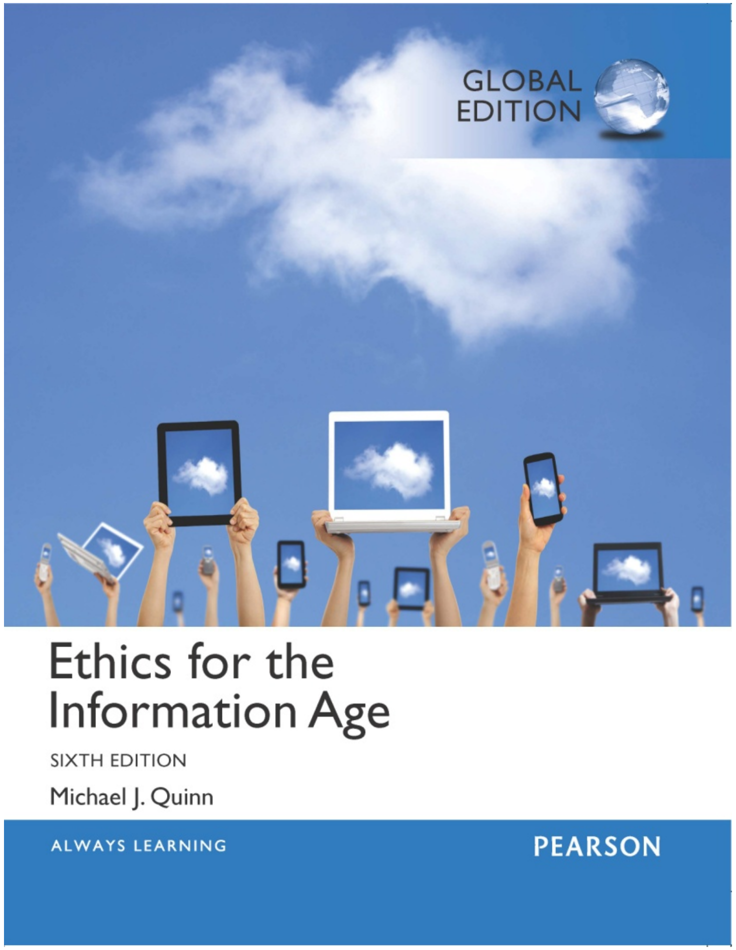


Chapter 8: Computer Reliability

Chapter Overview

- Introduction
- Data entry or data retrieval errors
- Software and billing errors
- Notable software system failures
- Therac-25
- Computer simulations
- Software engineering
- Software warranties and vendor liability

8.1 Introduction

- Computer systems are sometimes unreliable
  - Erroneous information in databases
  - Misinterpretation of database information
  - Malfunction of embedded systems
- Effects of computer errors
  - Inconvenience
  - Bad business decisions
  - Fatalities

8.2 Data-Entry or Data-Retrieval Errors

Two Kinds of Data-related Failure

- A computerized system may fail because wrong data entered into it
- A computerized system may fail because people incorrectly interpret data they retrieve

Disfranchised Voters

- November 2000 general election
- Florida disqualified thousands of voters
- Reason: People identified as felons
- Cause: Incorrect records in voter database
- Consequence: May have affected election’s outcome

False Arrests

- Sheila Jackson Stossier mistaken for Shirley Jackson
  - Arrested and spent five days in detention
- Roberto Hernandez mistaken for another Roberto Hernandez
  - Arrested twice and spent 12 days in jail
- Terry Dean Rogan arrested after someone stole his identity
  - Arrested five times, three times at gun point

Accuracy of NCIC Records

- March 2003: Justice Dept. announces FBI not responsible for accuracy of NCIC information
- Exempts NCIC from some provisions of Privacy Act of 1974
- Should government take responsibility for data correctness?

Dept. of Justice Position

- Impractical for FBI to be responsible for data's accuracy
- Much information provided by other law enforcement and intelligence agencies
- Agents should be able to use discretion
- If provisions of Privacy Act strictly followed, much less information would be in NCIC
- Result: fewer arrests

Position of Privacy Advocates

- Number of records is increasing
- More erroneous records → more false arrests
- Accuracy of NCIC records more important than ever

Act Utilitarian Analysis: Database of Stolen Vehicles

- Over 1 million cars stolen every year
- Just over half are recovered, say 500,000
- Assume NCIC is responsible for at least 20%
- 100,000 cars recovered because of NCIC
- Benefit of $5,000 per car (owner gets car back; effects on national insurance rates; criminal doesn't profit)
- Total value of NCIC stolen vehicle database: $500,000/year
- Only a few stories of false arrests
- Assume 1 false arrest per year (probably high)
- Assume harm caused by false arrest $55,000 (size of award to Rogan)
- Benefit surpasses harm by $445,000/year
- Conclusion: Good to have NCIC stolen vehicles database

8.3 Software and Billing Errors

Errors When Data Are Correct

- Assume data correctly fed into computerized system
- System may still fail if there is an error in its programming

Errors Leading to System Malfunctions

- Qwest sent incorrect bills to cell phone customers
- Faulty USDA beef price reports
- U.S. Postal Service returned mail addressed to Patent and Trademark Office
- Spelling and grammar error checkers increased errors
- New York City Housing authority overcharged renters
- About 450 California prison inmates mistakenly released

Errors Leading to System Failures

- Ambulance dispatch system in London
- Chicago Board of Trade
- BMW limousine
- Japan’s air traffic control system
- Los Angeles County + USC Medical Center laboratory computer system
- Comair’s Christmas Day shutdown
- Boeing 777

Comair Cancelled All Flights on Christmas Day, 2004

AP Photo/Al Behrman, File

Analysis: E-Retailer Posts Wrong Price, Refuses to Deliver

- Amazon.com in Britain offered iPaq for £7 instead of £275
- Orders flooded in
- Amazon.com shut down site, refused to deliver unless customers paid true price
- Was Amazon.com wrong to refuse to fill the orders?

Rule Utilitarian Analysis

- Imagine rule: A company must always honor the advertised price
- Consequences
  - More time spent proofreading advertisements
  - Companies would take out insurance policies
  - Higher costs → higher prices
  - All consumers would pay higher prices
  - Few customers would benefit from errors
- Conclusion
  - Rule has more harms than benefits
  - Amazon.com did the right thing

Kantian Analysis

- Buyers knew 97.5% markdown was an error
- They attempted to take advantage of Amazon.com’s stockholders
- They were not acting in “good faith”
- Buyers were in the wrong, not Amazon.com

8.4 Notable Software System Failures

Patriot Missile

- Designed as anti-aircraft missile
- Used in 1991 Gulf War to intercept Scud missiles
- One battery failed to shoot at Scud that killed 28 soldiers
- Designed to operate only a few hours at a time
- Kept in operation > 100 hours
- Tiny truncation errors added up
- Clock error of 0.3433 seconds → tracking error of 687 meters

Patriot Missile Failure

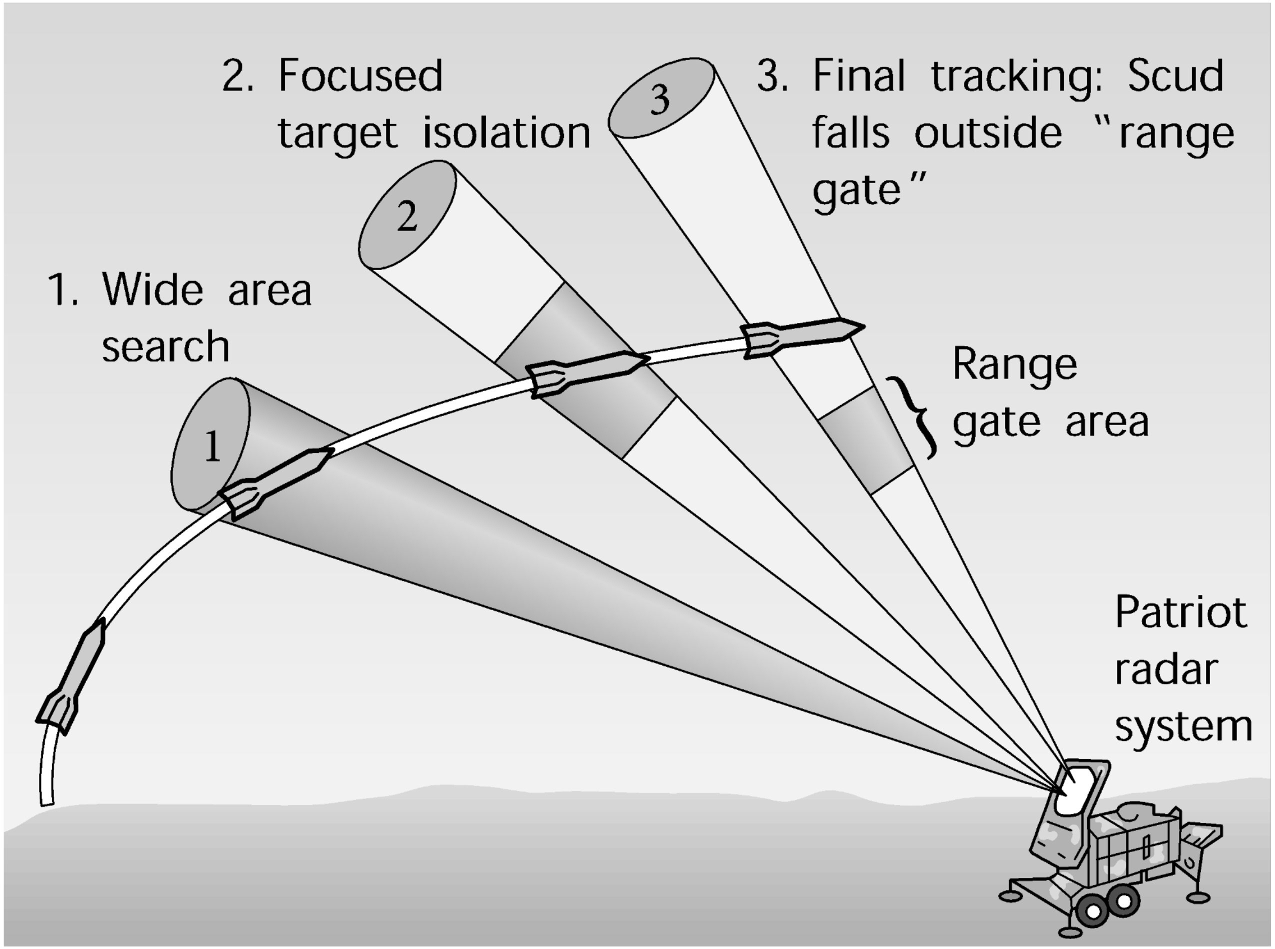

2. Focused target isolation
3. Final tracking: Scud falls outside "range gate"
3
2
1. Wide area search
1
Range gate area
Patriot radar system

Figure from SCIENCE 255:1347. Copyright ©1992 by The American Association for the Advancement of Science. Reprinted with permission.

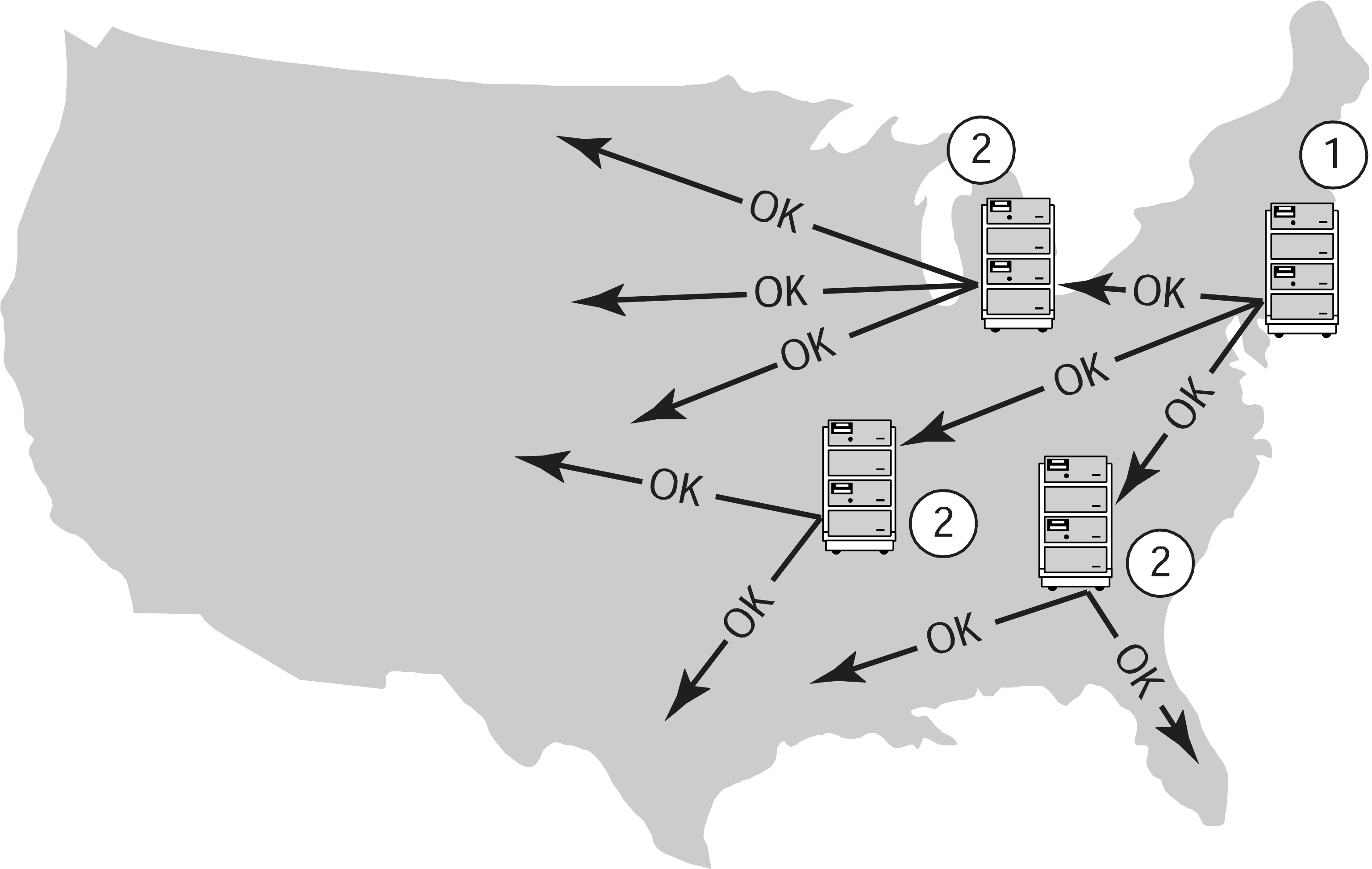
Ariane 5

- Satellite launch vehicle
- 40 seconds into maiden flight, rocket self-destructed
  - $500 million of uninsured satellites lost
- Statement assigning floating-point value to integer raised exception
- Exception not caught and computer crashed
- Code reused from Ariane 4
  - Slower rocket
  - Smaller values being manipulated
  - Exception was impossible

AT&T Long-Distance Network

- Significant service disruption
  - About half of telephone-routing switches crashed
  - 70 million calls not put through
  - 60,000 people lost all service
  - AT&T lost revenue and credibility
- Cause
  - Single line of code in error-recovery procedure
  - Most switches running same software
  - Crashes propagated through switching network

AT&T Long Distance Network Failure



Robot Missions to Mars

- Mars Climate Orbiter
  - Disintegrated in Martian atmosphere
  - Lockheed Martin design used English units
  - Jet Propulsion Lab design used metric units
- Mars Polar Lander
  - Crashed into Martian surface
  - Engines shut off too soon
  - False signal from landing gear

Denver International Airport

- BAE built automated baggage handling system
- Problems
  - Airport designed before automated system chosen
  - Timeline too short
  - System complexity exceeded development team’s ability
- Results
  - Added conventional baggage system
  - 16-month delay in opening airport
  - Cost Denver $1 million a day

Tokyo Stock Exchange

- First day of trading for J-Com
- Mizuho Securities employee mistakenly enters order to sell 610,00 shares at 1 yen, instead of 1 share at 610,000 yen
- Employee overrides computer warning
- After sell order posted on exchange’s display board, Mizuho tries to cancel order several times; software bug causes attempts to fail
- Mizuho loses $225 million buying back shares

Direct Recording Electronic Voting Machines

- After problems with 2000 election, Congress passed Help America Vote Act of 2002
- HAVA provided money to states to replace punch card voting systems
- Many states used HAVA funds to purchase direct recording electronic (DRE) voting machines
- Brazil and India have run national elections using DRE voting machines exclusively
- In November 2006 1/3 of U.S. voters used DRE voting machines

Diebold Electronic Voting Machine

© AP Photo/Rogelio Solis

Issues with DRE Voting Machines

- Voting irregularities
  - Failure to record votes
  - Overcounting votes
  - Misrecording votes
- Lack of a paper audit trail
- Vulnerability to tampering
- Source code a trade secret, can’t be examined
- Possibility of widespread fraud through malicious programming

8.5 Therac-25

Genesis of the Therac-25

- AECL and CGR built Therac-6 and Therac-20
- Therac-25 built by AECL
  - PDP-11 an integral part of system
  - Hardware safety features replaced with software
  - Reused code from Therac-6 and Therac-20
- First Therac-25 shipped in 1983
  - Patient in one room
  - Technician in adjoining room

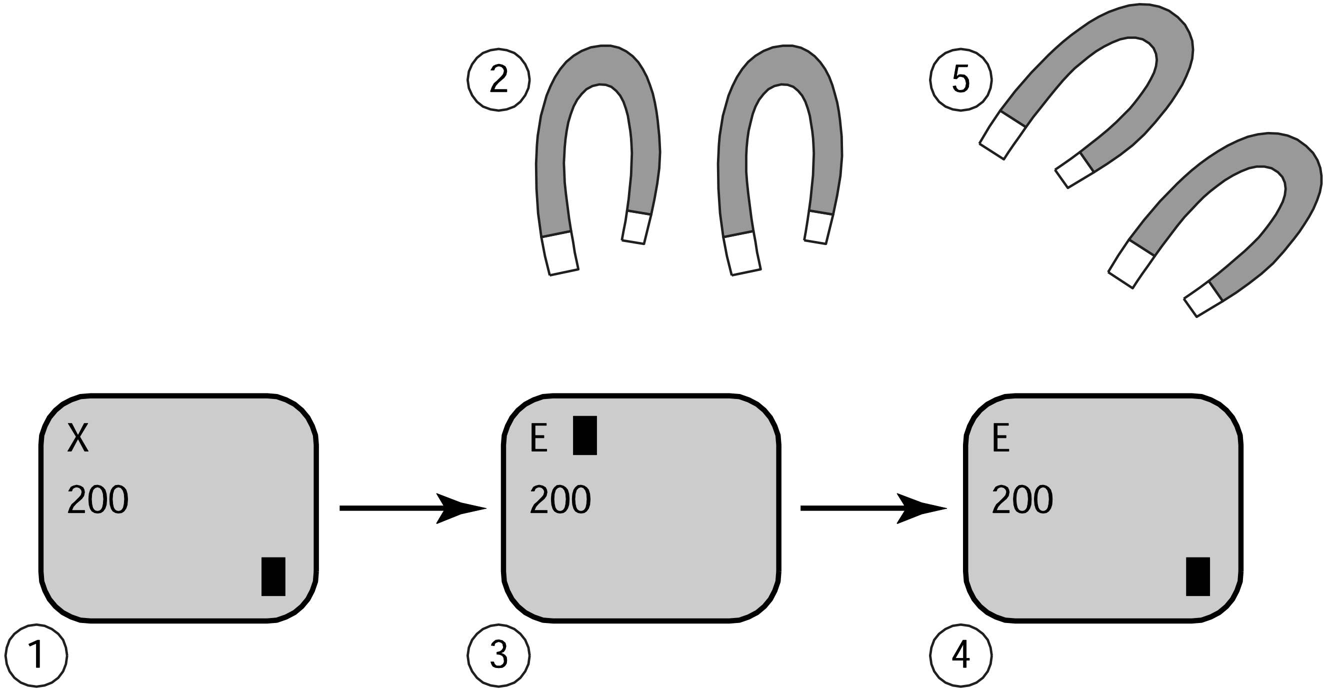
Chronology of Accidents and AECL Responses

- Marietta, Georgia (June 1985)
- Hamilton, Ontario (July 1985)
- First AECL investigation (July-Sept. 1985)
- Yakima, Washington (December 1985)
- Tyler, Texas (March 1986)
- Second AECL investigation (March 1986)
- Tyler, Texas (April 1986)
- Yakima, Washington (January 1987)
- FDA declares Therac-25 defective (February 1987)

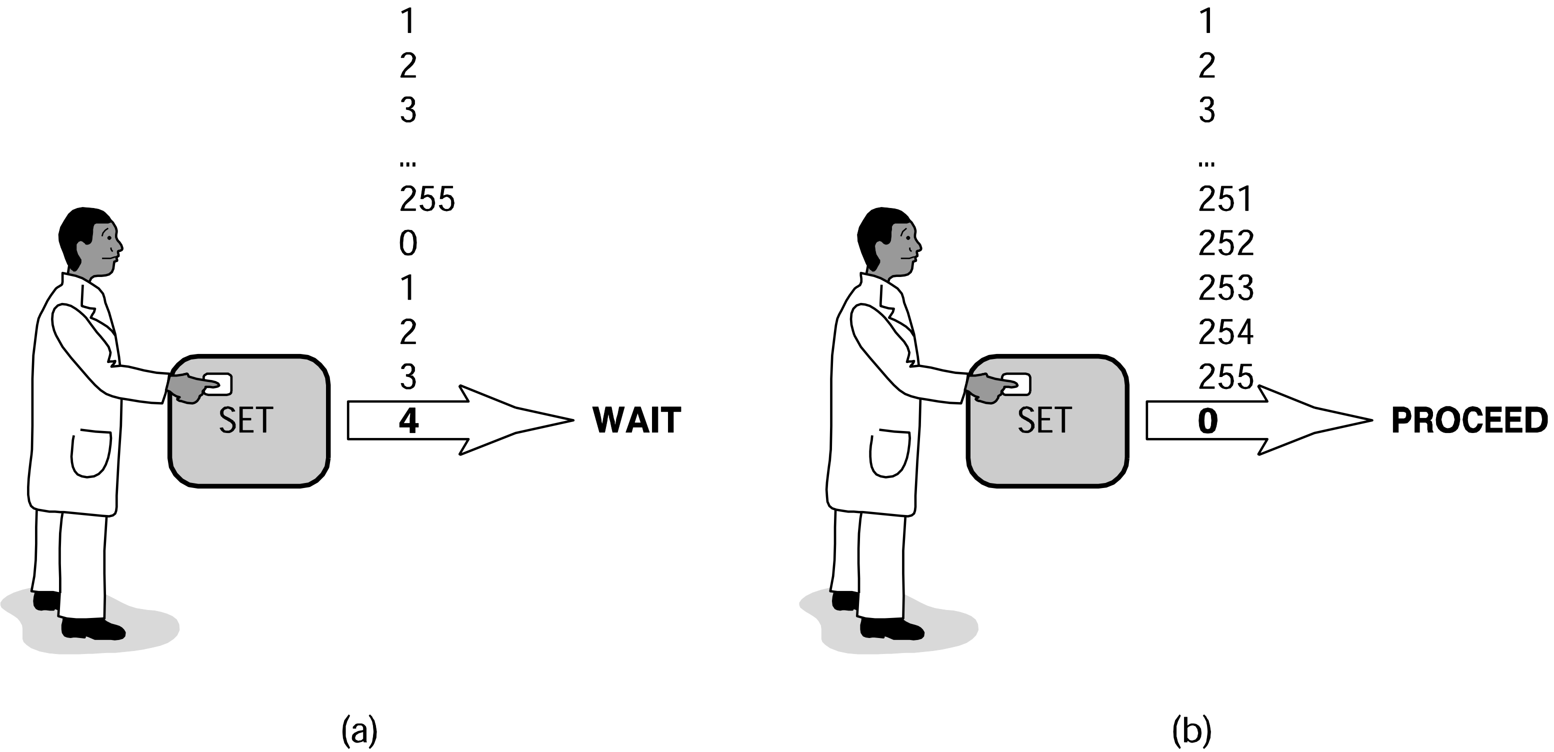
Software Errors

- Race condition: order in which two or more concurrent tasks access a shared variable can affect program's behavior
- Two race conditions in Therac-25 software
  - Command screen editing
  - Movement of electron beam gun

Race Condition Revealed by Fast-typing Operators



Race Condition Caused by Counter Rolling Over to Zero



1
2
3
...
255
0
1
2
3
4

SET

WAIT

(a)

1
2
3
...
251
252
253
254
255
0

SET

PROCEED

(b)

Post Mortem

- AECL focused on fixing individual bugs
- System not designed to be fail-safe
- No devices to report overdoses
- Software lessons
  - Difficult to debug programs with concurrent tasks
  - Design must be as simple as possible
  - Documentation crucial
  - Code reuse does not always lead to higher quality
- AECL did not communicate fully with customers

Moral Responsibility of the Therac-25 Team

- Conditions for moral responsibility
  - Causal condition: actions (or inactions) caused the harm
  - Mental condition
    - Actions (or inactions) intended or willed -OR-
    - Moral agent is careless, reckless, or negligent
- Therac-25 team morally responsible
  - They constructed the device that caused the harm
  - They were negligent

Postscript

- Computer errors related to radiation machines continue to maim and kill patients
- Investigation by *The New York Times*
  - Scott Jerome-Parks, New York (2006)
  - Alexandra Jn-Charles, New York (2006)

8.6 Computer Simulations

Uses of Simulations

- Simulations replace physical experiments
  - Experiment too expensive or time-consuming
  - Experiment unethical
  - Experiment impossible
- Model past events
- Understand world around us
- Predict the future

Simulations Predict Path and Speed of Hurricanes

Courtesy of NASA

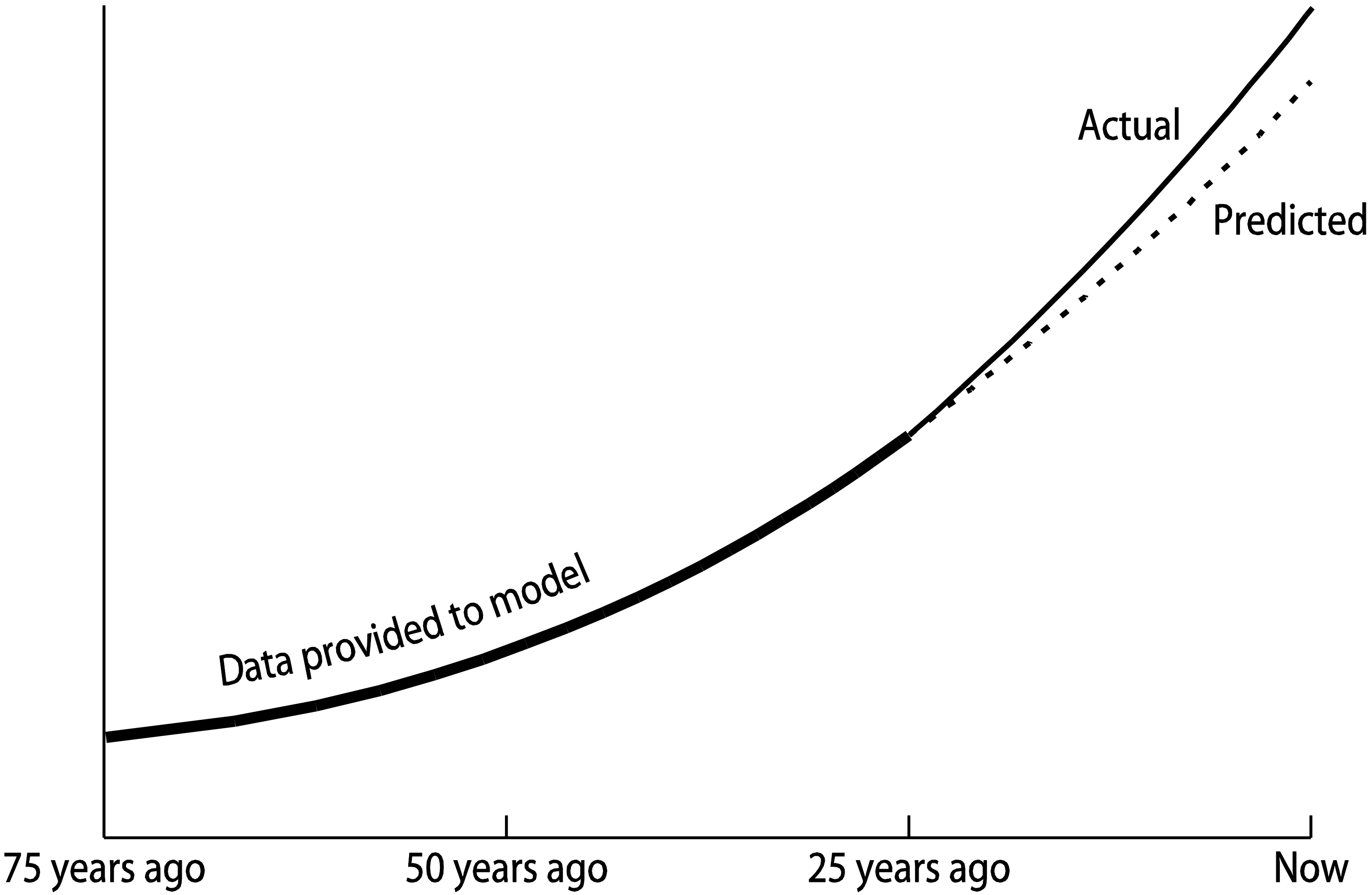
Validating Simulations

- Verification: Does program correctly implement model?
- Validation: Does the model accurately represent the real system?
- Validation methods
  - Make prediction, wait to see if it comes true
  - Predict the present from old data
  - Test credibility with experts and decision makers

Validating a Model

<insert Figure 8.8>

Validation by “Predicting the Present”



8.7 Software Engineering

Specification

- Determine system requirements
- Understand constraints
- Determine feasibility
- End products
  - High-level statement of requirements
  - Mock-up of user interface
  - Low-level requirements statement

Development

- Create high-level design
- Discover and resolve mistakes, omissions in specification
- CASE tools to support design process
- Object-oriented systems have advantages
- After detailed design, actual programs written
- Result: working software system

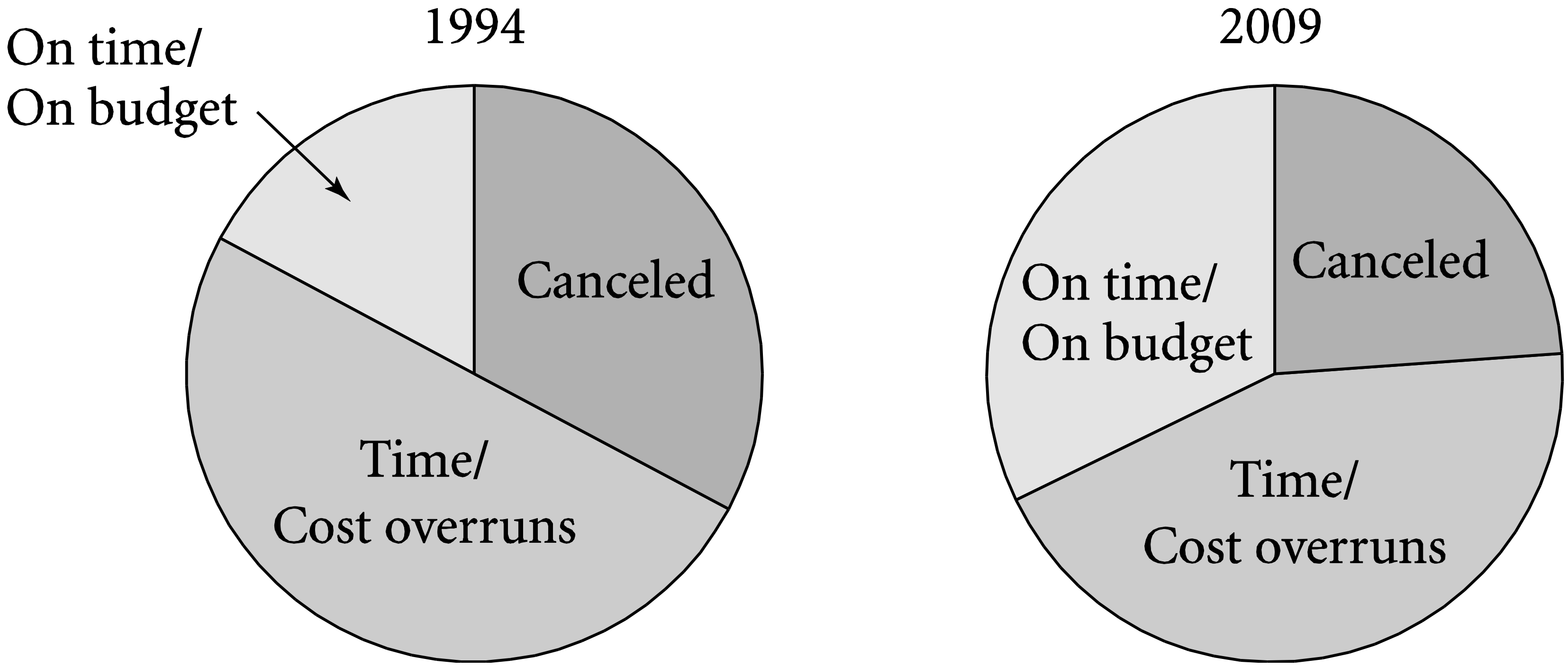
Validation (Testing)

- Ensure software satisfies specification
- Ensure software meets user’s needs
- Challenges to testing software
  - Noncontinuous responses to changes in input
  - Exhaustive testing impossible
  - Testing reveals bugs, but cannot prove none exist
- Test modules, then subsystems, then system

Software Quality Is Improving

- Standish Group tracks IT projects
- Situation in 1994
  - 1/3 projects cancelled before completion
  - 1/2 projects had time and/or cost overruns
  - 1/6 projects completed on time and on budget
- Situation in 2009
  - 1/4 projects cancelled
  - 5/12 projects had time and/or cost overruns
  - 1/3 projects completed on time and on budget

Success of IT Projects Over Time



8.8 Software Warranties and Vendor Liability

Shrinkwrap Warranties

- Some say you accept software “as is”
- Some offer 90-day replacement or money-back guarantee
- None accept liability for harm caused by use of software

Are Software Warranties Enforceable?

- Mass-marketed software and software included in sale of hardware likely to be considered a good by a court of law
- Uniform Commercial Code applies to goods, despite what warranties may say

Key Court Cases

- Step-Saver Data Systems v. Wyse Technology and the Software Link
  - Court ruled that provisions of UCC held
- ProCD v. Zeidenberg
  - Court ruled shrinkwrap licenses are enforceable
- Mortenson v. Timberline Software
  - Court ruled in favor of Timberline and licensing agreement that limited consequential damages

Moral Responsibility of Software Manufacturers

- If vendors were responsible for harmful consequences of defects
  - Companies would test software more
  - They would have to purchase liability insurance
  - Software would cost more
  - Start-ups would be affected more than big companies
  - Less innovation in software industry?
  - Software would be more reliable?
- Making vendors responsible for harmful consequences of defects may be a bad idea, but…
- Consumers should not have to pay for bug fixes