

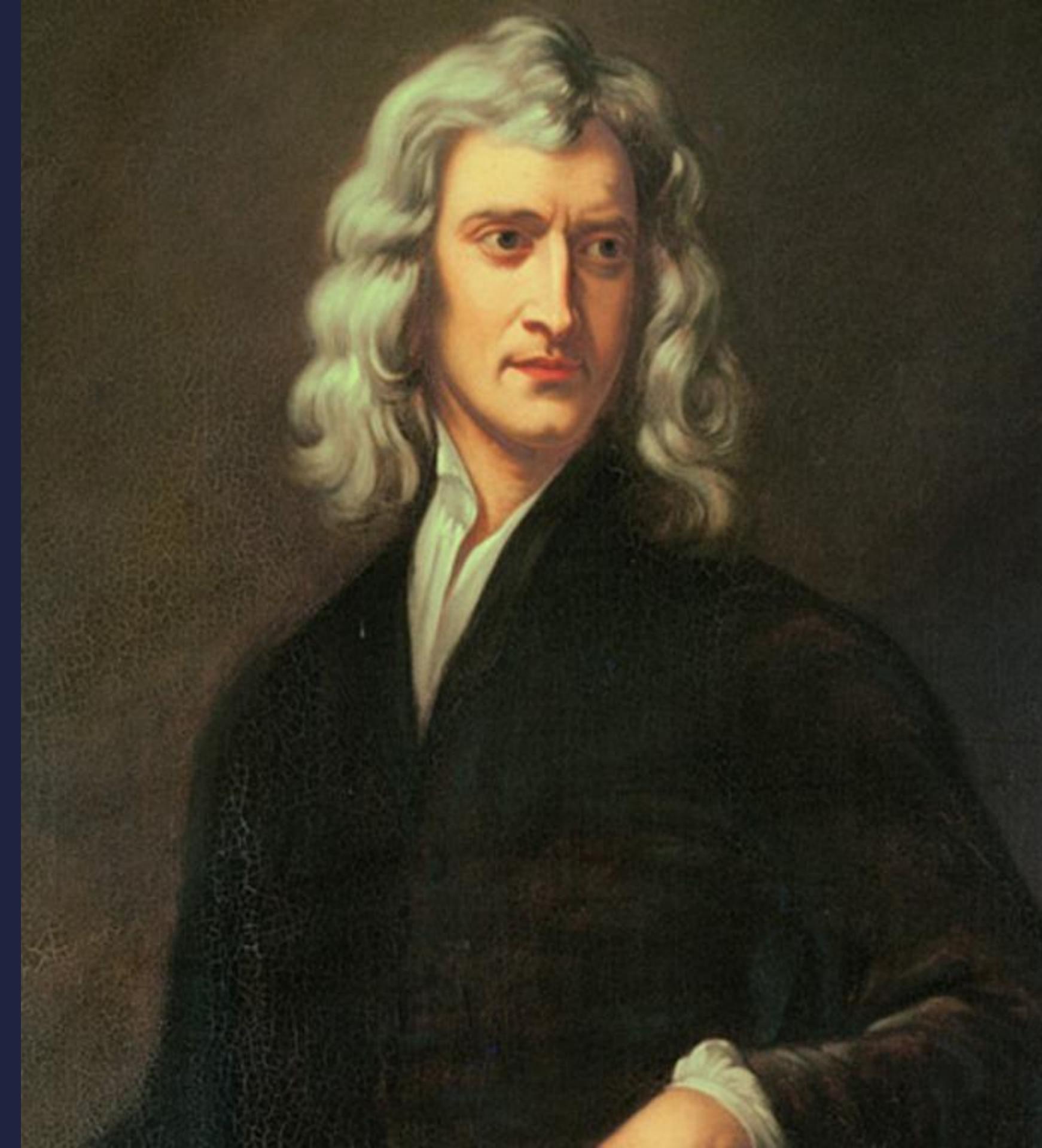
*Life* BEYOND  
*the* ILLUSION  
*of* PRESENT

Jonas Bonér  
CTO Typesafe  
@jboner

**"Time is what prevents everything from happening at once."**

**- John Archibald Wheeler**

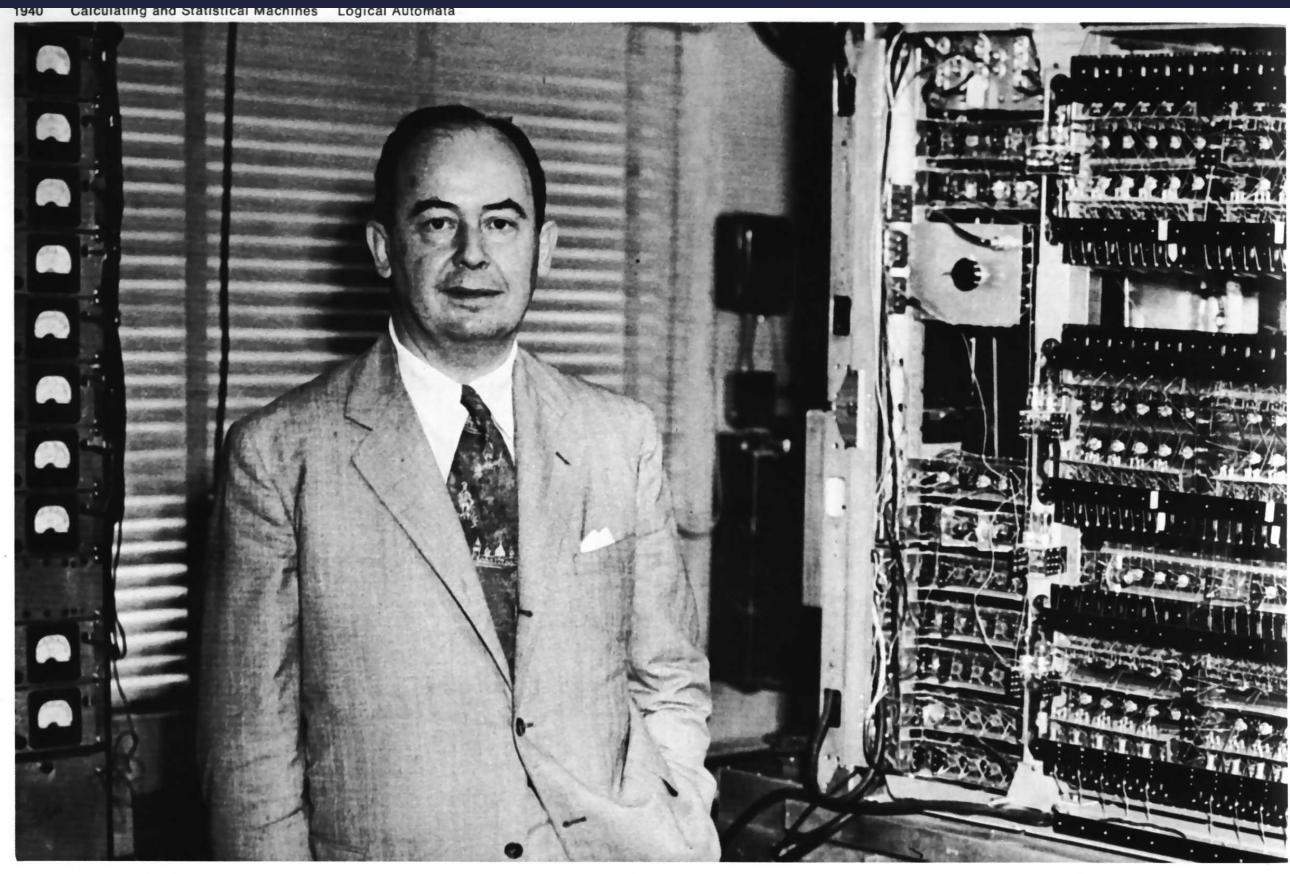
# *Newton's* **PHYSICS**



THIS SIMPLIFIED MODEL IS  
VERY APPEALING TO US

# *Von Neumann*

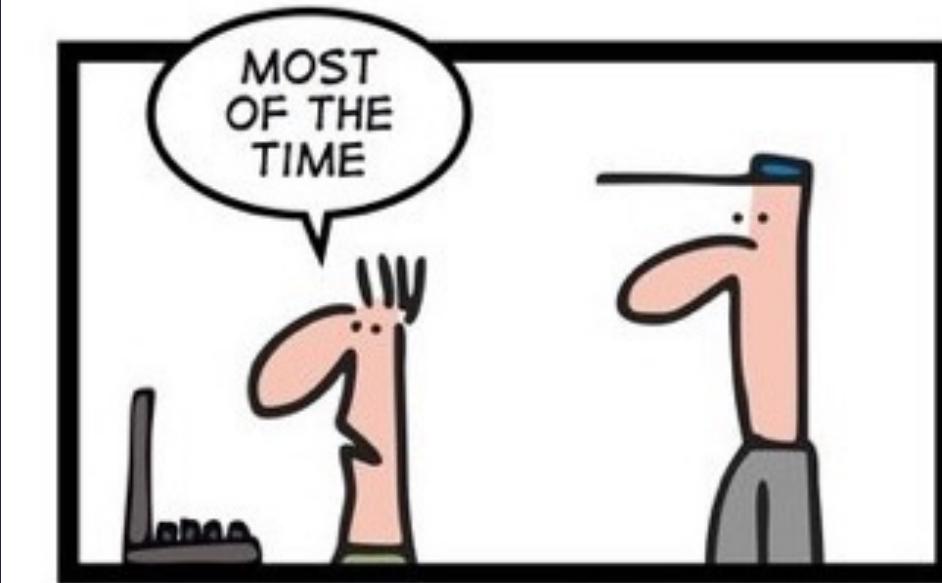
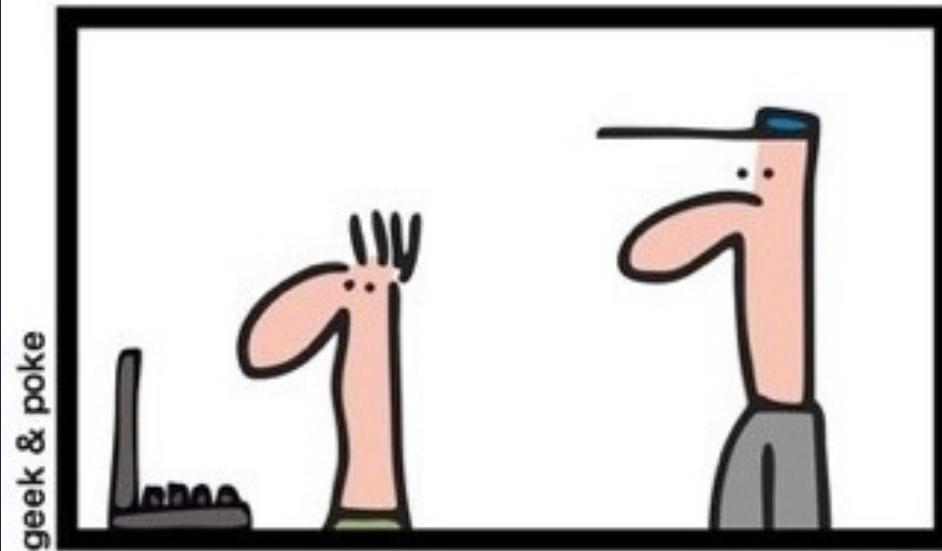
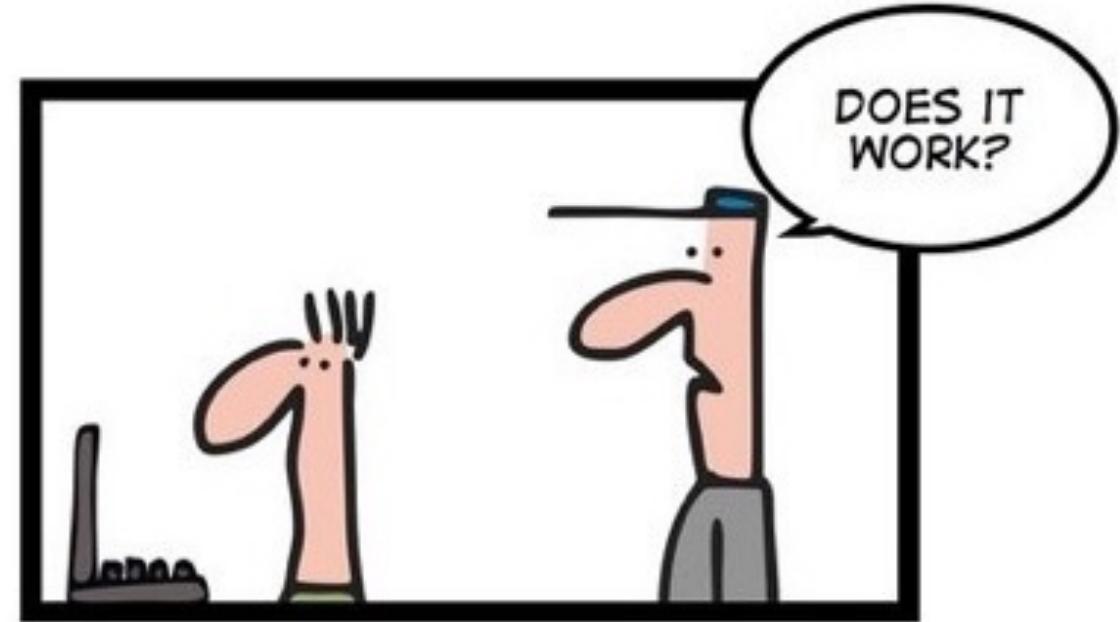
# ARCHITECTURE



**BACK THEN  
LIFE WAS GOOD**



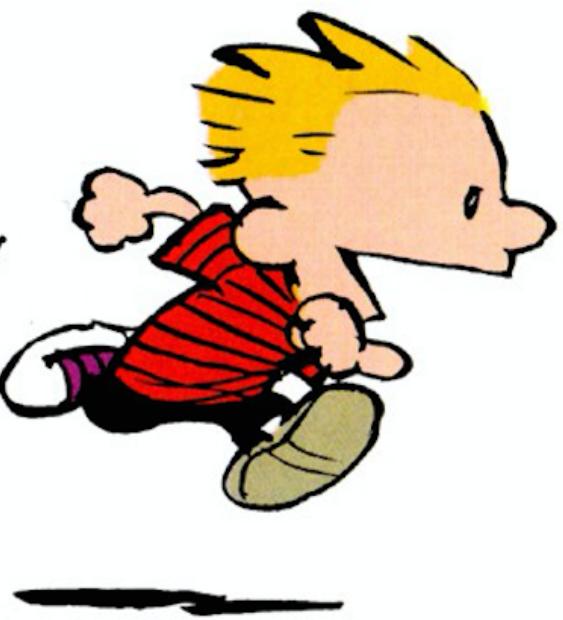
# THEN, ALONG CAME CONCURRENCY MADE LIFE MISERABLE





*Jim Gray's*  
**TRANSACTIONS**  
**SAVE THE DAY**

Y OH BOY OH BOY



**WELL, ALONG CAME  
DISTRIBUTION  
MADE LIFE MISERABLE, *again...***



But don't be surprised  
**UNFORTUNATELY,**  
**THIS IS NOT**  
**HOW THE WORLD WORKS**

The dream had vanished.  
Unfortunately the  
Lifestyle Remained.

(c)gapingvoid.com



$$c = a + b + d$$

$$c = (\pi \cdot 8 \cdot (2 \cdot 10^6) + 3a + 2 \cdot 3 \ln 11)^2$$

$$c = (\pi \cdot 8 \cdot \log \frac{1}{2+e} + 3a + 6 \ln 11)^2$$

$$c = \left[ \sqrt{\sum_{x_1}^{x_2} \alpha dx} + \frac{3[(3+7x)^2 + 6+3\pi]}{(5+y)(8+z)+1} + 6 \ln 11 \right]^2$$

$$c = \left[ \sqrt{\sum_{x_1}^{x_2+100} \frac{(3+7x)^2 + 6+3\pi}{(5+y)(8+z)+1} dx} + \frac{3[(3+7x)^2 + 6+3\pi]}{(5+y)(8+z)+1} + 6 \ln 11 \right]^2$$

$$c = \left[ \sqrt{\sum_{x_1}^{x_2} \frac{(3+7x)^2 + (\beta - 180^\circ) + 3\pi}{(5+y)(8+z)+1} dx} + \frac{3[(3+7x)^2 + (\beta - 180^\circ) + 3\pi]}{(5+y)(8+z)+1} + 6 \ln 11 \right]^2$$

$$c = \left[ \sqrt{\sum_{x_1}^{x_2} \frac{\sqrt{3+7x} + (\beta - 180^\circ) + 3\pi}{(5+y)(8+z)+1} dx} + \frac{\sqrt{3+7x} + (\beta - 180^\circ) + 3\pi}{(5+y)(8+z)+1} + 6 \ln 11 \right]^2$$

$$c = \sqrt{\left[ \sqrt{\sum_{x_1}^{x_2} \alpha dx} + \frac{\sqrt{3+7x} + (\beta - 180^\circ) + 3\pi}{(5+y)(8+z)+1} + 6 \ln 11 \right]^2}$$

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$$c = \sqrt{\left[ \sqrt{\sum_{x_1}^{x_2} \alpha dx} + \frac{\sqrt{3+7x} + (\beta - 180^\circ) + 3\pi}{(5+y)(8+z)+1} + 6 \ln 11 \right]^2}$$

"The future is a function of the past."  
- A. P. Robertson



**"The (local) present is a merge function of  
multiple concurrent pasts."**

**– Me**

```
val newLocalPresent = observedPasts.  
foldLeft(oldLocalPresent) { _ merge _ }
```



WE NEED TO EXPLICITLY MODEL THE  
LOCAL PRESENT AS  
FACTS DERIVED FROM THE  
MERGING OF MULTIPLE  
CONCURRENT PASTS

# INFORMATION IS ALWAYS FROM THE PAST



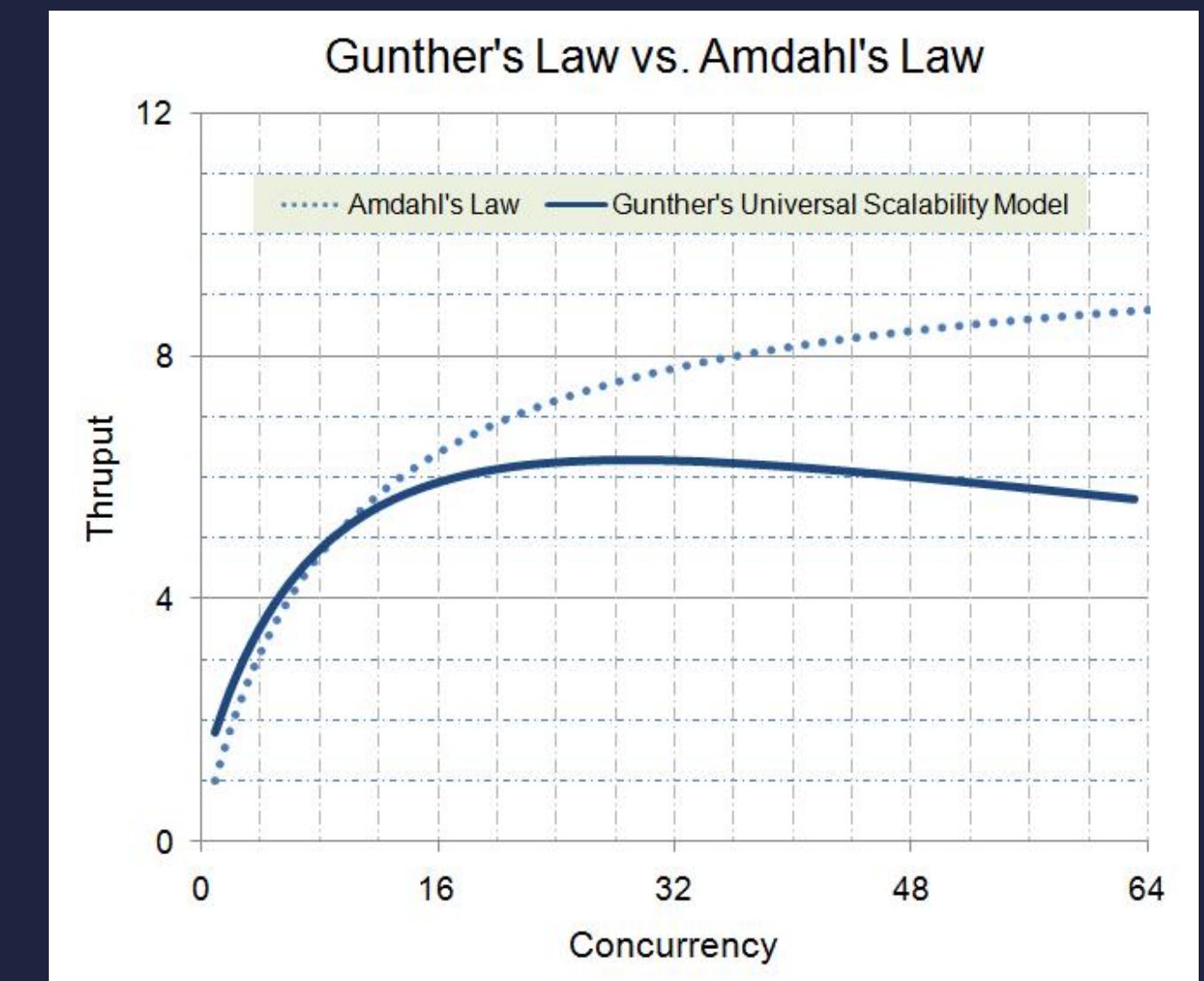
THE TRUTH  
IS CLOSER TO  
EINSTEIN'S  
PHYSICS





INFORMATION HAS  
**LATENCY**

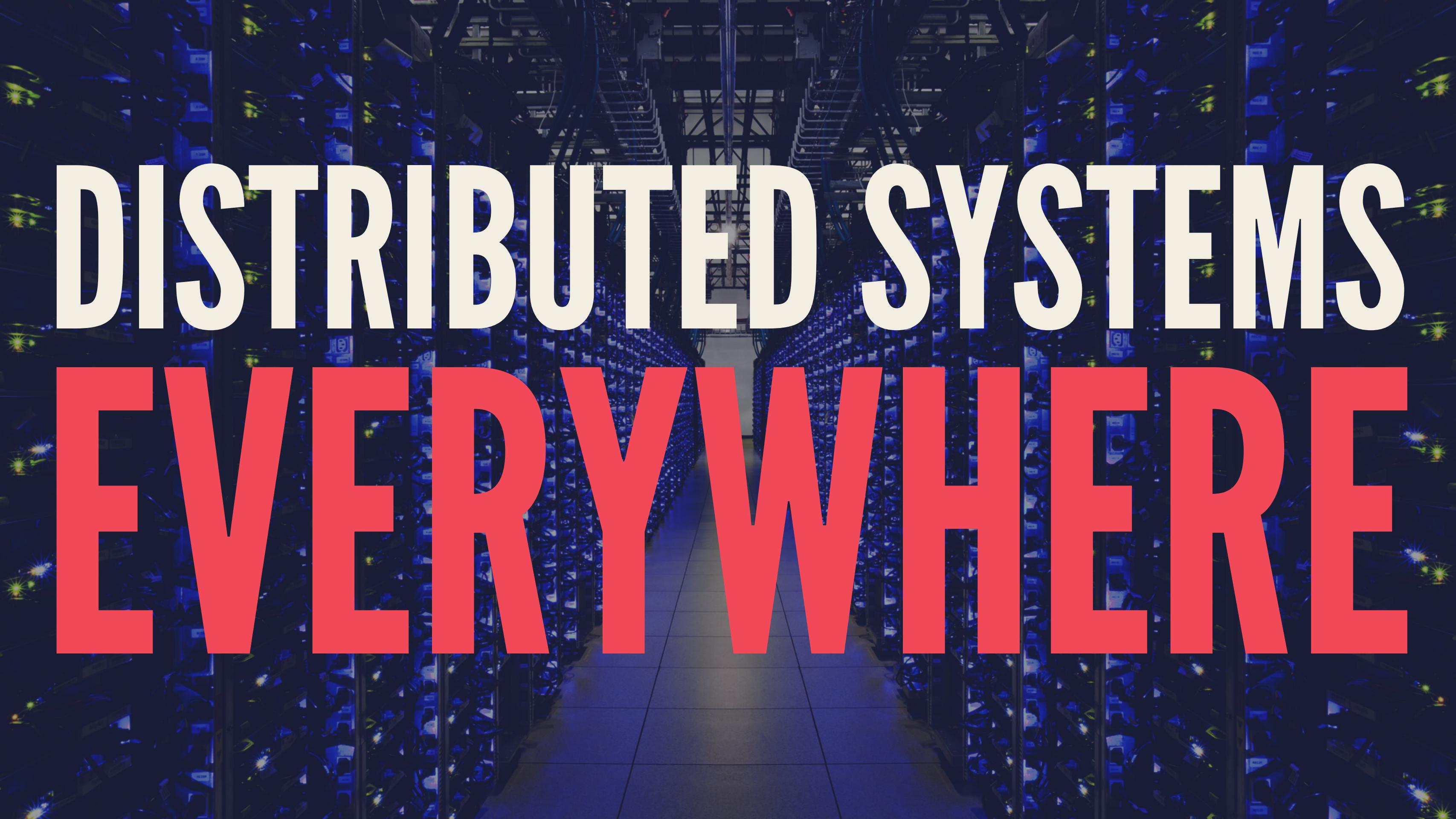
THE COST OF MAINTAINING  
THIS ILLUSION IS INCREASED  
**CONTENTION &  
COHERENCY**





AS LATENCY GETS HIGHER, THE  
ILLUSION CRACKS EVEN MORE

# DISTRIBUTED SYSTEMS FUNDAMENTALS



A photograph of Borat Sagdiyev, a character from the TV show "Saturday Night Live". He is wearing a light-colored suit jacket over a patterned shirt, sunglasses, and has a mustache. He is giving two thumbs up. The background shows a desert landscape with several large saguaro cacti. The sky is clear and blue.

THE NETWORK IS RELIABLE...NAT

A dark, atmospheric forest scene. In the foreground, several large, fallen tree trunks and branches are scattered across the ground. The forest is dense with tall, thin trees and thick undergrowth, all set against a dark, hazy background.

**"If a tree falls in a forest and no one is around to hear it, does it make a sound?"**

**– Charles Riborg Mann**

# *Information CAN (and will) GET LOST*



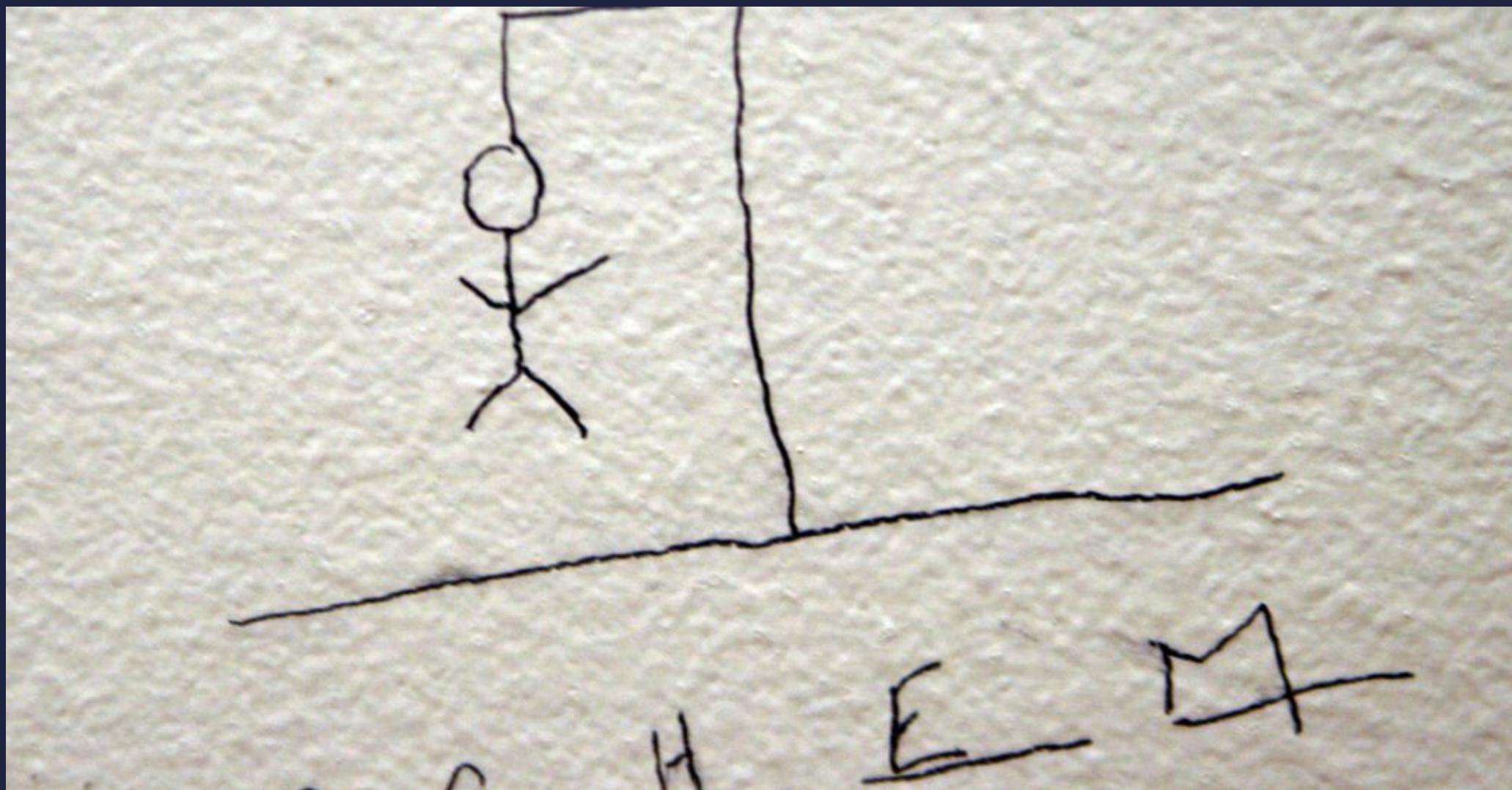
HOW DO WE DEAL WITH  
INFORMATION LOSS  
IN REAL LIFE?

WE USE A SIMPLE PROTOCOL OF

*Confirm, Wait & Repeat*



We fill in THE BLANKS



**...AND IF WE ARE WRONG, WE TAKE  
COMPENSATING ACTION**

**APOLOGY-ORIENTED PROGRAMMING - PAT HELLAND (IN MEMORIES, GUESSES, AND APOLOGIES)**

*The bottom line:*

**WE CAN'T FORCE THE WORLD INTO A  
SINGLE GLOBALLY CONSISTENT  
PRESENT**

Should we just GIVE UP?



A photograph of a forest path. The path is made of wooden logs and is surrounded by dense green foliage, including ferns and other forest undergrowth. Several large, fallen tree trunks are scattered across the path, some partially submerged in a small stream of water. The overall atmosphere is one of a natural, undisturbed environment.

I BELIEVE THAT THERE IS A  
PATH FORWARD

WE NEED TO TREAT  
TIME AS A  
FIRST CLASS CONSTRUCT

**WHAT IS TIME, really?**

TIME IS THE  
SUCCESSION OF  
CAUSALLY RELATED EVENTS

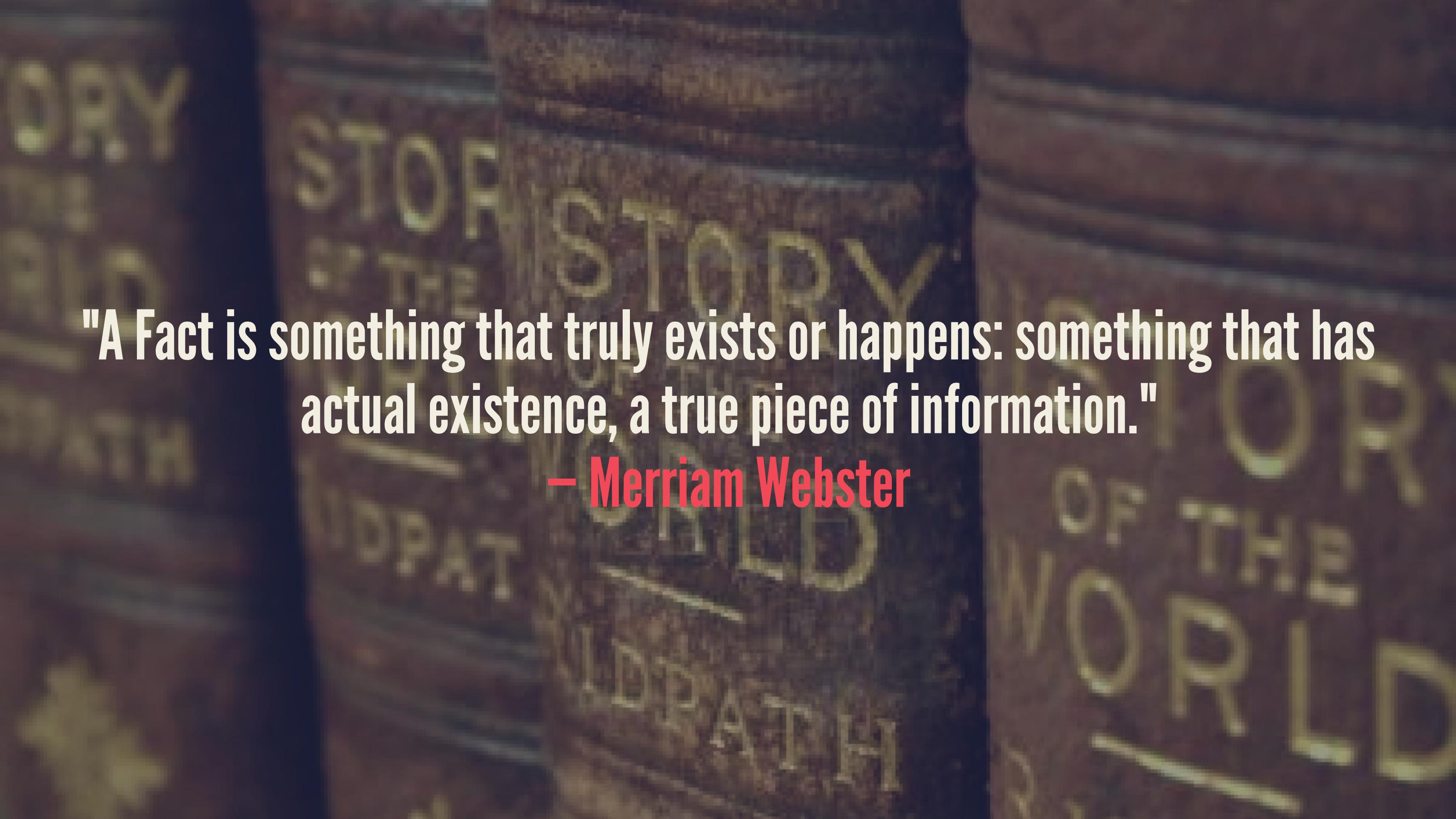


How can we  
**MANAGE**  
**TIME?**



*think in* FACTS

What is a  
**FACT?**

The background of the image shows a stack of several antique books. The spines of the books are visible, featuring gold-tooled lettering in a classic serif font. The colors of the book covers range from deep maroon to dark brown and tan. The edges of the books are worn, with some showing the underlying board material.

**"A Fact is something that truly exists or happens: something that has actual existence, a true piece of information."**

**— Merriam Webster**

# IMMUTABILITY

*is a requirement*

*So, do variables*

**HAVE A PURPOSE IN LIFE?**

**"The assignment statement is the von Neumann bottleneck of programming languages and keeps us thinking in word-at-a-time terms in much the same way the computer's bottleneck does."**

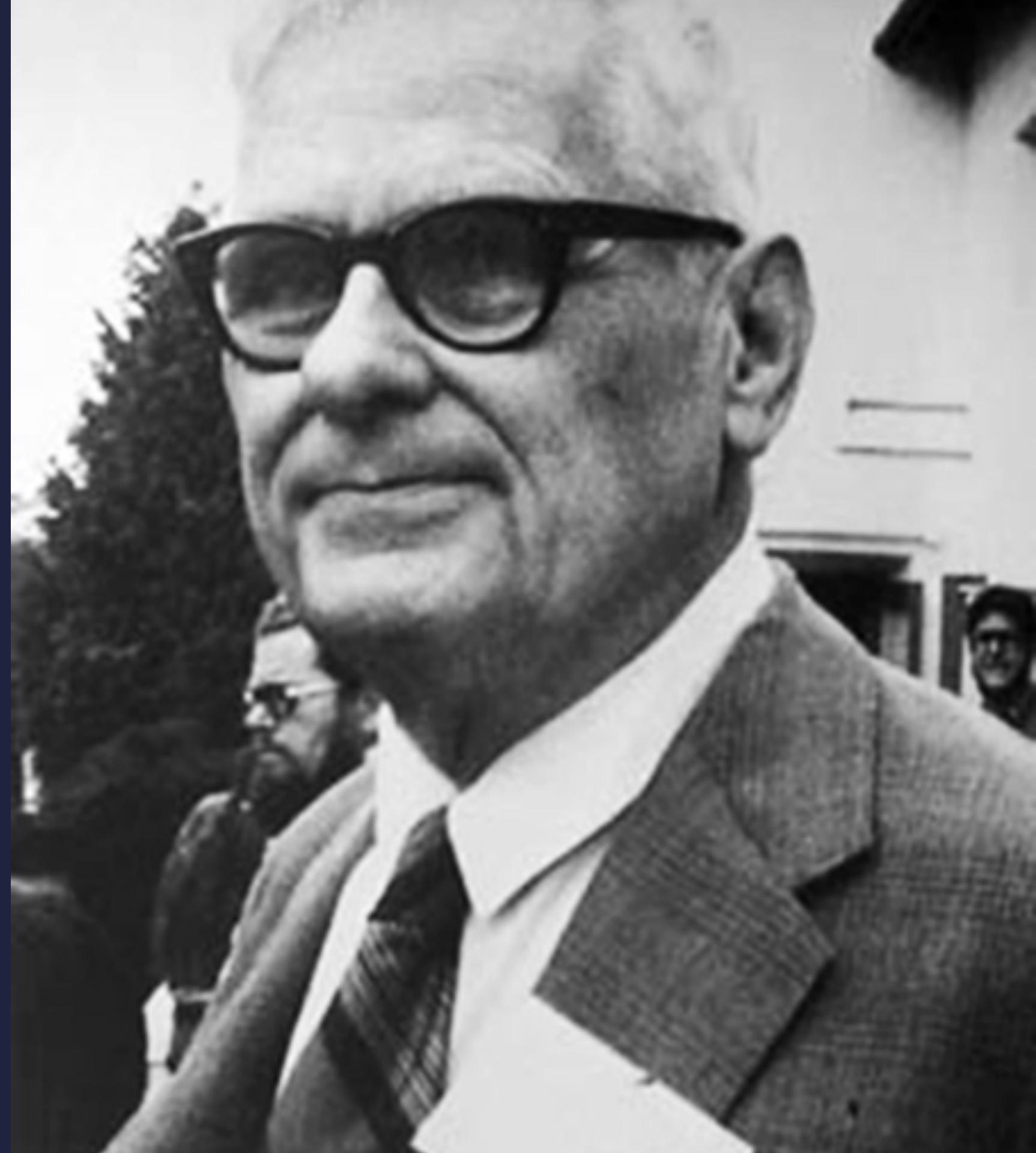
**– John Backus (Turing Award lecture 1977)**

# MUTABLE STATE NEEDS TO BE CONTAINED



*Ok, but how should we  
MANAGE FACTS?*

# *Functional* **PROGRAMMING**



# *logic* PROGRAMMING



# Dataflow PROGRAMMING



**NEVER  
DELETE  
FACTS**

"When bookkeeping was done with clay tablets or paper and ink, accountants developed some clear rules about good accounting practices. One never alters the books; if an error is made, it is annotated and a new compensating entry is made in the books. The books are thus a complete history of the transactions of the business. Update-in-place strikes many systems designers as a cardinal sin: it violates traditional accounting practices that have been observed for hundreds of years."

– Jim Gray (1981)

Just Read

**"Database is a cache of a subset of the log."**  
**– Pat Helland (2007)**

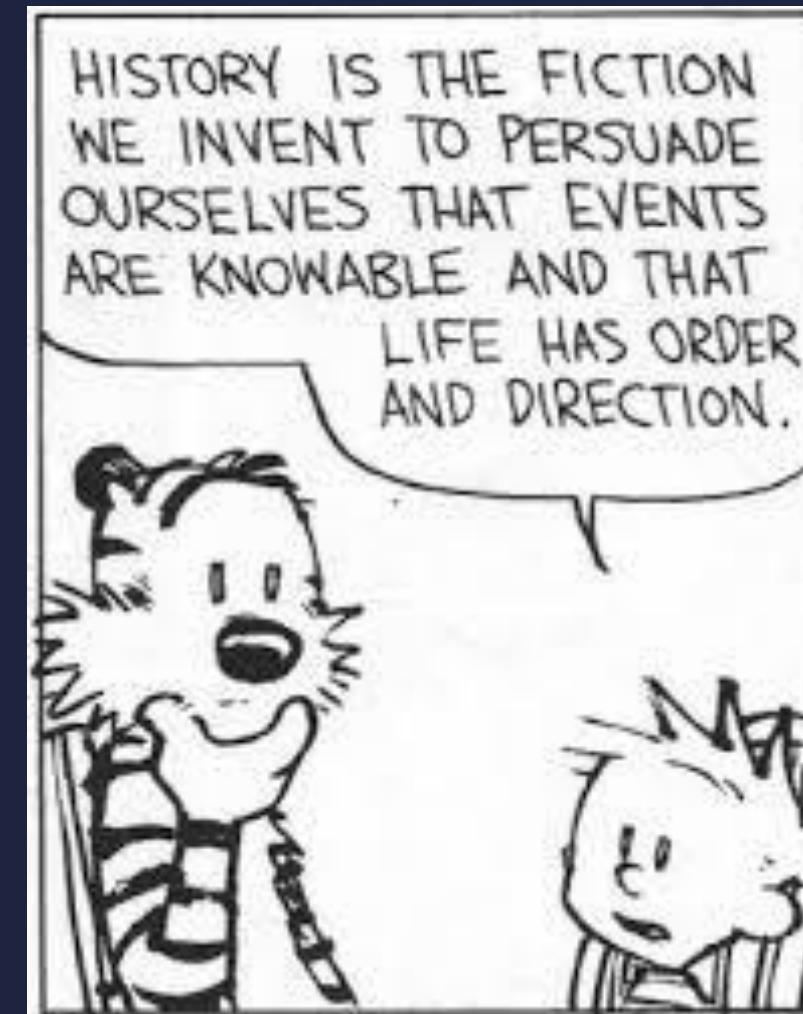
Store facts in an

**EVENT LOG**

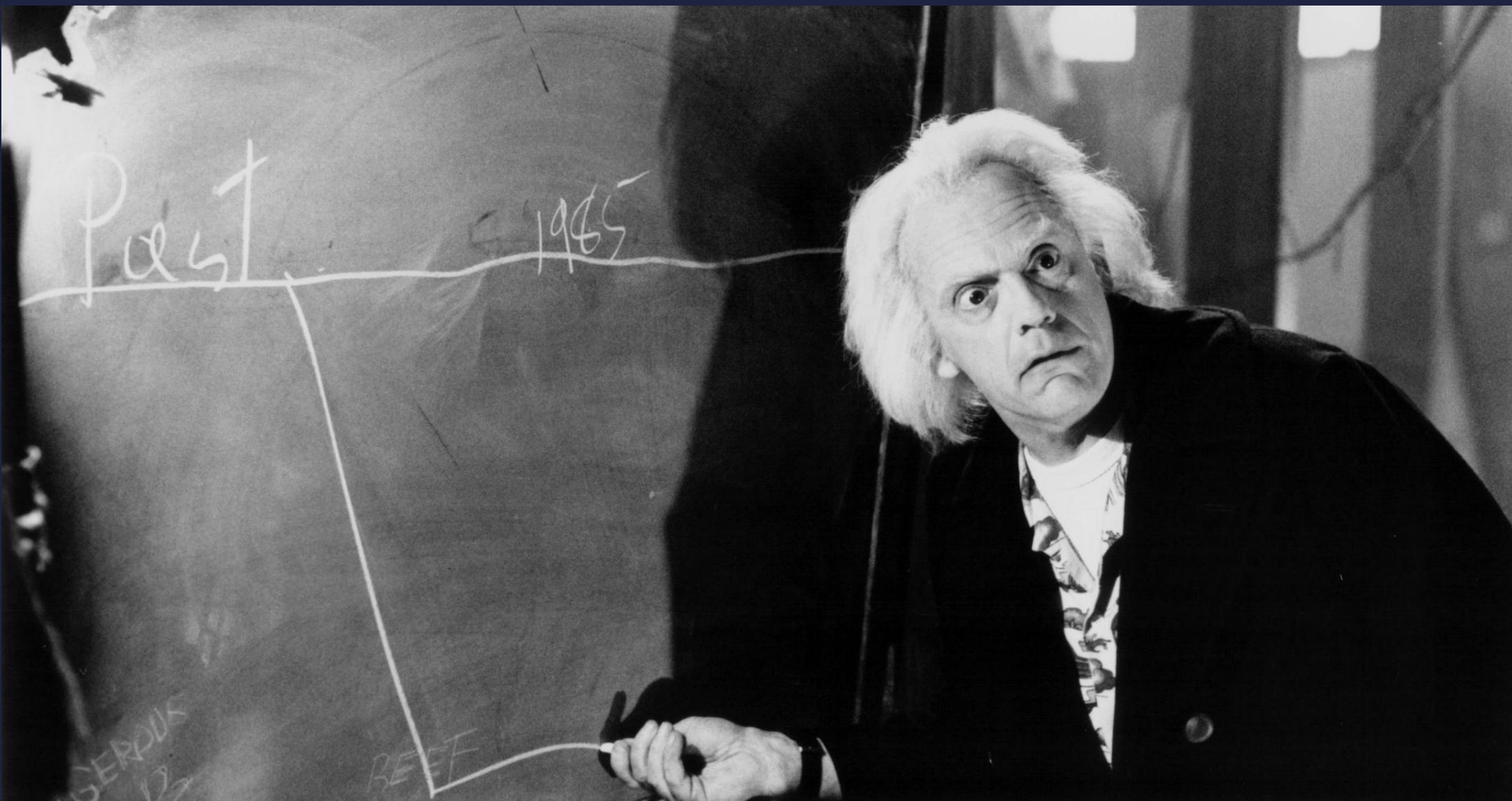
The log allows

**TIME**

**TRAVEL**



# Can we REWRITE THE PAST?



Allows us to *shift* our focus from

**DATA AT REST**, to

**DATA IN MOTION**

# Stream Processing



CONSTRUCTING A SUFFICIENTLY CONSISTENT

LOCAL PRESENT

MEANS EMPLOYING

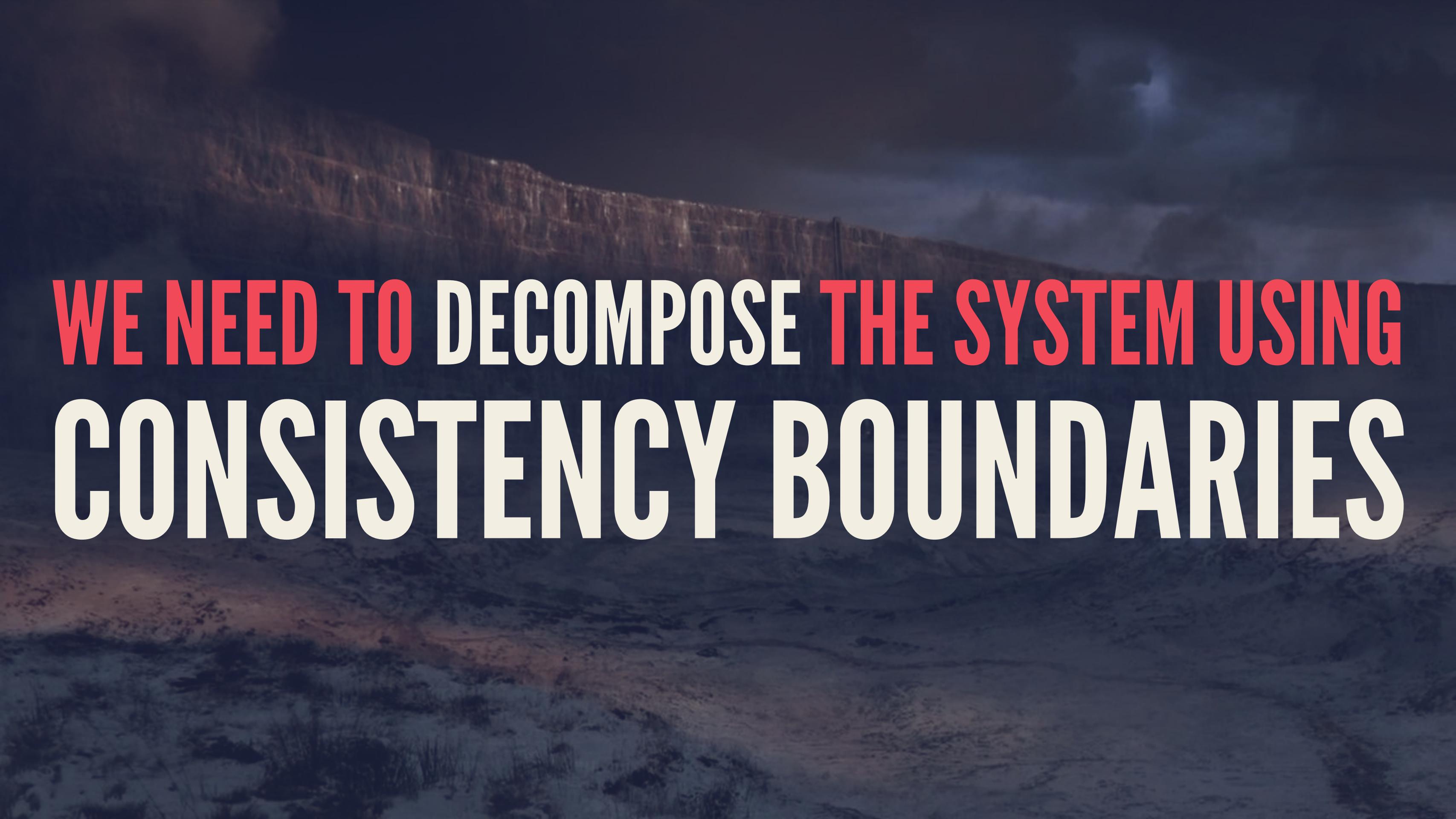
CONSISTENCY MECHANISMS

*Consistency*

**WHAT?**

**WHY?**

**WHEN?**



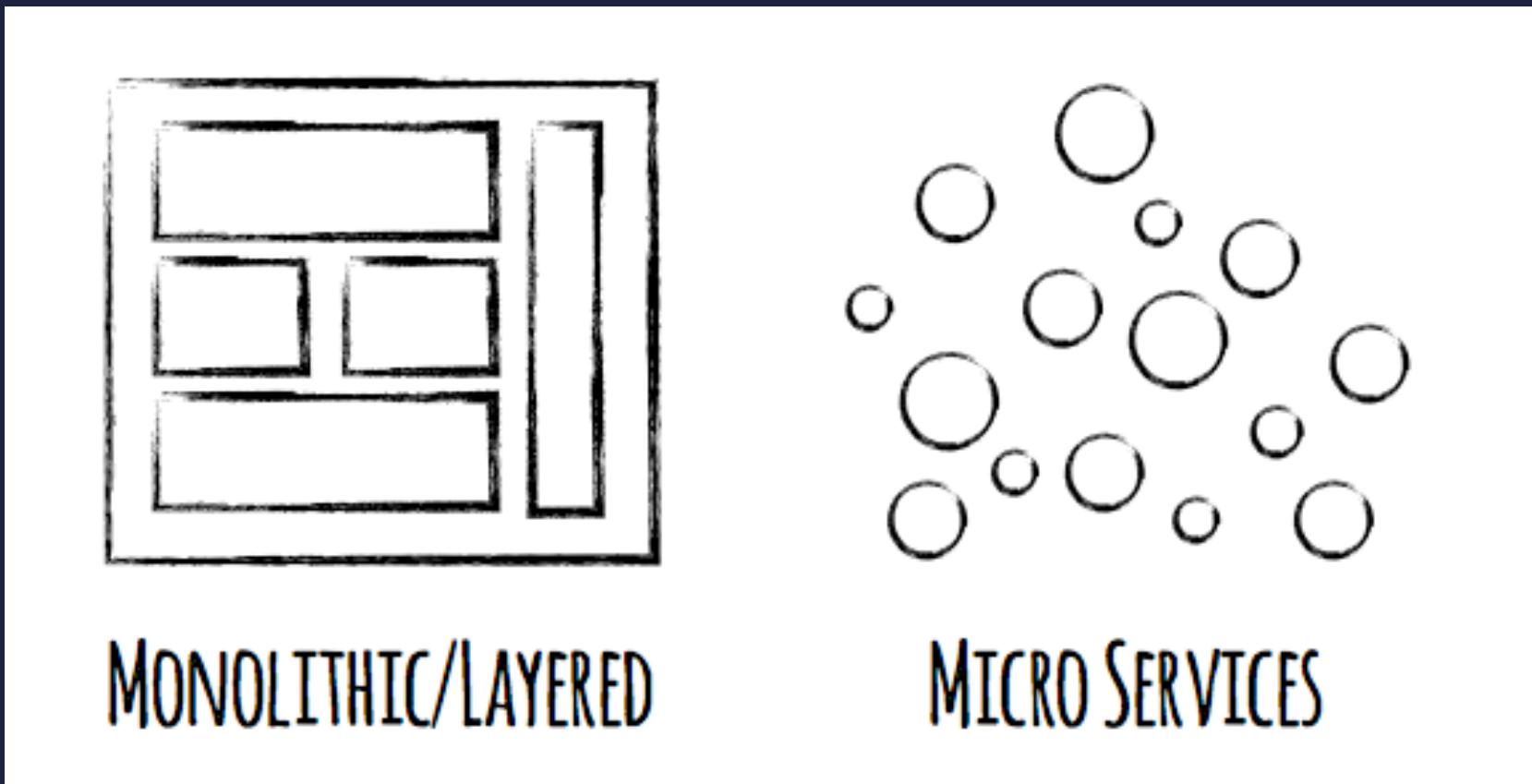
**WE NEED TO DECOMPOSE THE SYSTEM USING  
CONSISTENCY BOUNDARIES**

The background of the image is a dark, atmospheric landscape featuring a long bridge stretching across a body of water under a cloudy sky.

**INSIDE DATA: OUR CURRENT PRESENT  
OUTSIDE DATA: BLAST FROM THE PAST  
BETWEEN SERVICES: HOPE FOR THE FUTURE**

**– PAT HELLAND (DATA ON THE INSIDE VS DATA ON THE OUTSIDE)**

# MicroSERVICE

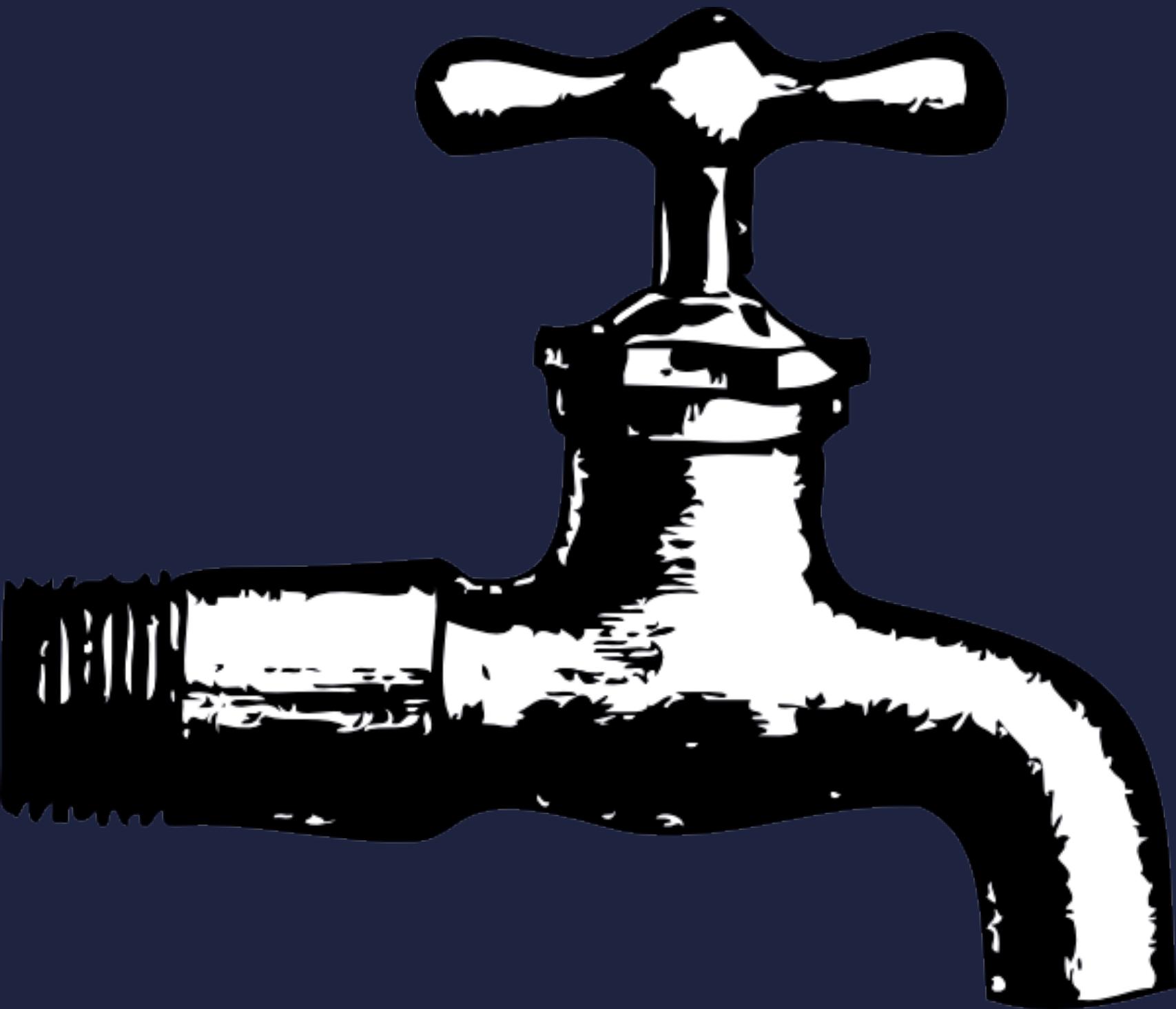


# AGGREGATE Root



A landscape photograph of a small town at sunset. In the foreground, a road curves to the left. On the right side, there's a red barn and a white church with a steeple. The town extends into the background with more houses and trees. The sky is filled with warm orange and yellow hues from the setting sun. A large, semi-transparent white sphere is overlaid on the image, centered over the town. The sphere has a soft shadow on the ground to its left.

**WITHIN THE CONSISTENCY BOUNDARY**



**EVENT**  
*Sourcing*



BETWEEN THE  
*Consistency*  
*Boundaries*  
IT'S A ZOO

*Decoupling in*

**TIME / SPACE**



# STRONG CONSISTENCY

*The wrong default*



*Here, we are living in the  
LOOMING SHADOW OF  
**IMPOSSIBILITY**  
**THEOREMS***



FILIP

CONSENSUS IS IMPOSSIBLE

# PROTOCOLS CLIMB THE LADDER OF KNOWLEDGE

$C\phi$ : Common Knowledge (infinite number of i)

$Ei\phi$ : (Everyone knows \* i)  $\phi$

$E3\phi$ : (Everyone knows \* 3)  $\phi$

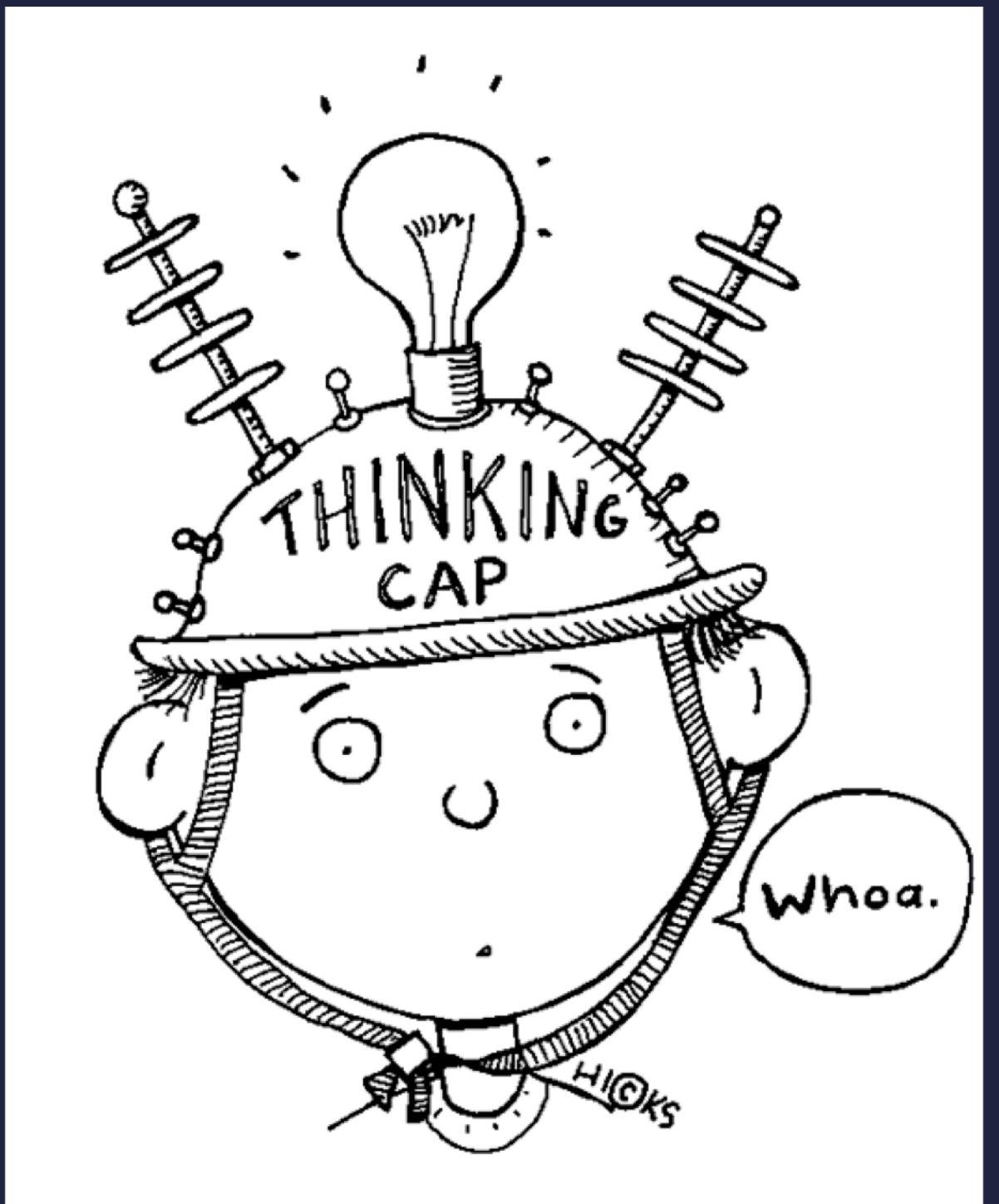
$E2\phi$ : Everyone knows Everyone knows  $\phi$

$E1\phi$ : Everyone knows  $\phi$

$S\phi$ : Someone knows  $\phi$

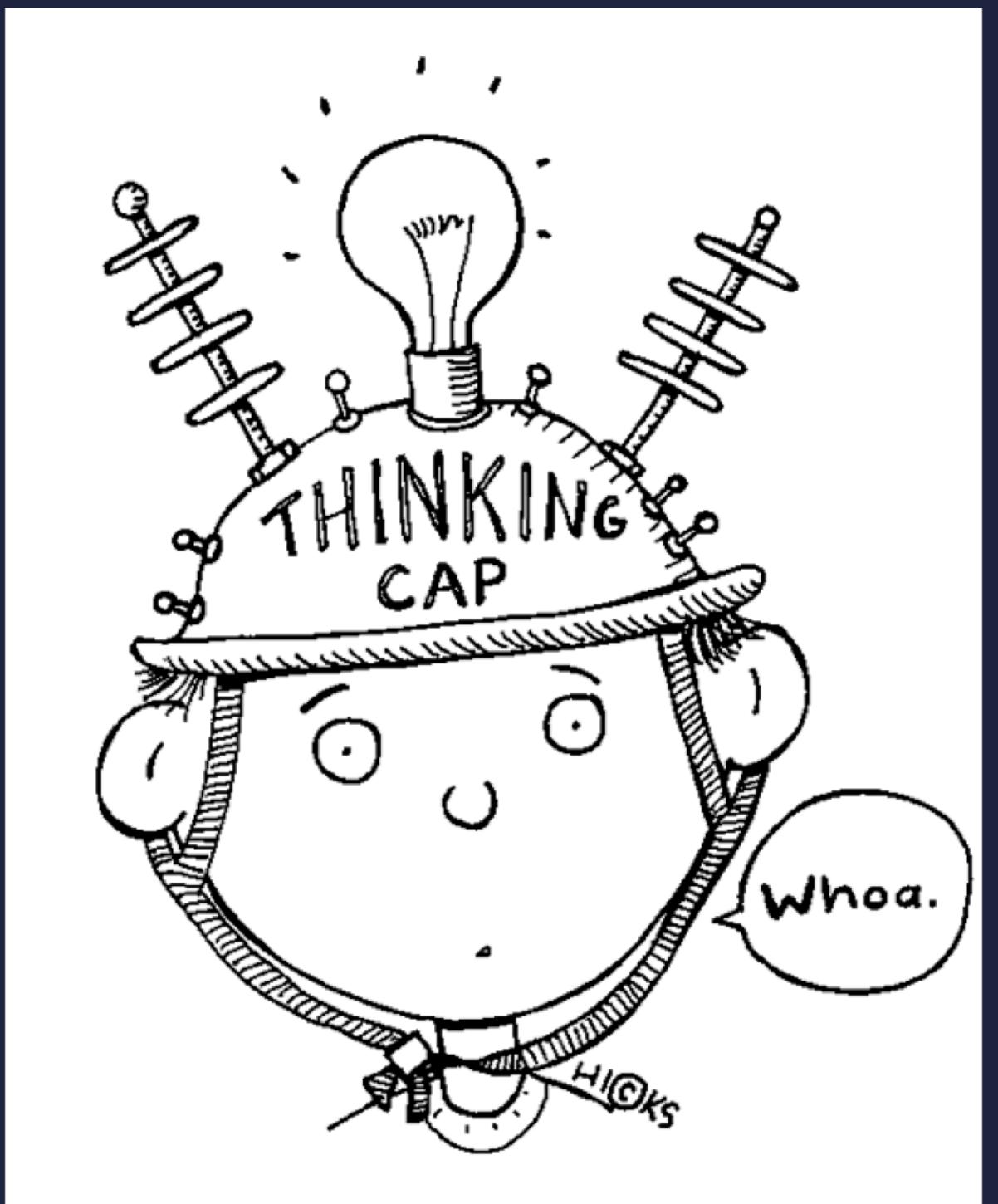
**COMMON KNOWLEDGE  
IS NOT ATTAINABLE VIA PROTOCOL**

**- JOSEPH HALPERN**



# CAP

## CONSISTENCY IS IMPOSSIBLE



# Dissecting **CAP**

**"The first principle of successful scalability is to batter the consistency mechanisms down to a minimum."**

**- James Hamilton**

# EVENTUAL CONSISTENCY

*What does it really mean?*

*Tracking TIME is tracking CAUSALITY*

# RELYING ON TIMESTAMPS IS A BAD IDEA



*Instead, rely on*

**LOGICAL TIME**

*Lawport*

CLOCKS

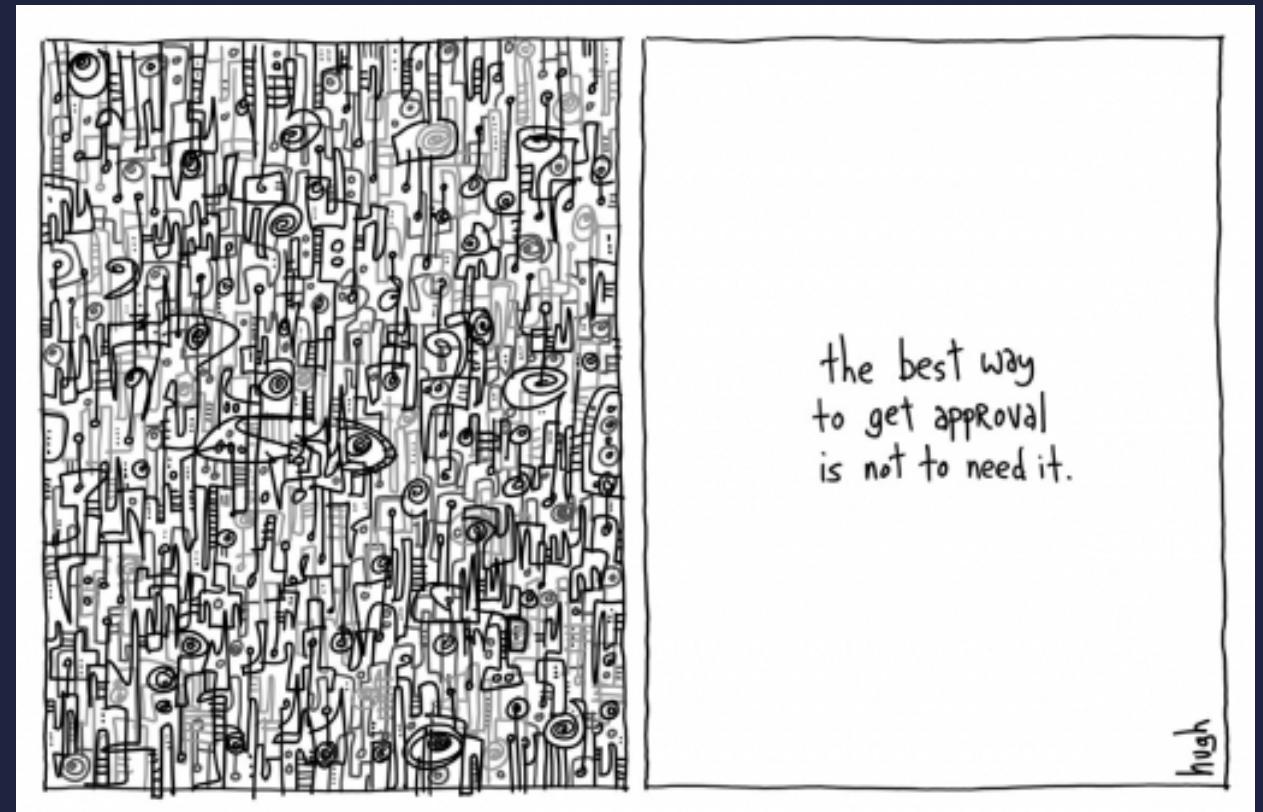
GLOBAL CAUSAL ORDERING BETWEEN

# *Vector* CLOCKS

PARTIAL CAUSAL ORDERING BETWEEN EVENTS

*Causal*  
CONSISTENCY

*What*  
**CONSISTENCY**  
**DO YOU REALLY NEED AND**  
*when?*



the best way  
to get approval  
is not to need it.

# ACID 2.0

ASSOCIATIVE  
COMMUTATIVE  
IDEMPOTENT  
DISTRIBUTED



# CONFFLICT-FREE REPLICATED DATA TYPES

# DISORDERLY PROGRAMMING

CALM THEOREM



CALMER  
THAN  
YOU  
ARE

A dynamic photograph of several male sprinters in mid-air, performing a triple jump. The athlete in the center is wearing a yellow Jamaican singlet with 'JAMAICA' and 'BOLT' printed on it, along with green and blue shorts. He is in the middle of a powerful jump, with his arms extended forward and legs tucked. Other athletes in red, green, and white singlets are visible around him. The background is filled with spectators and flags, including the British flag. The overall scene conveys a sense of intense competition and athletic performance.

WE ARE JUST GETTING STARTED

**WE HAVE A LONG ROAD AHEAD OF US...**





**Thanks  
FOR LISTENING**



*Life* BEYOND  
*the* ILLUSION  
*of* PRESENT

Jonas Bonér  
CTO Typesafe  
@jboner