Exposing Design Flaws in Shared-Clock Systems using TLA+

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TLA+ Conf

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About Me

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- Decide how much it matters (Assign a Safety Integrity Level - SIL)
- Analyze the parts of the system that matter (Fault Tree Analysis)
- Not good enough? Add redundancy.

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- Safety requirement: Turn off press with emergency stop button
- SIL: 4
- Fault tree: the actuator is only SIL 3
- Redundancies: use two, design a SIL 4 failover mechanism

Functional Safety

- IEC 61508
- Power plants, chemical plants, cars, trains, heavy machinery, etc.



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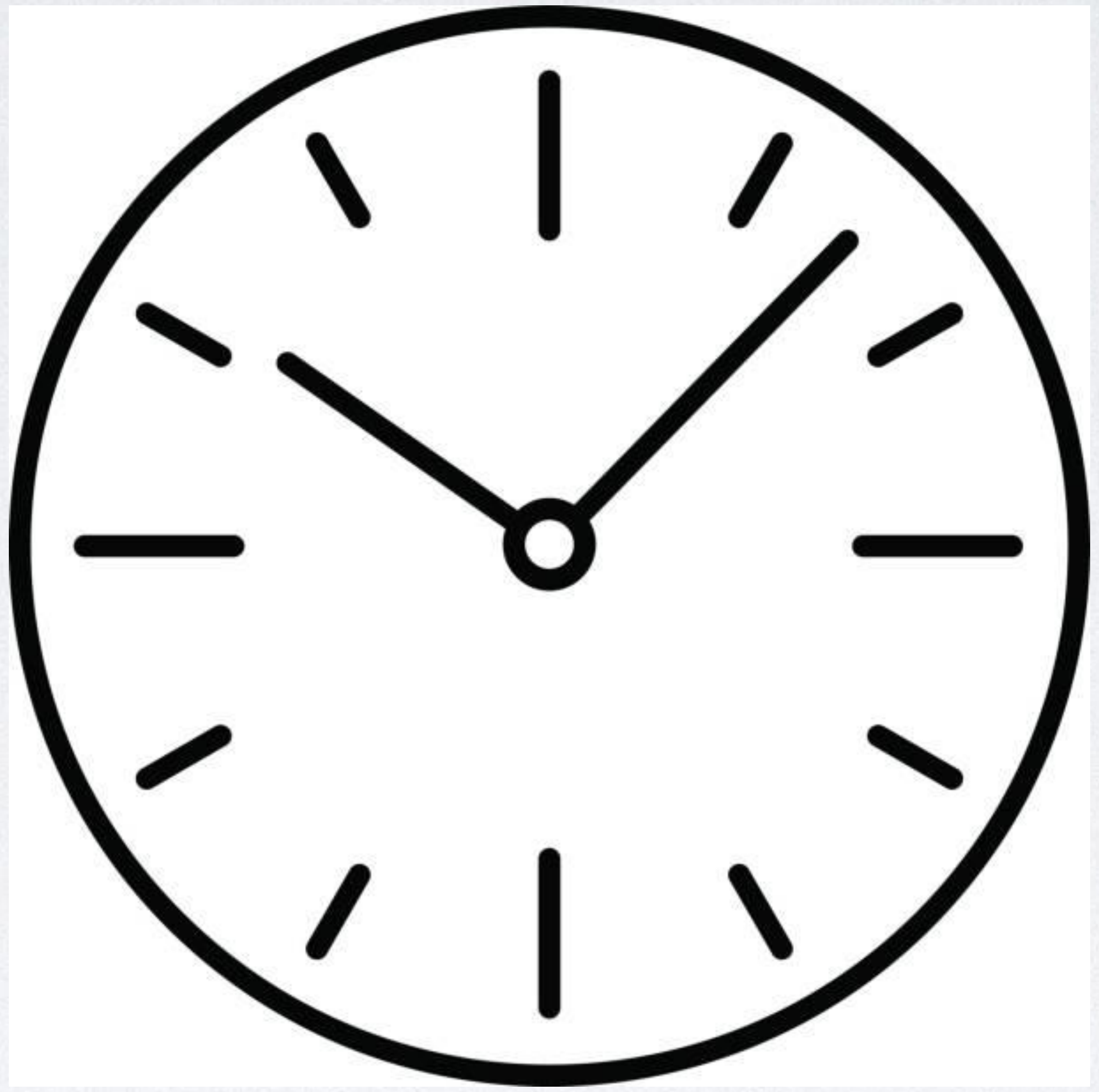

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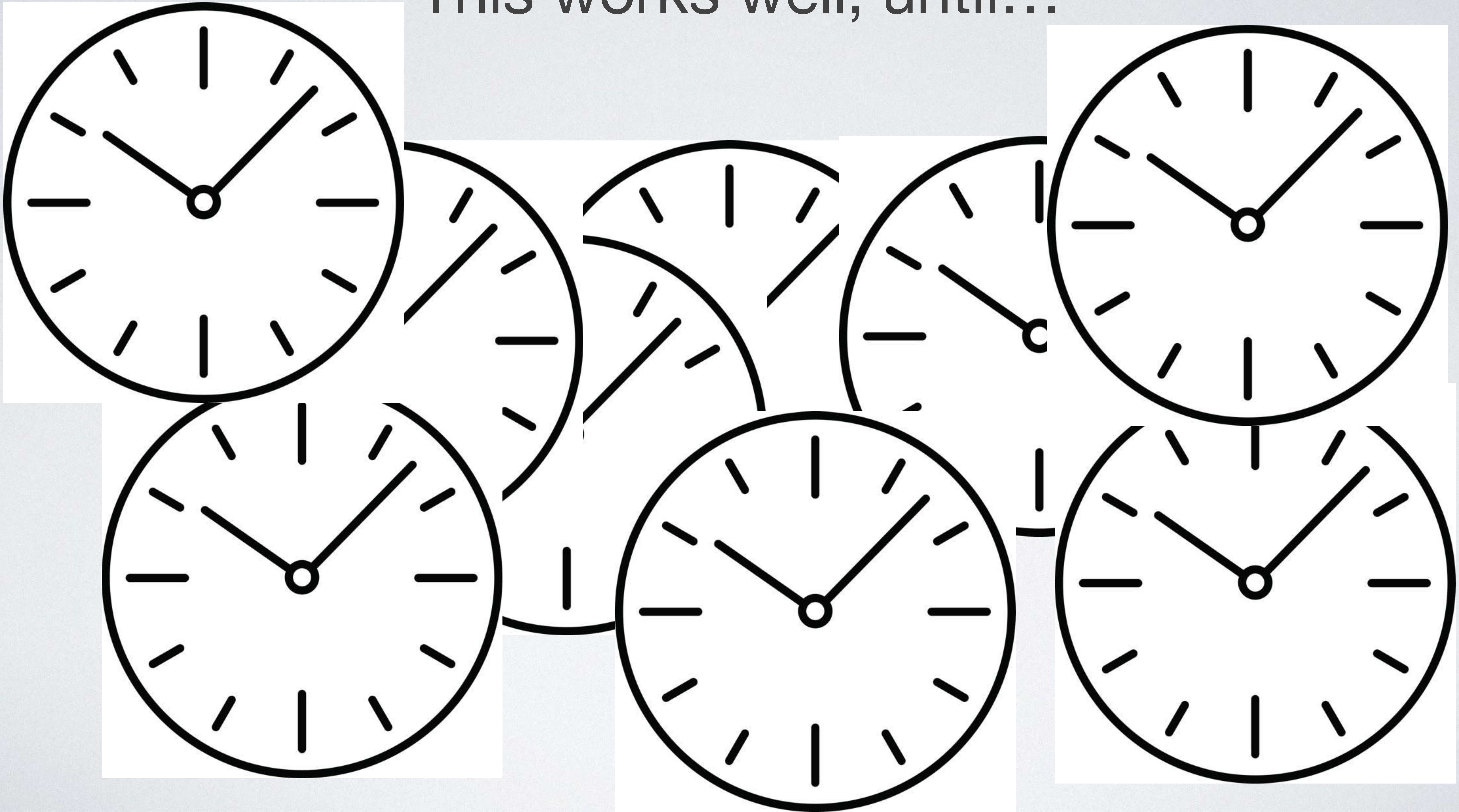

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In software, shared clock failures are lumpy and unpredictable

The story of a system made from lots of computers, sensors, actuators, and clocks

A client project for [redacted]

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- Relies fundamentally on a common timebase

A client project for [redacted]

- Can’t say anything specific
- Relies fundamentally on a common timebase
- Appeared to be vulnerable to drift

My Goal: Demonstrate the problem

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       /\ UNCHANGED << system >>
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     /\ UNCHANGED << system >>
  \/ /\ SystemStep(system)
     /\ UNCHANGED << node_clock >>
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  \/ SyncClocks(node_clock, system)
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SystemStep(s) == ...
SyncClocks(cs,s) == ...
```

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- Customer doesn’t care about the sync protocol

Model the drift, not the sync

Drift Modeling (1)

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VARIABLES node_clock, system, global_clock
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  \/ ClockStep /\ UNCHANGED system
  \/ SystemStep /\ UNCHANGED global_clock /\ UNCHANGED node_clock
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SystemStep == ...
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ClockStep ==
  \* Tick the global clock
  \/ /\ global_clock' = global_clock + 1
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  \/ \E node \in DOMAIN node_clock:
     /\ node_clock' = [node_clock EXCEPT ![node] = @ + 1]
     /\ UNCHANGED << global_clock >>
     /\ ClockDriftInBounds(global_clock, node_clock')
```

Drift Modeling (3)

```
ClockDriftInBounds(g, n) ==
  /\ g <= SIMULATED_CYCLES
  /\ \A node \in DOMAIN n :
     /\ n[node] <= SIMULATED_CYCLES
     /\ Abs(c[node] - g) <= BOUNDED_DRIFT
```

This works better

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- Narrower state space

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- Narrower state space
- Directly addresses relevant failure domain

The system was more vulnerable to drift than previously thought

Delivering a Model

- Literate PDF
- Makefile / .cfg file
- Config Instructions

TLA+ is tricky to use this way

- Difficult setup
- Easier development
- Easier delivery

Give models to your customers

Extending the technique

- Asymmetric Drift
- Action on Tick
- Cyclical Clock

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Closing Thoughts

- Fake a real clock
- Bound the drift
- Give models to your customers
- I owe Hillel Wayne a great debt

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