hazards of verification

Daniel Jackson, MIT

Haifa Verification Conference · October 28, 2008

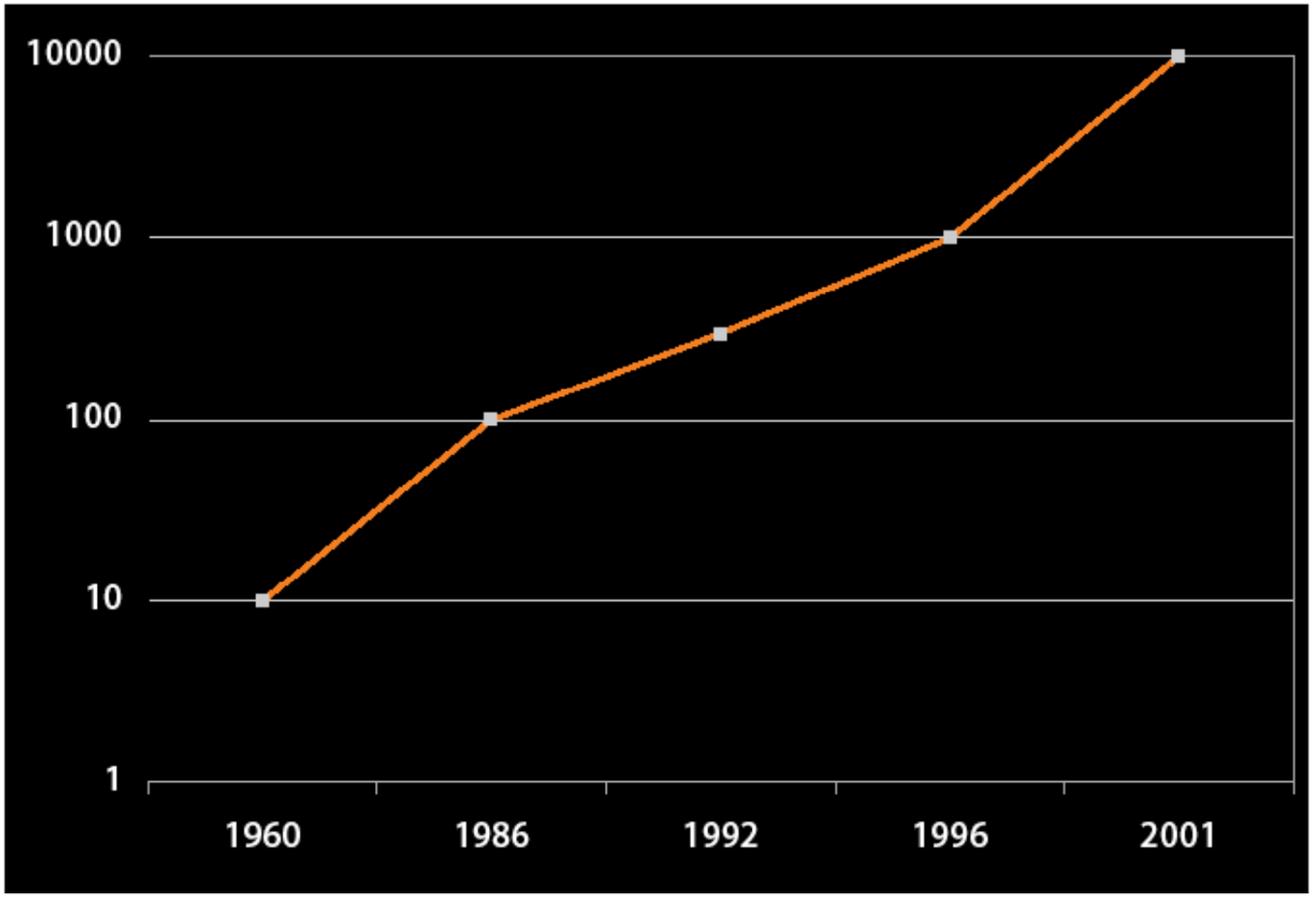
warnings

the contents of this talk are

- anecdotal, not analytical
- broad, not focused
- old, not novel

It is insufficiently considered that men more often require to be reminded than informed.
--Samuel Johnson

how we got here



growth in SAT power (number of variables, data from Sharad Malik)

- one example of why early pessimism about verification was misplaced

hazards

but will verification made software safe and dependable?

- on the road ahead: much progress, but hazards too

hazards due to

- technical factors
- engineering factors
- social/managerial factors

technical factors

unsound confirmation

examples

- finite scope & unrolling [KOA, Dennis VSTTE08]
- lack of coverage [CP bug after 8 years, Holzmann]
- abstraction [binary search, Bloch]

```
L:=1; U:=N
loop
     { MustBe(L,U) }
     if L>U then
          P:=0; break
     M := (L+U) div 2
     case
          X[M] < T:   L:=M+1
          X[M] = T:   P:=M; break
          X[M] > T:   U:=M-1
  endloop
```


Holzmann paper: http://spinroot.com/spin/Workshops/ws08/HJG08.pdf
Bentley column: Communications of the ACM; Volume 26 , Issue 12 (Dec. 1983)
Joshua Bloch. Extra, Extra - Read All About It: Nearly All Binary Searches and Mergesorts are Broken.
http://googleresearch.blogspot.com/2006/06/extra-extra-read-all-about-it-nearly.html
Also see footnote (which page?) in http://www.cs.cmu.edu/~jcr/craftprog.html

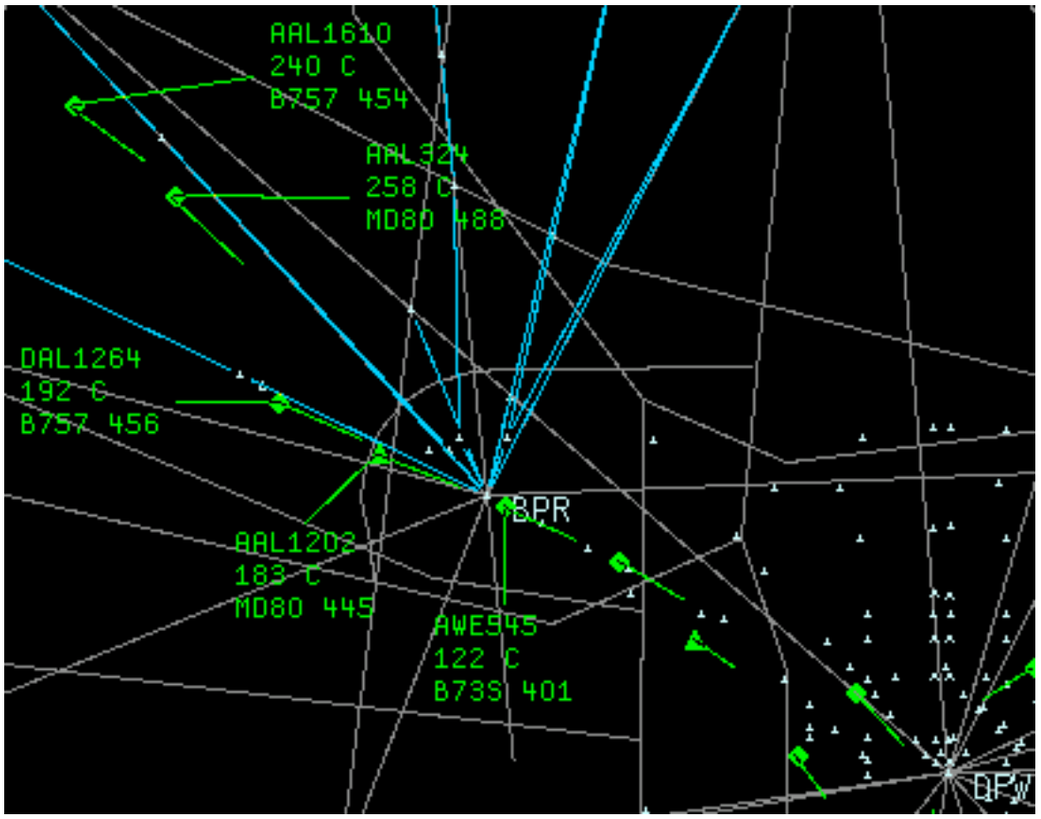
how big a bound?

minimum scope/bitwidth/unrolling to find bugs in voting code

class	method	error	min bound
CandidateListMetadata	init	under	1 / 3 / 1
KiesKring	addDistrict	bug	1 / 3 / 1
VoteSet	addVote(String)	over	1 / 3 / 1
KiesLijst	clear	over	1 / 3 / 3
AuditLog	getCurrentTimeStamp	over	2 / 1 / 1
Candidate	init	under	2 / 3 / 1
CandidateList	addDistrict	under	2 / 3 / 1
CandidateList	addKiesLijst	over	2 / 3 / 1
CandidateList	init	over	2 / 3 / 1
KiesKring	addKiesLijst	bug	2 / 3 / 1
KiesKring	init	under	2 / 3 / 1
KiesKring	make	under	2 / 3 / 1
KiesLijst	addCandidate	over	2 / 3 / 1
KiesLijst	compareTo	bug	2 / 3 / 1
KiesLijst	make	over	2 / 3 / 1
VoteSet	addVote(int)	over	2 / 3 / 1
VoteSet	validateKiesKringNumber	over	2 / 3 / 1
VoteSet	validateRedundantInfo	over	2 / 3 / 1
KiesKring	clear	over	2 / 3 / 3

Table from Dennis, VSTTE08

unsound counterexamples



examples

- unsound checker finds more bugs [Xie and Aiken 2005]
- most effort on error reporting [Pincus et al, Prefix]

Y. Xie and A. Aiken. Context- and Path-Sensitive Memory Leak Detection. In Proceedings of the 5th Joint Meeting of the European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering, pages 115-125, September 2005.

overconstraint

```
abstract sig MemberEvent extends Event {
   by: Member
   }
   {
   by in before.members
   }

abstract sig MembershipEvent extends MemberEvent {
   }

sig Join extends MembershipEvent {
   }
   {
   by not in before.members
   after.members = before.members + by
   }
```

examples

- declarative models of software (Alloy, Z, VDM, B, etc)
- axioms for code verifiers
- 'unreachable states' in model checking

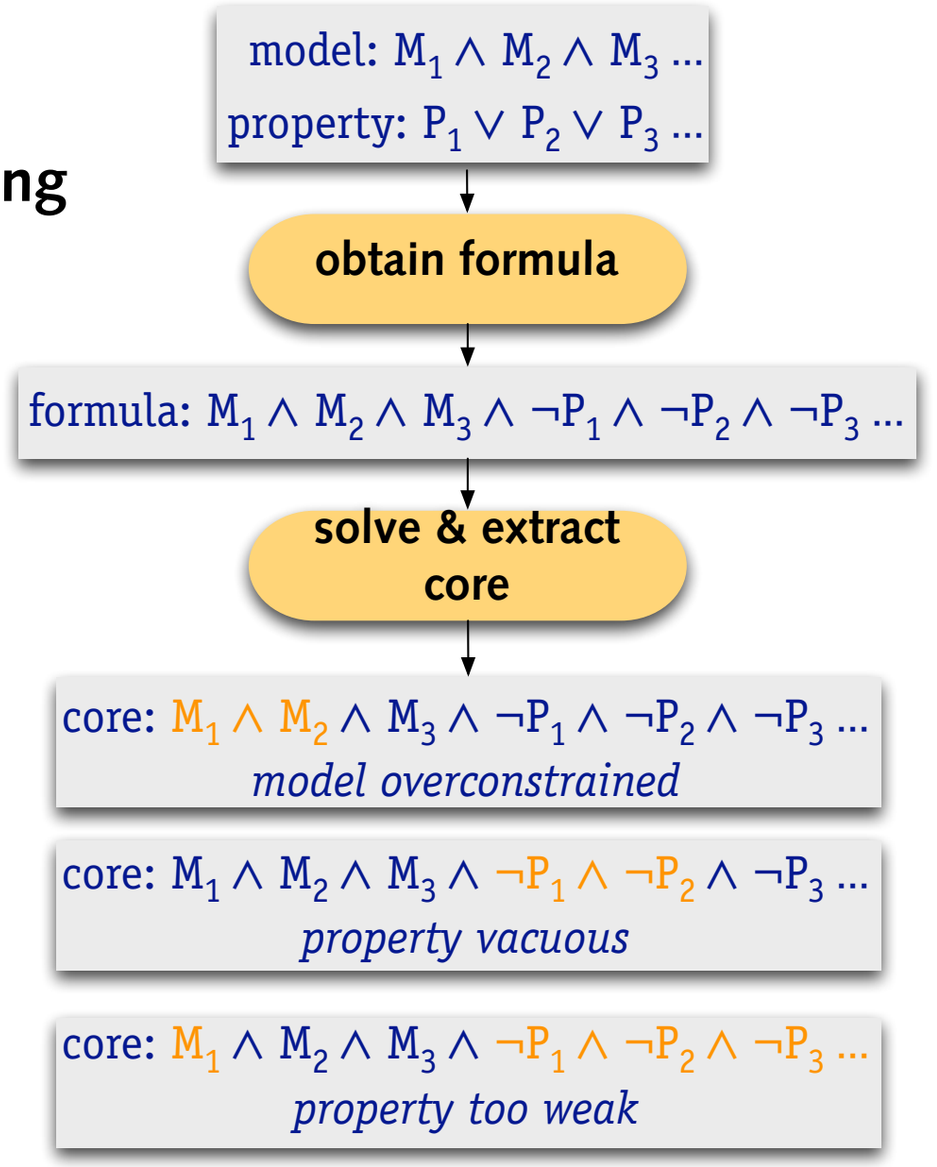
approaches

vacuity and coverage in model checking

- Beer, Ben-David, Eisner, Rodeh
- Chockler, Kupferman, Vardi
- Chechik, Devereux, Gurfinkel

coverage in Alloy

- new algorithm [Torlak, FME08]



engineering factors

end-to-end

are bugs in code the problem?

- Mackenzie: 3% of software fatalities due to code
- most problems in human/computer interaction

is run-time-error elimination enough?

- 'Sorry no more bugs' -- Greg Nelson, 1980

sad examples

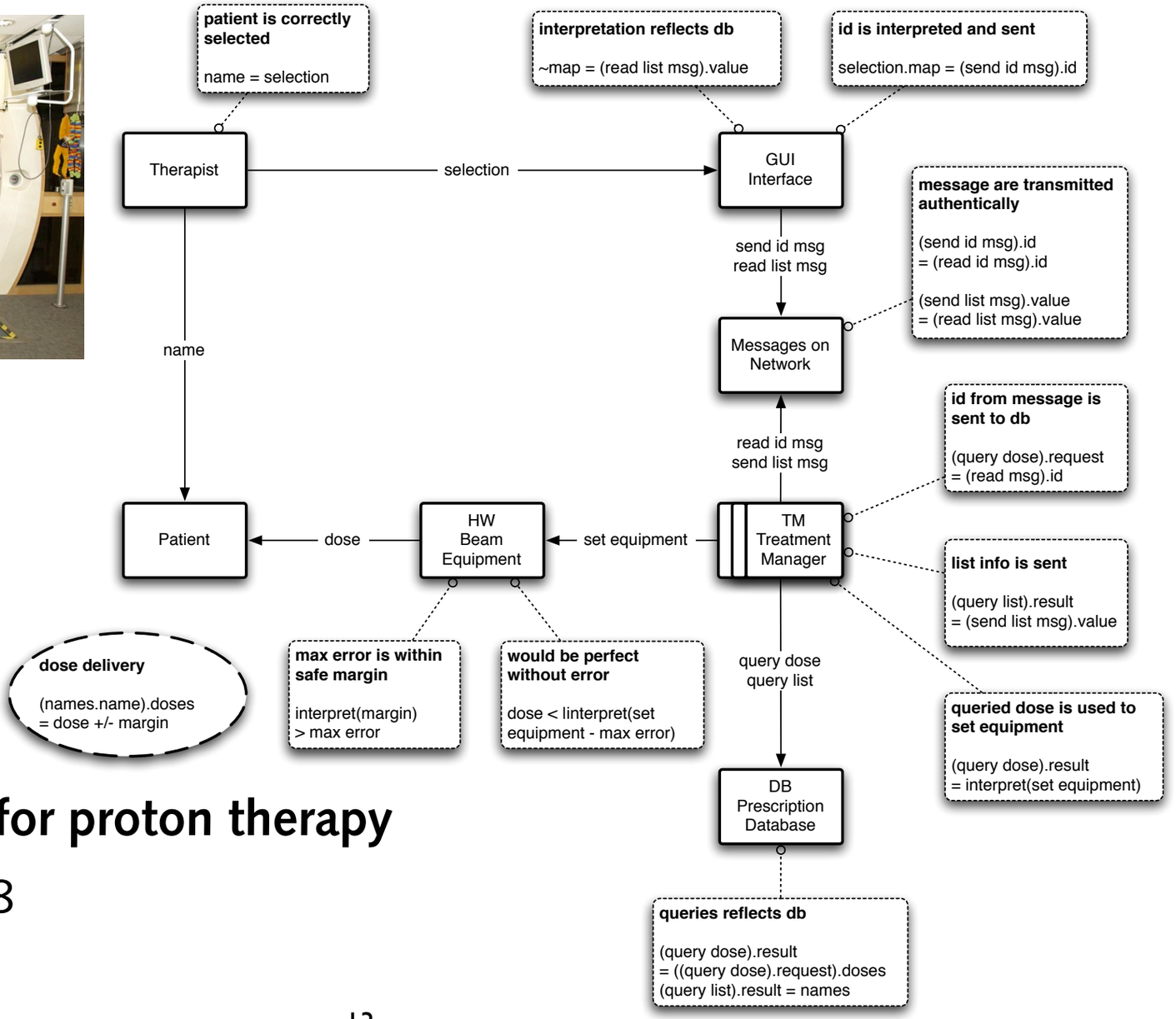
- PLUGR, Afghanistan 2001
- Airbus A320, Warsaw 1993

airborne ⇔ not WheelPulse ⇔ disabled

ENV ✗ MACHINE ✓

see Michael Jackson, Problem Frames, Addison Wesley, 2001

an approach



dependability case for proton therapy

- Robert Seater, 2008

conservative ≠ good

Korean Air 747, Guam 1997: 200 killed

If the ARTS IIA minimum safe altitude warning system had been operating as initially intended, a visual and aural warning would have activated about 64 seconds before flight 801 impacted terrain --*NTSB report*

ignoring design

early blender patent

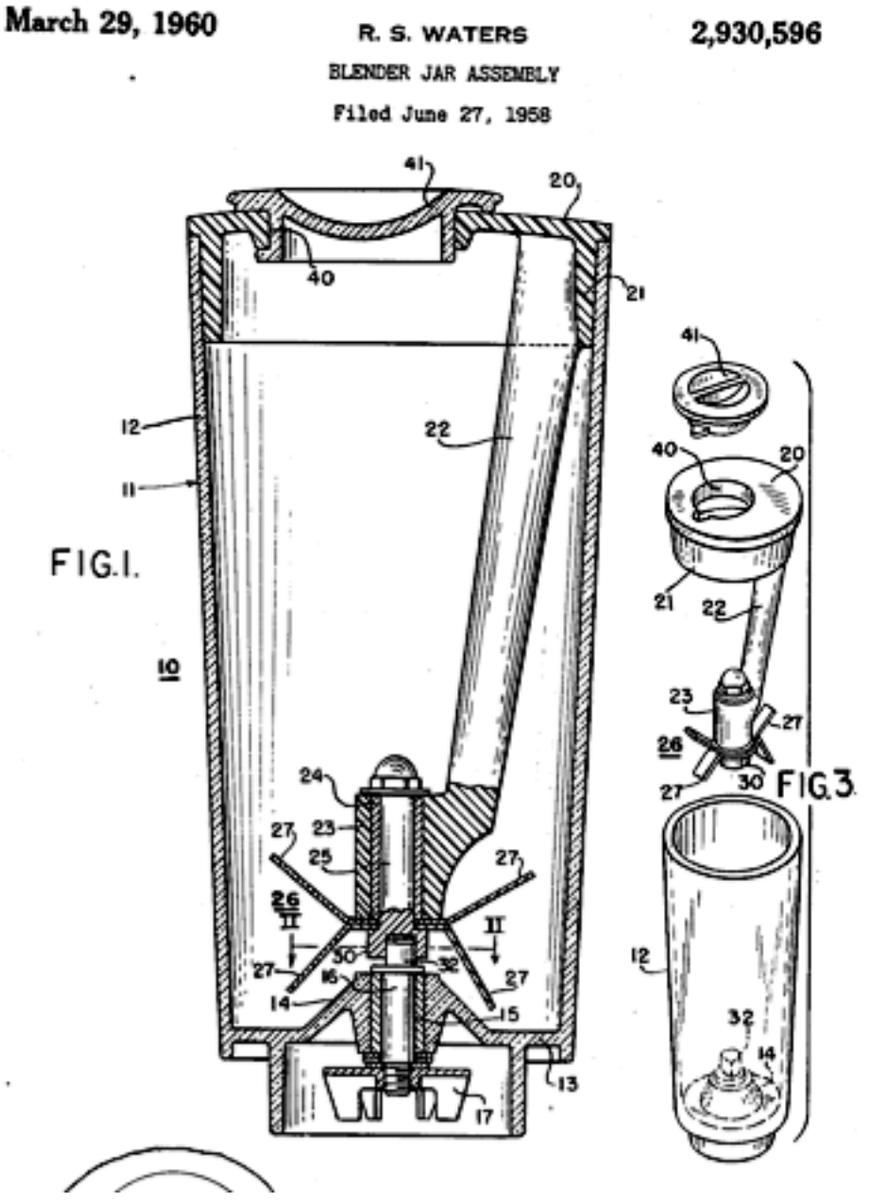
- opening too small for child's hand
- removal of closure disconnects blade

examples

- Therac 25: removed hardware interlock
- voting software: immutable types
- emergency stop: uses message queue

time to think again about

- safety kernels and modularity



platform risk

IDE risk

- refactoring may not preserve meaning
- >7 such bugs open in Eclipse

language risk

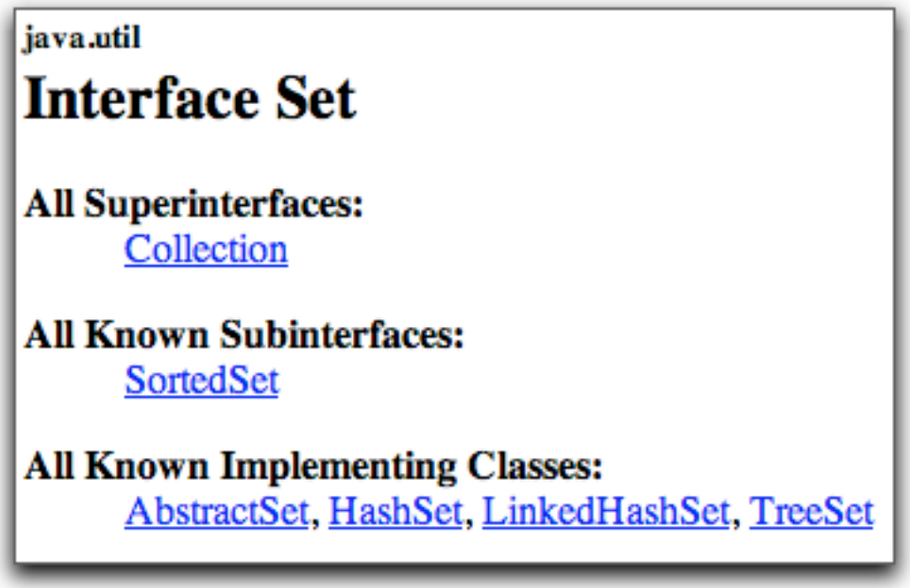
- in Java, eg: memory model, generics

operating system viruses

- time to infection for new PC: 4 mins

configuration problems

- DLLs, classpaths, etc



java.util

Interface Set

All Superinterfaces:
Collection

All Known Subinterfaces:
SortedSet

All Known Implementing Classes:
AbstractSet, HashSet, LinkedHashSet, TreeSet

Note: Great care must be exercised if mutable objects are used as set elements. The behavior of a set is not specified if the value of an object is changed in a manner that affects equals comparisons while the object is an element in the set. A special case of this prohibition is that it is not permissible for a set to contain itself as an element.

Sample Eclipse refactoring bugs, thanks to Adam Kiezun:

[extract local] must not ignore value changes: https://bugs.eclipse.org/bugs/show_bug.cgi?id=27740
[inline] Inlining synchronized method should create a synchronized block: https://bugs.eclipse.org/bugs/show_bug.cgi?id=112100
[push down] field lets client access formerly hidden field instead [refactoring]: https://bugs.eclipse.org/bugs/show_bug.cgi?id=235118
[pull up] field ignores hiding of inherited field [refactoring]: https://bugs.eclipse.org/bugs/show_bug.cgi?id=235112
[use supertype] changes to static binding, changing program behaviour: https://bugs.eclipse.org/bugs/show_bug.cgi?id=233796
[generalize type] fails to see lack of overriding [Refactoring]: https://bugs.eclipse.org/bugs/show_bug.cgi?id=233437
[push down] method changes program semantics in presence of overloading: https://bugs.eclipse.org/bugs/show_bug.cgi?id=234981

social/managerial factors

process

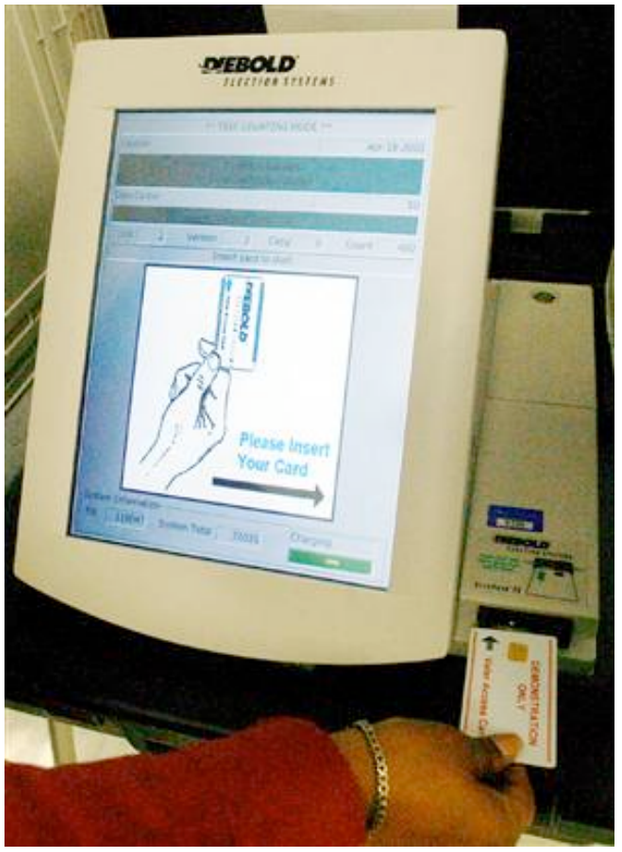
does process really matter?

© Scott Adams, Inc./Dist. by UFS, Inc.

bad process

Alameda County, CA, 2003

- 25% of voting machines crashed on boot
- so Diebold installed uncertified patches



Accuvote-TSx

on Diebold incident: http://www.wired.com/politics/law/news/2003/11/61068

bad process

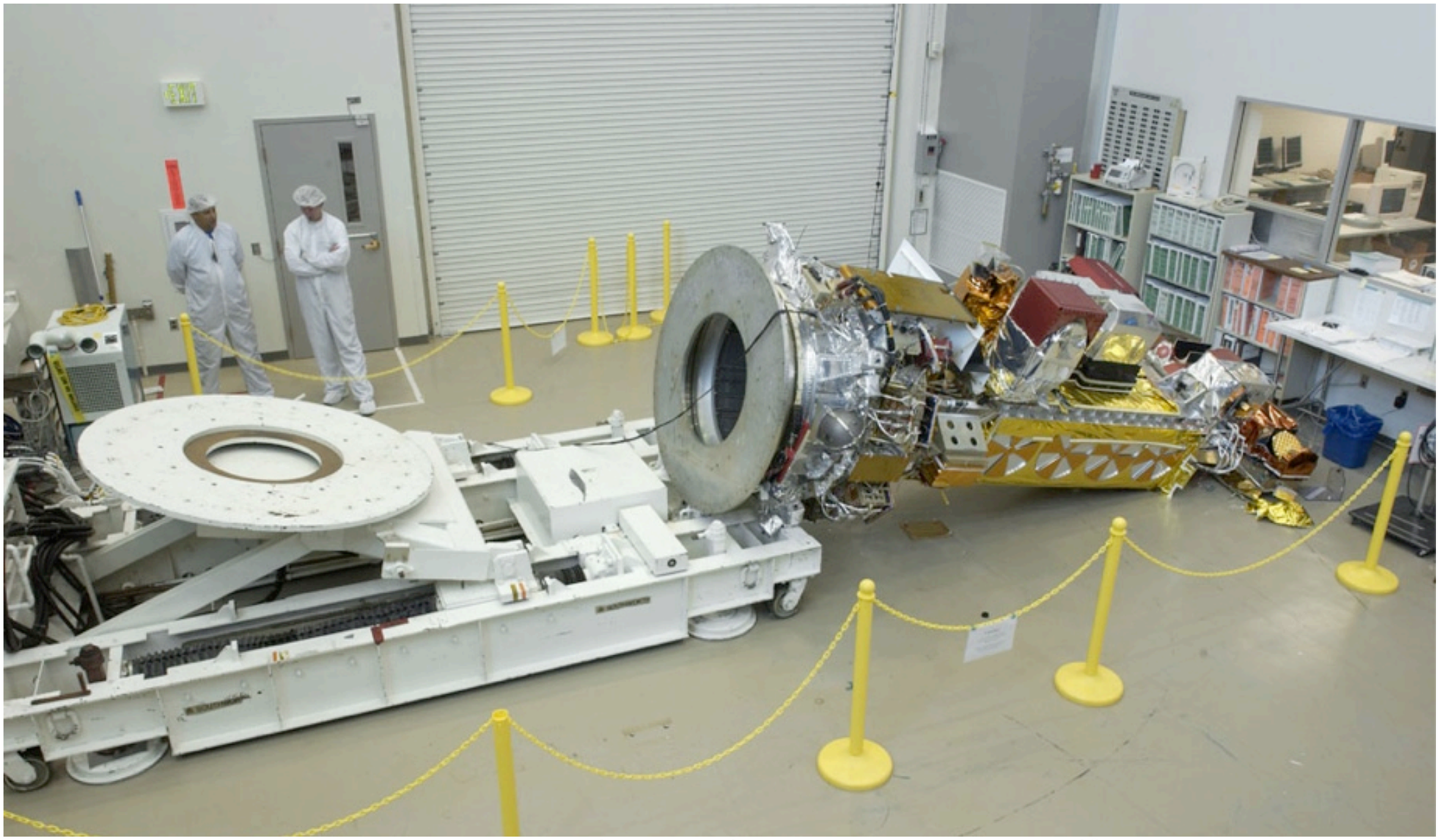
London Ambulance, 1992

- contract awarded to lowest bidder
- report from Arthur Andersen ignored
- no independent QA, software changes on-the-fly
- no incremental deployment, no paper backup
- untested change in operations

on Ambulance failure: http://www.comp.lancs.ac.uk/computing/resources/IanS/SE7/CaseStudies/LondonAmbulance/LASFailure.pdf; http://www.dcs.gla.ac.uk/~johnson/papers/safecomp_best/
35 bidders; lowest bidder almost half price of next

neglecting process

NOAA weather satellite at Lockheed Martin, September 2003



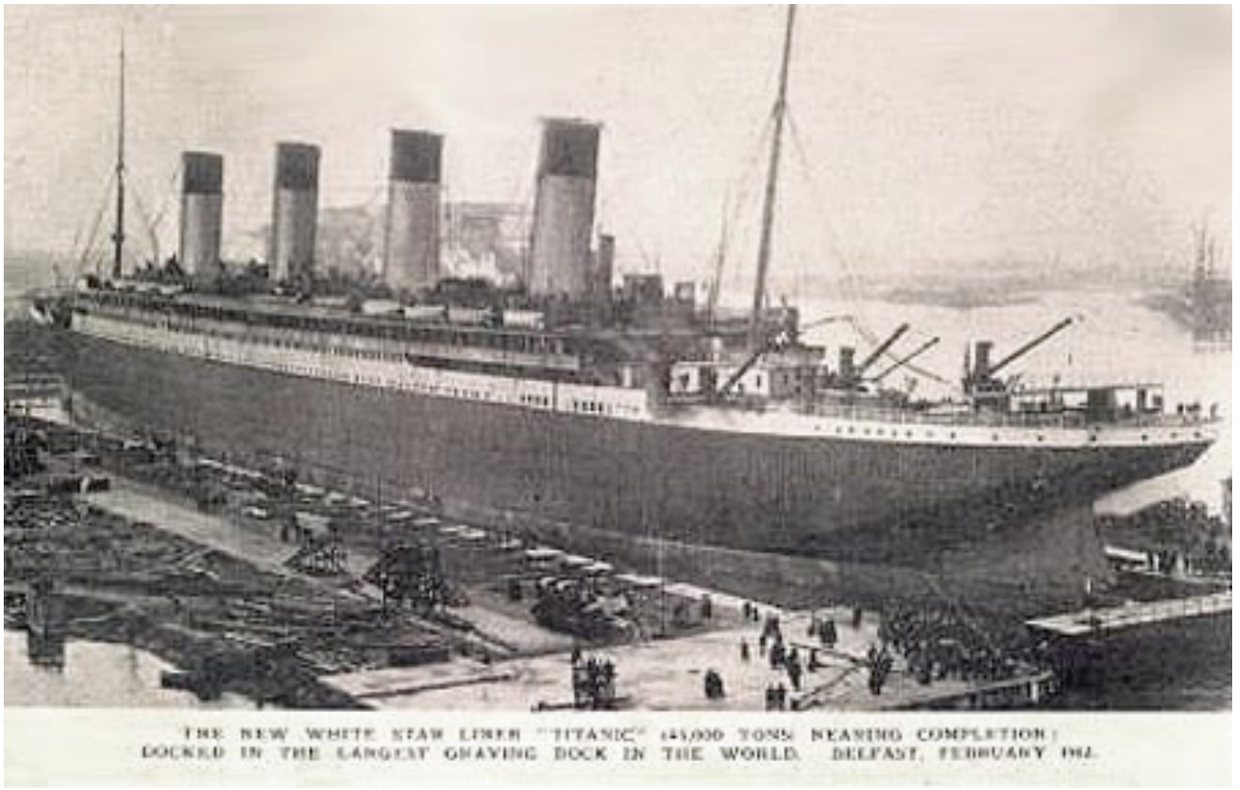
NOAA N-PRIME Mishap Investigation Final Report. http://www.nasa.gov/pdf/65776main_noaa_np_mishap.pdf

“Proximate Cause: The NOAA N-PRIME satellite fell because the LMSSC operations team failed to follow procedures to properly configure the TOC, such that the 24 bolts that were needed to secure the TOC adapter plate to the TOC were not installed.”

overconfidence

Titanic, 1912

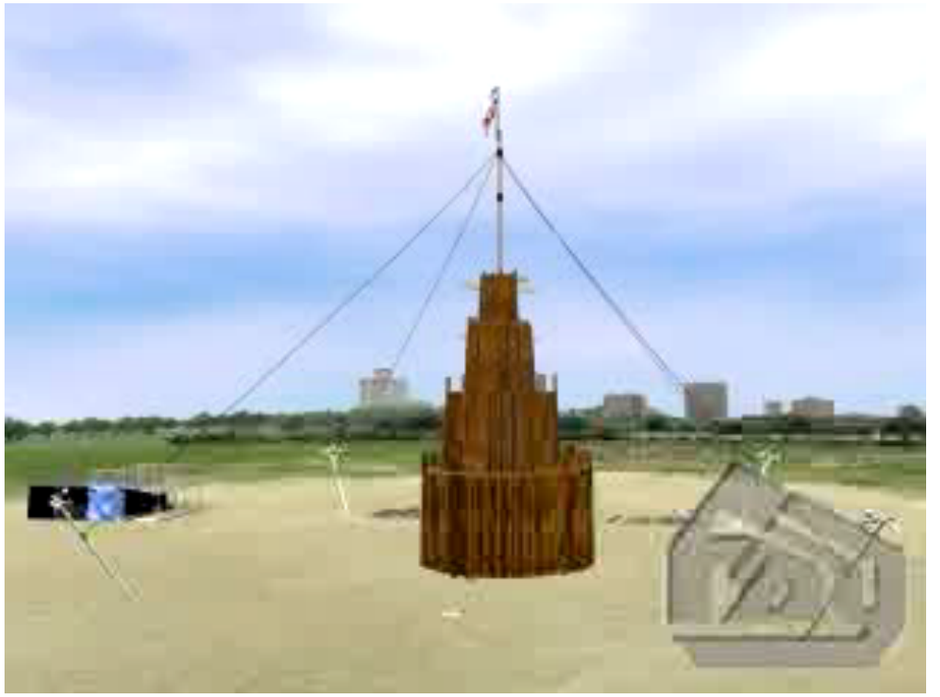
- advanced technology, 'unsinkable'
- so enough lifeboats not needed



on Titanic: http://en.wikipedia.org/wiki/RMS_Titanic

growing dangers

what happened in 1999



Texas A&M bonfire

- traditional began in 1928
- by 1990's, crane needed

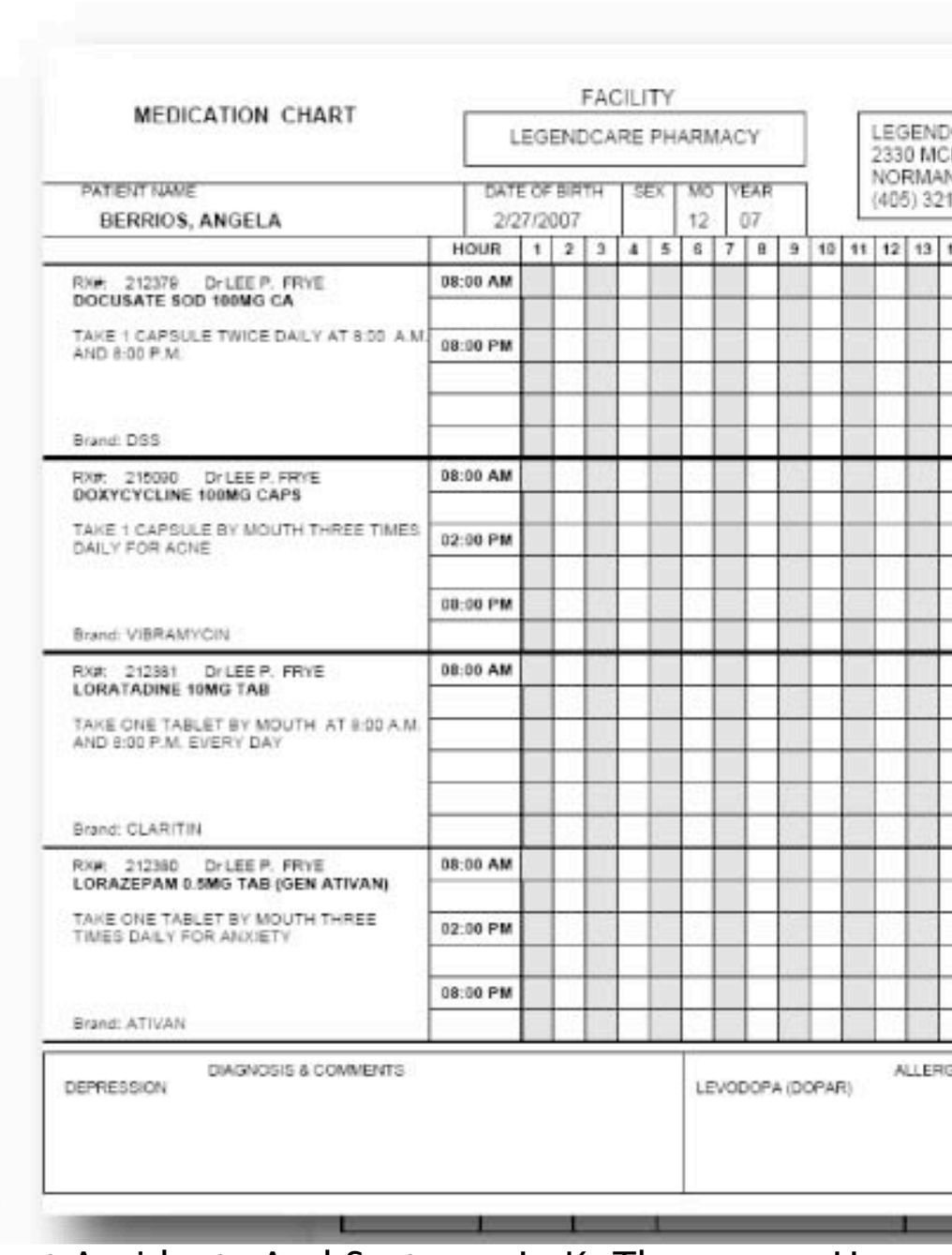
http://www.fayengineering.com/structural.html
Final settlement due tomorrow: http://www.theeagle.com/local/Bonfire-suits-to-be-settled-in-court-Tuesday
(thanks to Moshe Vardi for spotting this!)

the risks of dependence

MAR knockout

- major Chicago hospital
- pharmacy database failure
- medication records lost

"Accidents are signals sent from deep within the system about the vulnerability and potential for disaster that lie within"
--Richard Cook and Michael O'Connor



MEDICATION CHART

FACILITY: LEGENDCARE PHARMACY

PATIENT NAME: BERRIOS, ANGELA | DATE OF BIRTH: 2/27/2007 | SEX | MO: 12 | YEAR: 07

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13
08:00 AM													
08:00 PM													

Rx#: 212379 Dr LEE P. FRYE
DOCUSATE SOD 100MG CA
TAKE 1 CAPSULE TWICE DAILY AT 8:00 A.M. AND 8:00 P.M.
Brand: DSS

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13
08:00 AM													
02:00 PM													
08:00 PM													

Rx#: 215090 Dr LEE P. FRYE
DOXYCYCLINE 100MG CAPS
TAKE 1 CAPSULE BY MOUTH THREE TIMES DAILY FOR ACNE
Brand: VIBRAMYCIN

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13
08:00 AM													

Rx#: 212381 Dr LEE P. FRYE
LORATADINE 10MG TAB
TAKE ONE TABLET BY MOUTH AT 8:00 A.M. AND 8:00 P.M. EVERY DAY
Brand: CLARITIN

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13
08:00 AM													
02:00 PM													
08:00 PM													

Rx#: 212380 Dr LEE P. FRYE
LORAZEPAM 0.5MG TAB (GEN ATIVAN)
TAKE ONE TABLET BY MOUTH THREE TIMES DAILY FOR ANXIETY
Brand: ATIVAN

DIAGNOSIS & COMMENTS: DEPRESSION

ALLERG: LEVODOPA (DOPAR)

Richard Cook and Michael O'Connor. Thinking About Accidents And Systems. In K. Thompson, H. Manasse, eds. Improving Medication Safety, ASHP, Washington, DC.

blame the user

USS Yorktown, 1997

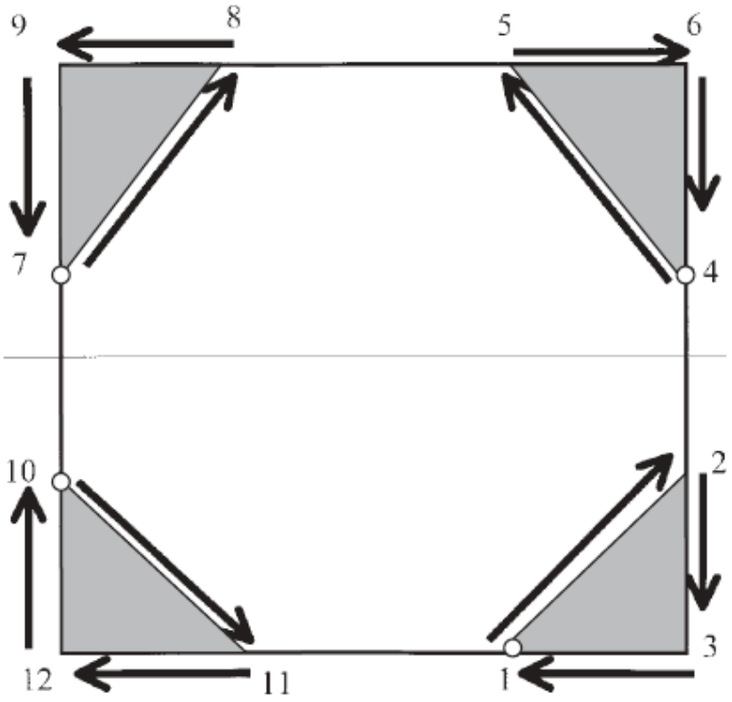
- dead in water for 3 hours

Managers are now aware of the problem of entering zero into database fields and are trained to bypass a bad data field and change the value... ships do go dead in the water... People sometimes make mistakes and systems break. The trick is we have trained our crew...
-- Commanding Officer, USS Yorktown

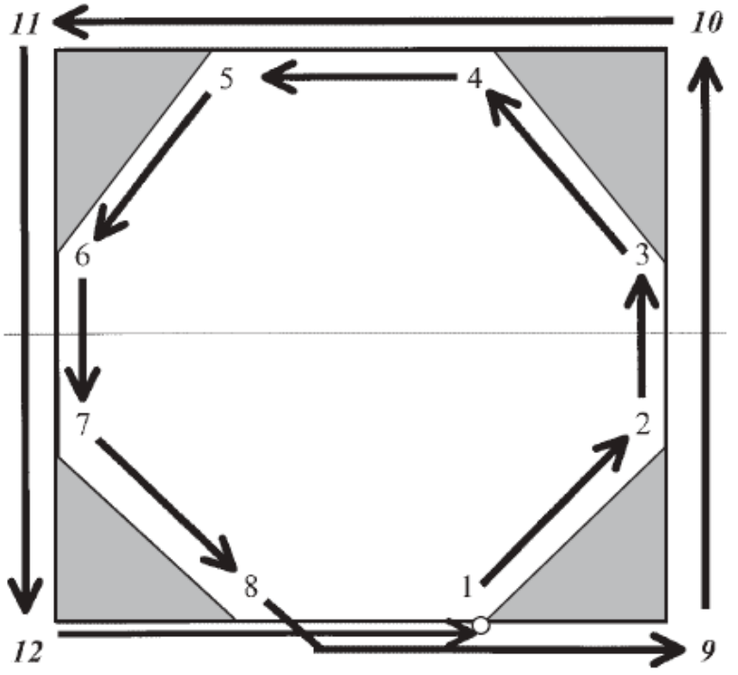
Government Computer News / July 13, 1998
Software glitches leave Navy Smart Ship dead in the water
Gregory Slabodkin, http://www.gcn.com/print/17_17/33727-1.html

panama radiation accident

dose = D



dose = 2D



Panama City Hospital, 2001

- Theratronic-780 with therapy planning system by Multidata
- 18 patients killed

diagrams from: International Atomic Energy Agency. Investigation Of An Accidental Exposure Of Radiotherapy Patients In Panama. Report Of A Team Of Experts, 26 May –1 June 2001.

Theratronic made by makers of Therac 25

panama consequences

3 Panama physicists tried for second-degree murder

- Olivia Saldaña González paid for her own defence; earns $585/month
- sentenced to four years in prison
- suit by families against Multidata rejected by Panama court

Given [the input] that was given, our system calculated the correct amount, the correct dose. It was an unexpected result. And, if [the staff in Panama] had checked, they would have found an unexpected result.
-- Mick Conley, Multidata

http://www.baselinemag.com/c/a/Intelligence/Panama-Technicians-Found-Guilty/
Conley quote: Deborah Gage and John McCormick. Can Software Kill? http://www.eweek.com/article2/0,1895,1544225,00.asp

conclusions

implications for research

if you reward publication, you get

- focus on logic & algorithms
- benchmarks, not real problems
- throwaway implementations

some good strategies

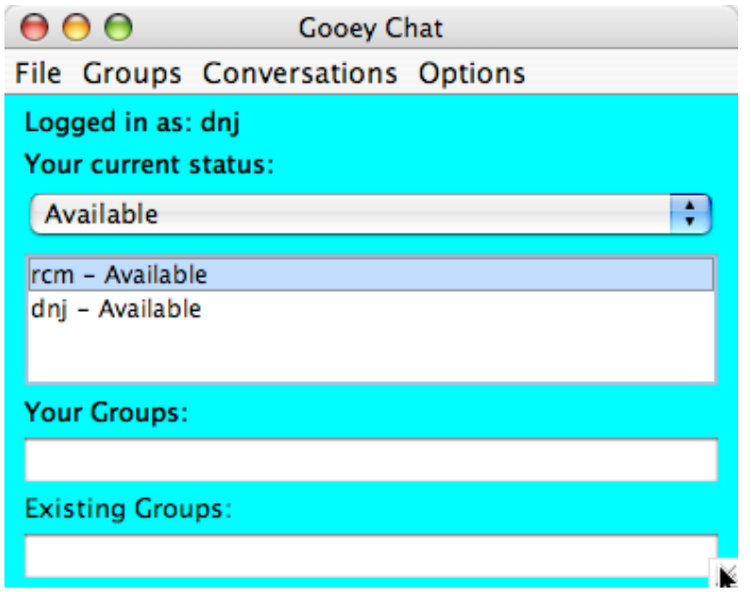
- fund tool development [NSF infrastructure]
- issue challenges [VSR's Mondex, Flash]
- publish case studies [Z, Patterns]

will interdisciplinary work help?

implications for teaching

what we typically do

- focus on 'respectable' topics (eg, semantics)
- illustrate with small problems
- say hard parts are out-of-scope
- set formal problems that are easy to grade



instead, we might

- explain 'soft' aspects too
- illustrate with substantial case studies
- address the hard parts
- set informal, open-ended problems

thank you!