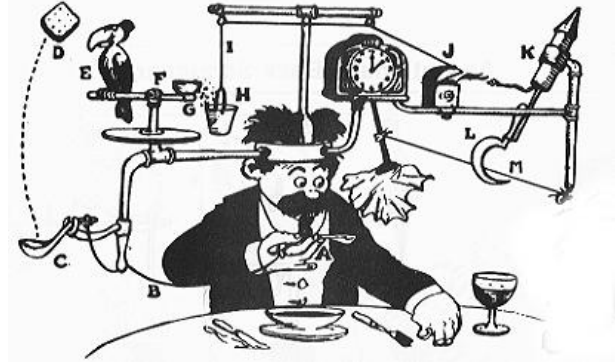


Testing Complex Systems in Complex Environments



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Topics



- **Types, examples, and failures of systems**
 - **Simple**
 - **Complex**
 - **Hyper-complex**
- **What can testing actually claim?**
- **The ethical aspects**
- **What to do**

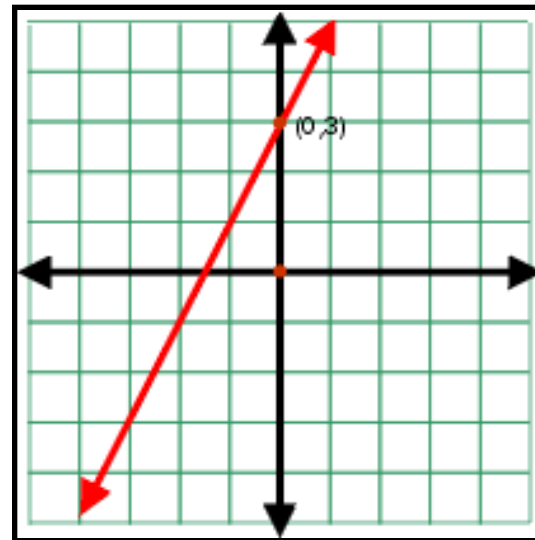
Simple Systems



- **Features**
 - **Linear relationships (perturbations cause a proportional effect).**
 - **Do not contain feedback loops.**
 - **Do not have memory (prior states do not influence current behavior).**

Example: Simple System

$$y=mx+b$$



Complex Systems



- **Features**
 - **Non-linear relationships (small perturbations may cause no effect, a proportional effect, or a large effect).**
 - **Contain feedback loops (both positive and negative).**
 - **Have memory (prior states may influence current behavior).**
 - **Are often nested (composed of other complex systems – networks of networks and systems of systems).**

Example: Complex System



<< Insert your company's current product here >>



Emergent Behavior



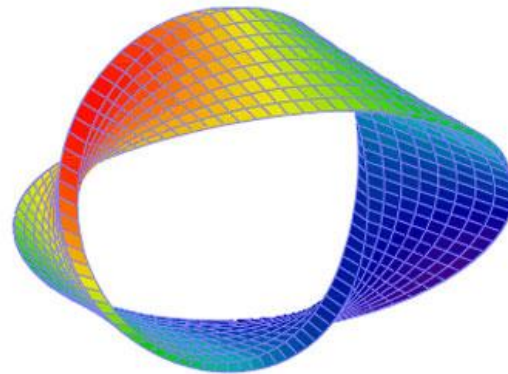
- **“Emergent behavior is that which cannot be predicted through analysis at any level simpler than that of the system as a whole. Explanations of emergence, like simplifications of complexity, are inherently illusory and can only be achieved by sleight of hand. Emergent behavior is what's left after everything else has been explained.”**

– George Dyson

Emergent Behavior



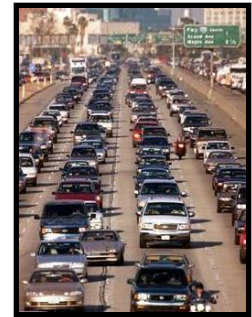
- **In complex systems, failures are often intermittent, transient, and convoluted. We are creating designs so complicated that we cannot anticipate all the possible interactions and all the inevitable failures.**



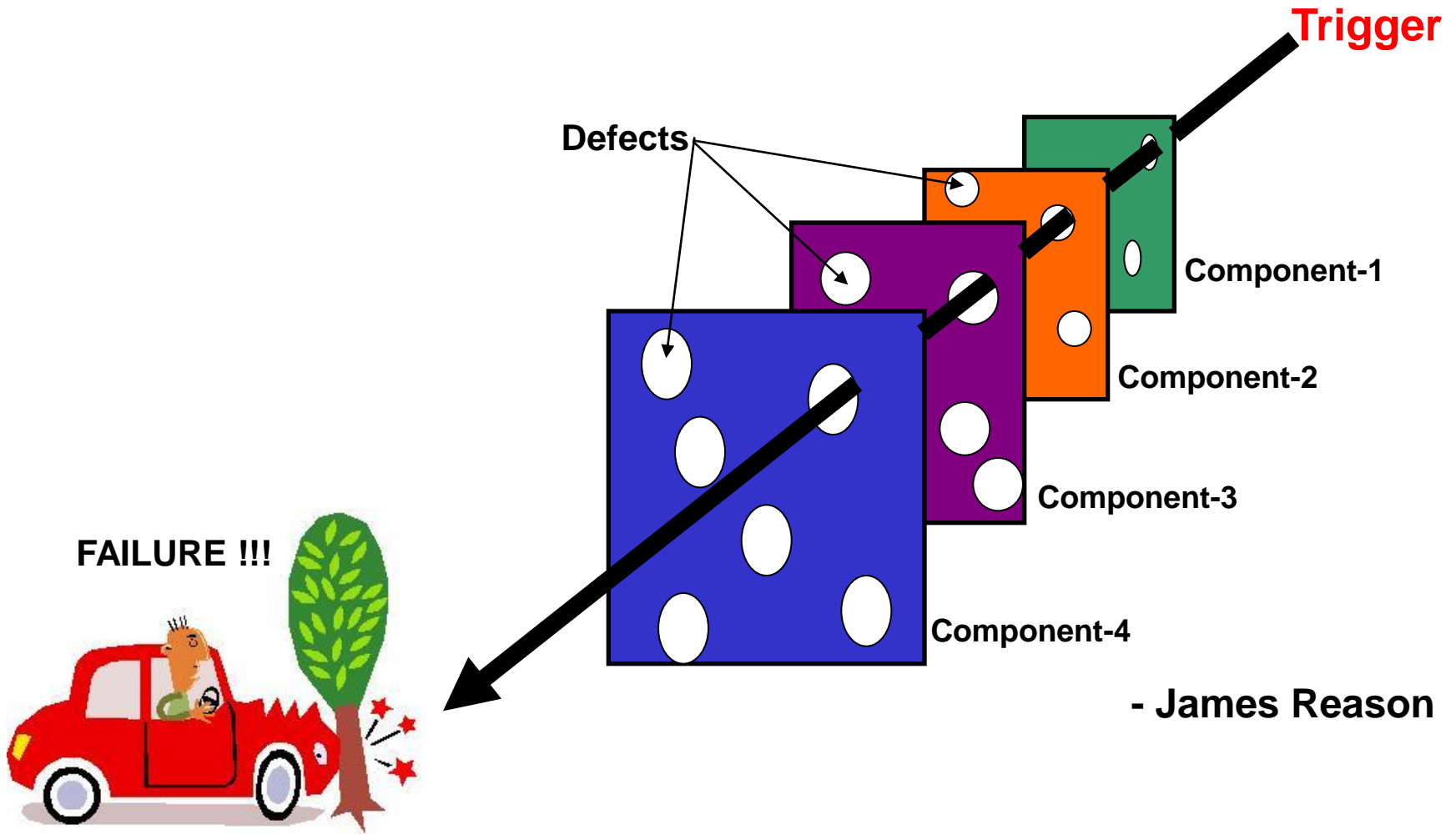
Example: Emergent Behavior



- **Highway traffic jams – you know there’s someone up there going only 25 mph.**
- **The movement of the Stock Market – who knows what tomorrow will bring?**
- **The Millennium Bridge in London – as people walked across, it started to sway.**



The Swiss Cheese Failure Model



- James Reason

Example: Emergent Behavior



- On May 11, 1996, ValuJet 592 crashed into the Florida Everglades killing all 110 passengers and crew.
- A massive fire doomed the aircraft.
- The proximate cause was oxygen generators, inadvertently loaded into the cargo hold, that ignited and burned, BUT ...



Reason's Model: ValuJet 592

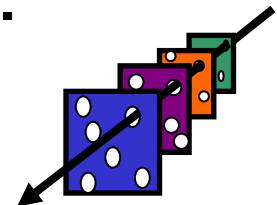


- **SabreTech (outsourced maintenance vendor)**
 - To complete work before deadline, required their technicians to work 12 hours/day, 7 days/week.
 - Outsourced half its work to other vendors.
 - For accuracy, they used “work cards” to detail the steps for every maintenance procedure. Work card 0069 called for disabling the oxygen generation canisters with locking caps or emptying them – neither was done.
 - Procedure called for red tags (condemned components) to be applied to the canisters, No red tags were available so green tags were used.

Reason's Model: ValuJet 592

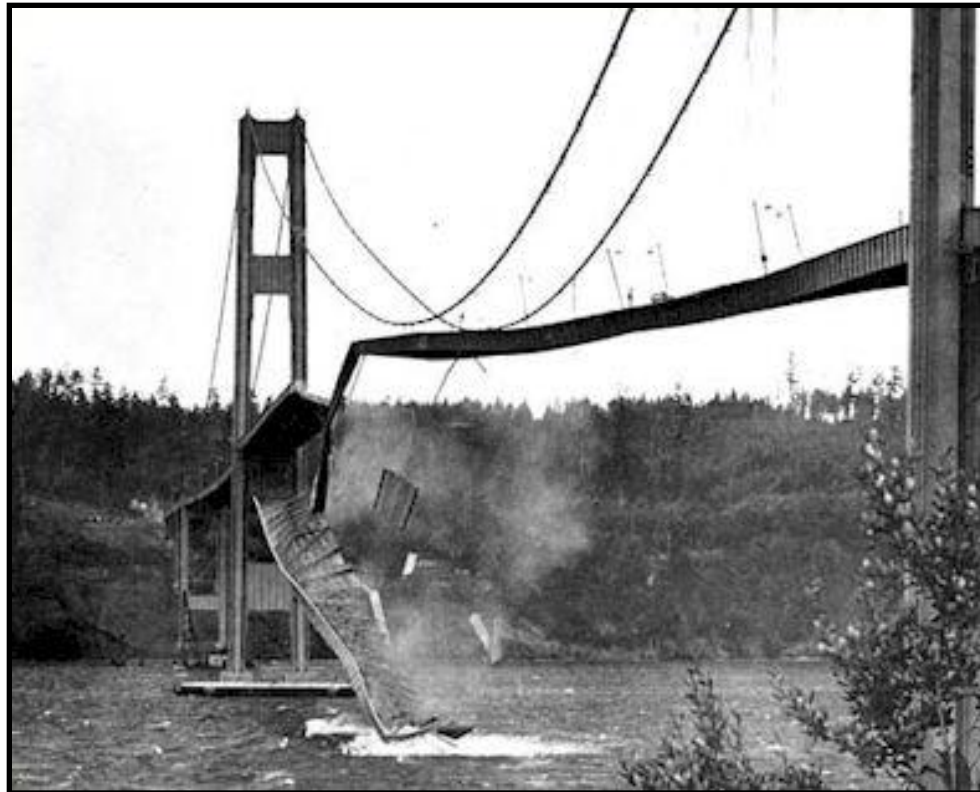


- **SabreTech (continued)**
 - Four technicians signed off that they had correctly performed the steps on card 0069 – none had.
 - Several days later, another technician placed three boxes of the oxygen generators on a shelf holding other ValuJet materials.
 - Because the work area was to be inspected, a clerk placed the canisters in other boxes and wrapped them in bubble pack and labeled them ValuJet aircraft parts, to be returned to the airline.
 - On May 11, 1996, they were loaded onto flight 592.



Example: Emergent Behavior

- **Tacoma Narrows Bridge, 1940**



Example: Emergent Behavior



**GRAND OPENING
JULY 1, 1940**

Warning On Emergent Behavior



- **“Too often, the potential range of behavior of complex systems has to be guessed at from a small set of data. When a system works normally, staying within a narrow range of parameters, engineers make their observations and hope they can extrapolate more or less linearly to less usual behavior.”**



- James Gleick

The Butterfly Effect



- **The Butterfly Effect – sensitive dependence on initial conditions – is the essence of Chaos Theory.**
- **The term was coined by Edward Lorenz, a meteorologist, who gave a paper entitled *Predictability: Does the Flap of a Butterfly's Wings in Brazil set off a Tornado in Texas?***



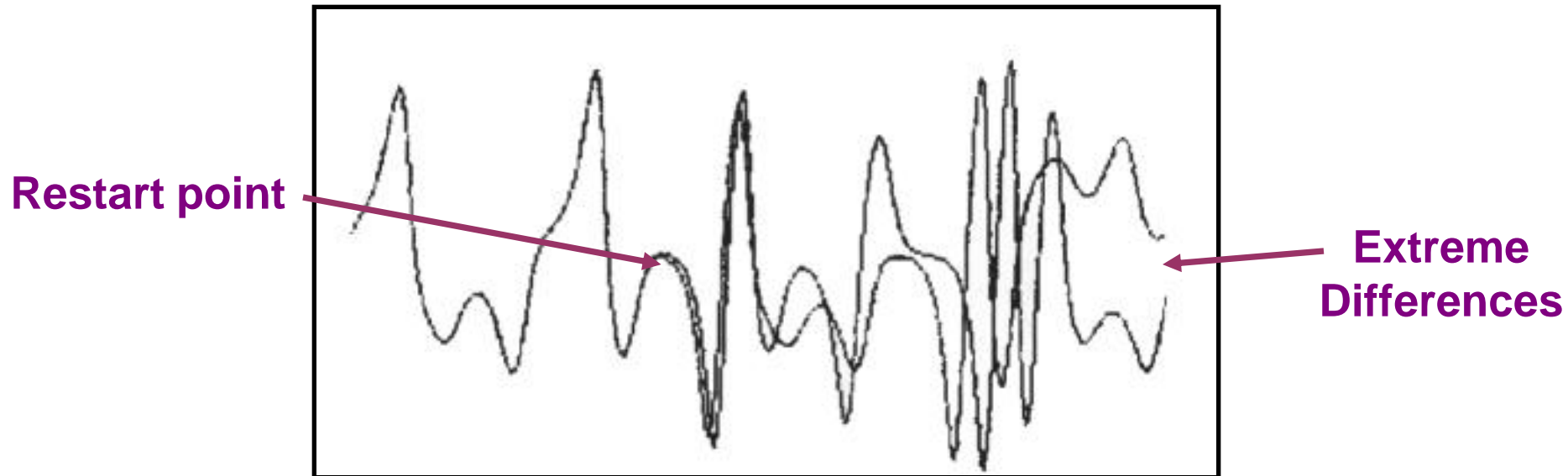
The Butterfly Effect

- You would expect that a set of inputs that were very close together would result in very similar system behaviors.
- Lorenz was modeling the atmosphere with a set of three simple partial differential equations.
- One day he wanted to restart his computations where he ended the day before. The previous day's last output was 0.506127. He entered 0.506 expecting to continue on.



The Butterfly Effect

- This is what he observed:



Sensitive dependence on initial conditions.

Hyper-Complex Systems



- **Features:**
 - All the features of complex systems **PLUS**
 - Components are dynamically located and composed into systems,
 - From multiple sources and with multiple versions,
 - With unknown component histories in terms of design, coding, testing, performance, security,
 - Communicating over non-reliable networks.

Example: Hyper-Complex System



<< Insert your company's NEXT product here >>



A Warning To All



- **“It is time to recognize that the standard education of a scientist gives the wrong impression. No matter how elaborate linear mathematics could get ... it inevitably misleads scientists about their overwhelmingly nonlinear world. The mathematical intuition so developed ill equips the student to confront the bizarre behavior exhibited by the simplest of discrete nonlinear systems.”**

- James Gleick

What Can Testing Actually Know?



- **Modern view**
 - **Find defects**
 - **Count them**
 - **Report them**

**Testing? So simple,
even a caveman
can do it.**



What Can Testing Actually Know?



- **Post-Modern view – “testing is an activity that provides information that others use to improve product and process quality”**



Tester



Testing status – number of tests planned, developed, executed, passed, failed



Defect status – count, severity, characteristics, patterns



Coverage assessment

Coverage Assessment



- Coverage is defined as

Stuff we've tested

Stuff there is to test

But, in hyper-complex systems, because of their emergent behavior, we cannot know the denominator.

Coverage Assessment



- In defining coverage that includes emergent behavior, we have **NO CLUE !!!!!**
- It's like saying:
 - I've pulled 54 dandelions
 - I've painted 124 ft² of fence
 - I've driven 432 kilometers
- It's data without context, it's numbers without information.



The Ethical Aspects

Who knew?

- **ISTQB Code of Ethics (excerpts)**

- **Certified software testers shall act consistently with the public interest**
- **Certified software testers shall ensure that that the deliverables they provide (on the products and systems they test) meet the highest professional standards possible**
- **Certified software testers shall maintain integrity and independence in their professional judgment**
- **Certified software testers shall advance the integrity and reputation of the profession**



The Ethical Aspects



- **How can we remain ethical when testing hyper-complex systems?**



What To Do?

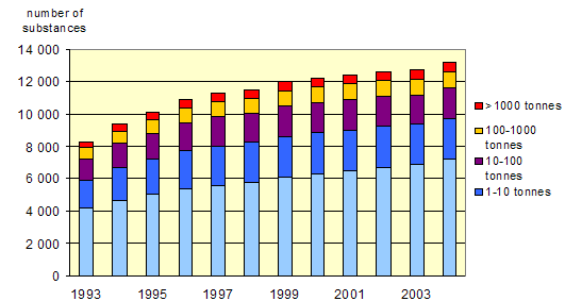
- We're going to have to change from

Quantitative testing

to



Qualitative testing



What To Do?



- **“We need to orient ourselves less towards confirmation, verification, and validation and more towards investigation and discovery.”**



— Michael Bolton

- **And our stakeholders may not like this! They'll still ask for guarantees, and will ignore our disclaimers**

Thanks



- **Thanks for joining with me today.**
- **If I can be of assistance, or if you'd just like to chat, please contact me at**

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