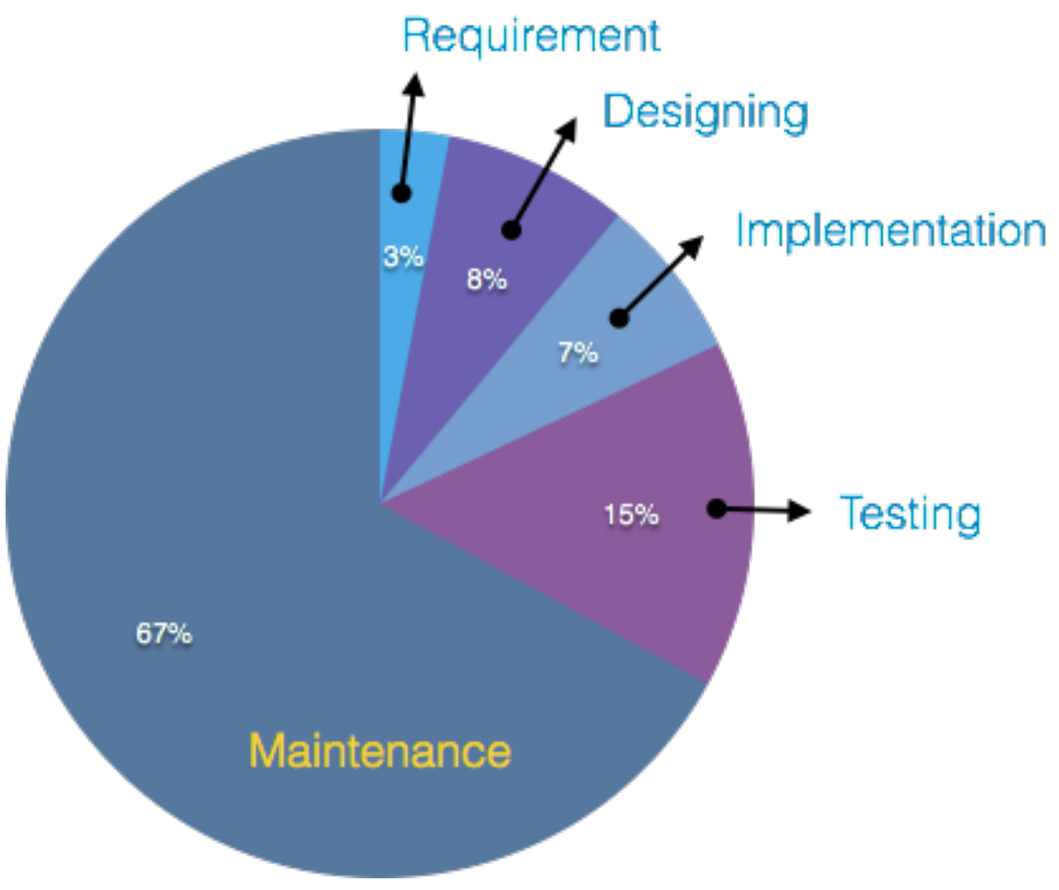
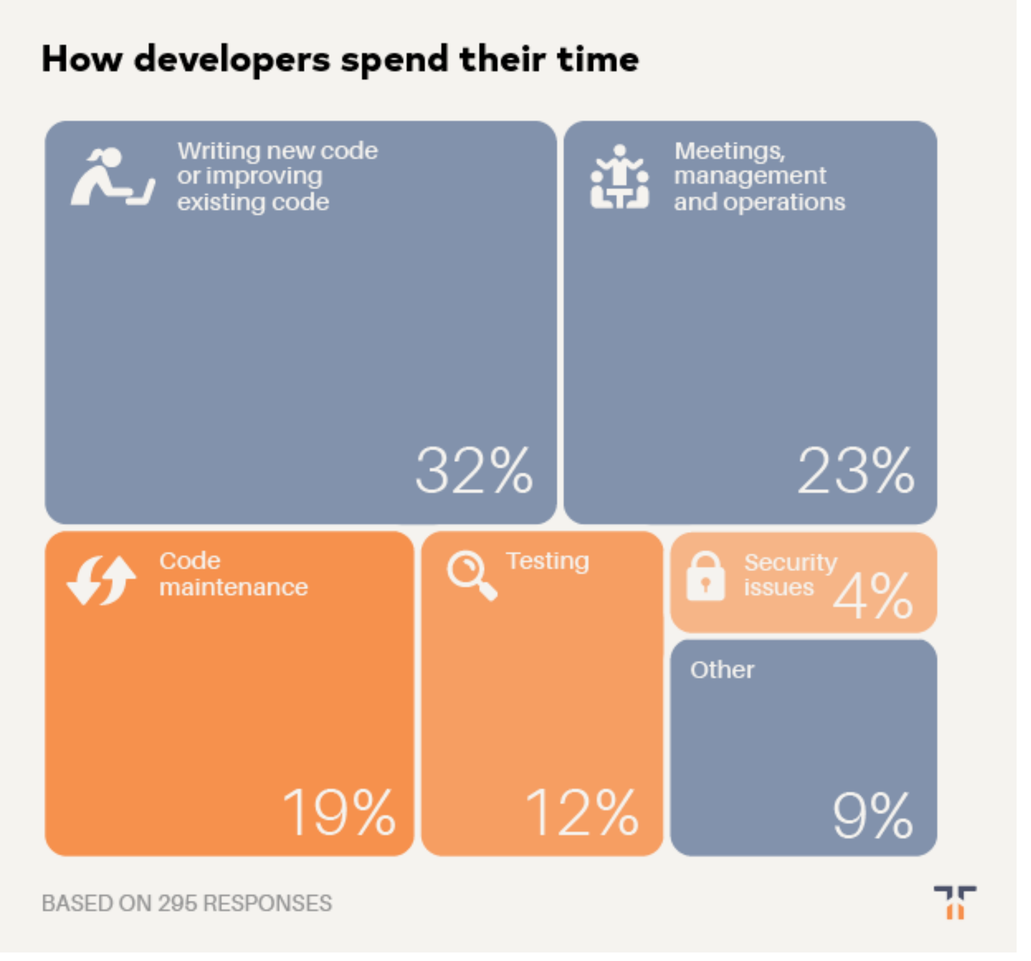
- Creating a toy model allowed us to write better unit tests - customer bug reports are easily captured in domain
- Stateful PBT checks increased confidence about deploying fixes / new features to blockchain where backwards compatibility is a hard requirement


Requirement
Designing
Implementation
Testing
Maintenance
3%
8%
7%
15%
67%


How developers spend their time
Writing new code or improving existing code
32%
Meetings, management and operations
23%
Code maintenance
19%
Testing
12%
Security issues
4%
Other
9%
BASED ON 295 RESPONSES

Oct. 24, 1961 G. K. CHRISTIANSEN 3,005,282

TOY BUILDING BRICK

Filed July 28, 1958 2 Sheets-Sheet 1

FIG. 1.

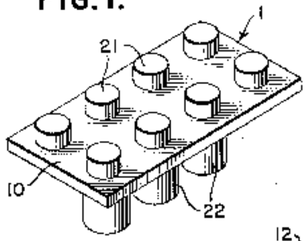


FIG. 2.

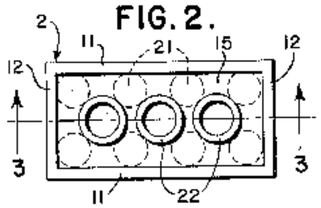


FIG. 3.

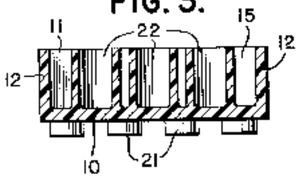


FIG. 4.

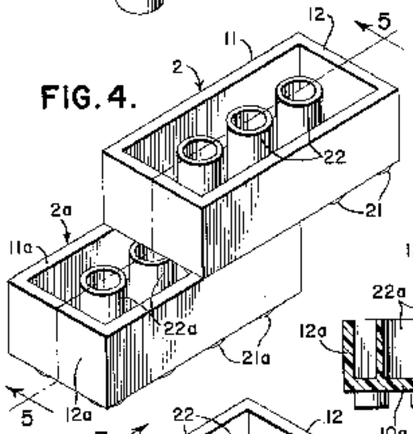


FIG. 5.

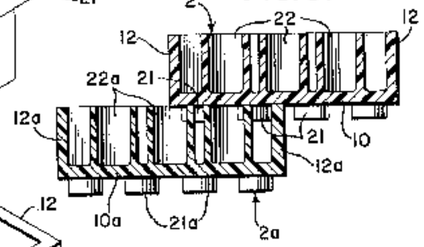
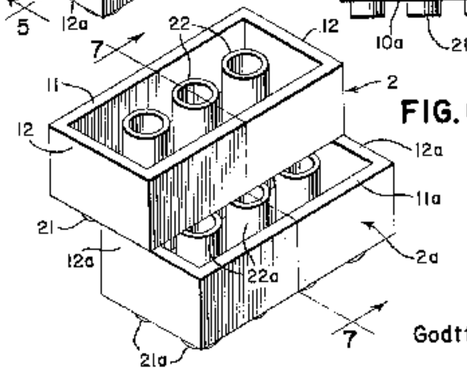


FIG. 6.



INVENTOR

Godtfred Kirk Christiansen

BY Stevens, Davis, Miller & Mosher
ATTORNEYS

Questions?