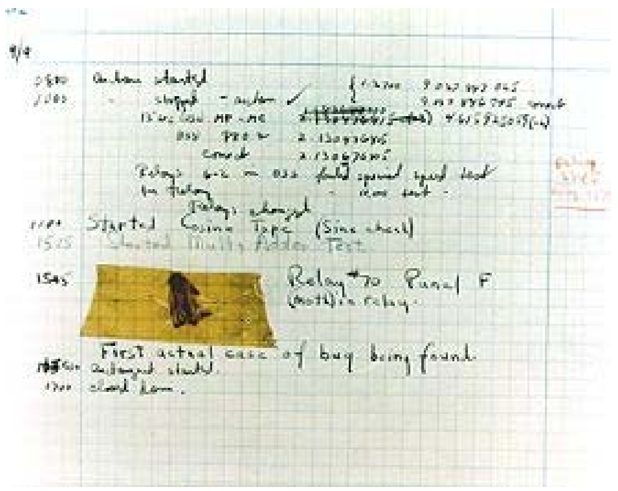
Debugging



9/9

0800 [illegible] started

1000 stopped - [illegible] ✓ [illegible]

[illegible]

Relays [illegible] failed special speed test

Relays changed

1100 Started Cosine Tape (Sine check)

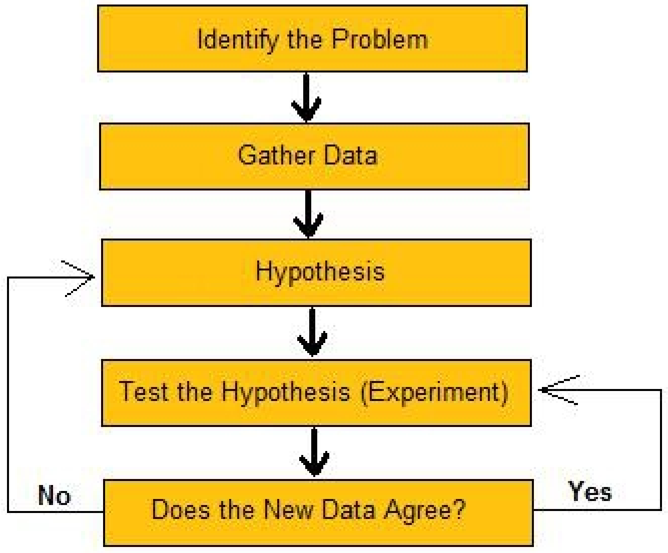
1525 Started Mult + Adder Test.

1545 Relay #70 Panel F (moth) in relay.

First actual case of bug being found.

[illegible] [illegible] started.

1700 closed down.



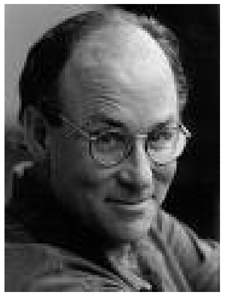
Debugging, in the Trenches

Rasala put his hands on his desk and buried his face in them.
It was just another routine day down at debugging headquarters.

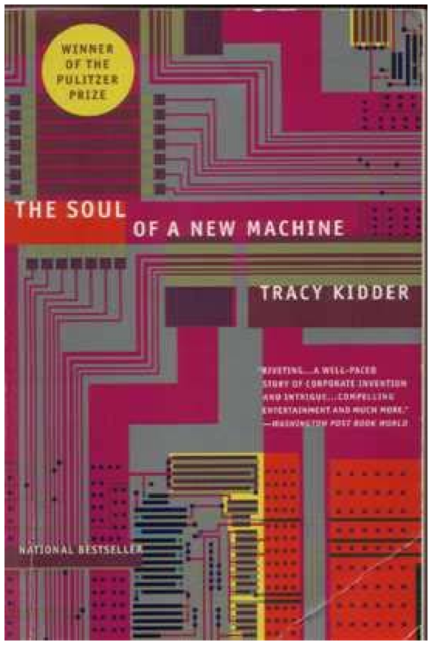
In the back of Veres's mind still lies a small suspicion that the problem might after all be noise. And now – much to Guyer's delight, when he finds out later on – it is Veres himself who disconnects the I-cache. Then he runs the program past the point of failure, and everything works. He puts the I-cache back in and once again Gollum fails. This doesn't prove the IP is to blame, but it does tend to eliminate noise as a suspect, once and for all. . .

---

from THE CASE OF THE MISSING NAND GATE (Chapter 10 of Kidder's The Soul of a New Machine)



(The Soul of a New Machine)


WINNER OF THE PULITZER PRIZE
THE SOUL OF A NEW MACHINE
TRACY KIDDER
"RIVETING... A WELL-PACED STORY OF CORPORATE INVENTION AND INTRIGUE... COMPELLING ENTERTAINMENT AND MUCH MORE." —WASHINGTON POST BOOK WORLD
NATIONAL BESTSELLER

Kidder's book tells the story of the development of a micro-computer in the early 80s. The book's a classic – won the American Book Award for non-fiction. Anyone who cares how computers are made (or how people work) should read it.

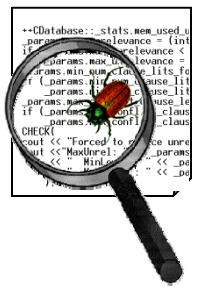
Chapter 10 is a classic story of debugging a hardware problem. The ideas apply just as well to software, and this is the best description of heavy-duty debug I've ever seen.

Debugging

- Debugging is really hard – even with a good failing test case in hand

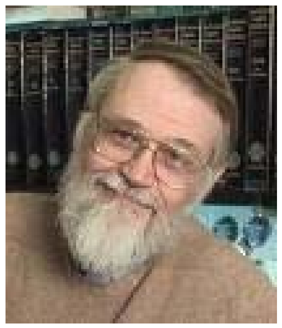
- One of the most time-consuming tasks in software development
- Locating the fault is the most time-consuming part of debugging

Debugging

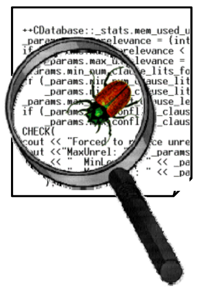


- Takes as much as 50% of development time on some projects
- Arguably the most scientific part of "computer science" practice
  - Even though it's *usually* done in a totally *ad hoc*, haphazard way!

"Debugging is twice as hard as writing the code in the first place. Therefore, if you write the code as cleverly as possible, you are, by definition, not smart enough to debug it." *- Brian Kernighan*



Debugging and Testing

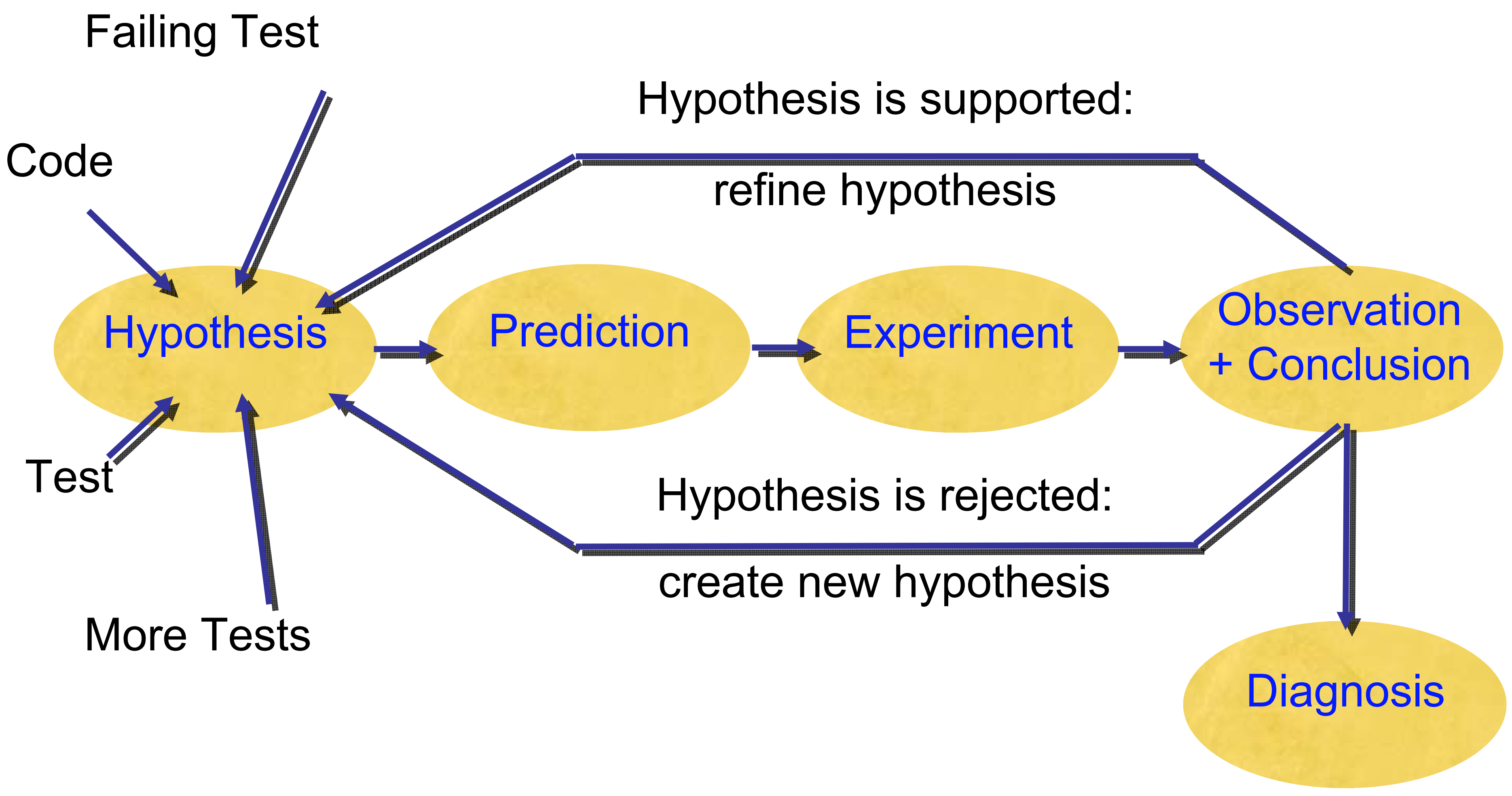


- What are test cases *for*, anyway?
  - Often: so we can locate and fix a fault
  - Or: so we can understand how serious the failure is, and triage / "flight rule" it away
    - If we have many bugs, and some may not be important enough to merit resources
    - Or if there is a reason we *can't* change the code and have to work around the problem
- In either case, we have a "debugging" task at hand – must at least *understand the failure*, even if only to triage

Scientific Debugging

- Test cases (ones that fail and ones that succeed) can be the experiments we perform to verify our hypotheses
  - The failing test case informs us that there is a phenomenon to explain (apple on the head)
  - Generate (or examine) more test cases to find out more about what is going on in the program

Scientific Debugging



Testing for Debugging

- Several ways to use test cases in debugging:
  - Test case minimization
  - Shrink the test case so we don't have to look at lots of irrelevant or redundant operations
  - Fault localization
    - Give suggestions about where the *fault* may be (based on test case executions)
  - Error explanation
    - Give a "story" of *causality*
      - *(A causes B; B causes C; C causes failure)*

attempt to automate part of scientific debugging

What’s a problem?

- A *problem* is a questionable property of a program run
- It becomes a *failure* if it’s incorrect…
- …a *request for enhancement* if missing…
- …and a *feature* if normal behavior.

It’s not a bug, it’s a feature!

Problem Life Cycle

- The user *informs* the vendor about some problem.
- The vendor
  1. *reproduces* the problem
  2. *isolates* the circumstances
  3. *locates* and *fixes* the defect
  4. *delivers* the fix to the user.

Vendor Challenges

- How do I organize the life cycle?
- Which problems are currently open?
- Which are the most severe problems?
- Did similar problems occur in the past?

User Challenges

- Solve my problem!

Problem Report

- **A problem comes to life with a *problem report*.**
- **A problem report includes all the information the vendor needs to fix the problem.**
- **Also known as *change request* or *bug report.***

Problem report #1

```
From: me@dot.com
To: zeller@gnu.org
Subject: Crash

Your program crashed.  (core
dumped)
```

Problem report #2

From: me@dot.com
To: zeller@gnu.org
Subject: Re: Crash

Sorry, here's the core - cu

📄 <core, 14MB>

Problem report #3

From: me@dot.com
To: zeller@gnu.org
Subject: Re: Crash

You may need that, too (just in case)

<drive_c.zip, 148GB>

What to report

- **The *product release***
- **The *operating environment***
- **The *problem history***
- ***Expected* and *experienced behavior***
- ***A* one-line *summary***

Product Release

- Typically, some *version number* or
- otherwise unique identifier
- Required to *reproduce the exact version:*
  - Perfect Publishing Program 1.1 (Build 7E47)
- Generalize: Does the problem occur only in this release?

Operating Environment

- **Typically, *version information* about the operating system**
- **Can be simple (”Windows 98 SE”) or complex (”Debian Linux ‘Sarge’ with the following packages…”)**
- **Generalize: In which environments does the problem occur?**

Problem History

- Steps needed to *reproduce* the problem:
  1. Create “bug.ppp”
  2. Print on the default printer…
- If the problem cannot be reproduced, it is unlikely to be fixed
- Simplify: Which steps are relevant?

Expected Behavior

- What should have happened according to the user:
  - The program should have printed the document.
- Reality check: What's the understanding of the user?

Observed Behavior

- The *symptoms* of the problem — in contrast to the *expected* behavior
  - The program crashed with the following information

```
*** STACK DUMP OF CRASH (LemonyOS)

 Back chain  ISA  Caller
 00000000    SPC  0BA8E574
 03EADF80    SPC  0B742428
 03EADF30    SPC  0B50FDDC  PrintThePage+072FC
SnicketPC unmapped memory exception at
        0B512BD0 PrintThePage+05F50
```

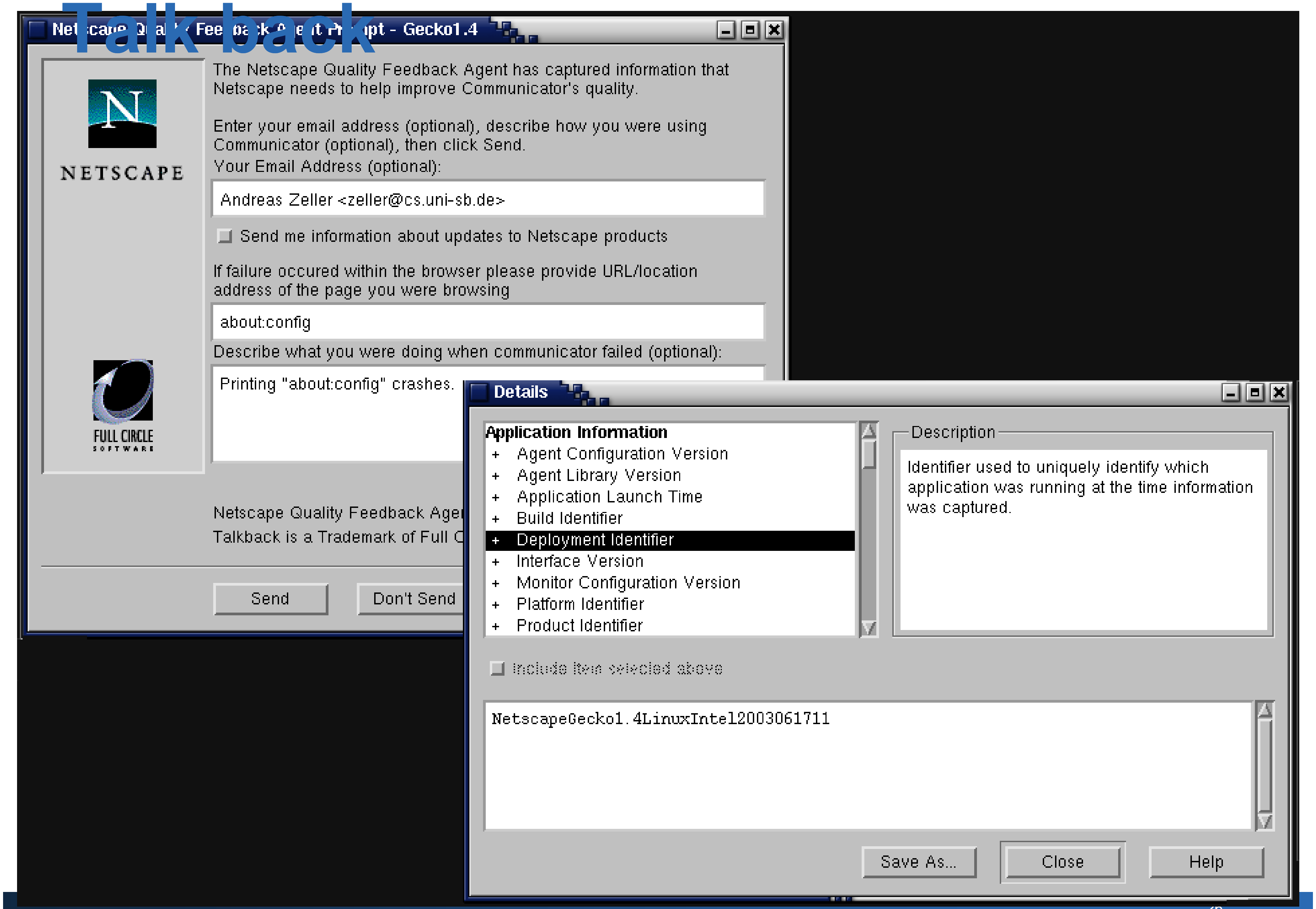
A one-line summary

- Captures the essential of the problem
  - PPP 1.1 crashes when printing

Things to avoid

- Humor
  - PPP (oops, gotta go to the restroom :-) …
- Sarcasm
  - Here's yet another "never-to-be-fixed" bug
- Attacks
  - If you weren't too incompetent to grasp…

Talk back



Netscape Quality Feedback Agent Prompt - Gecko1.4

The Netscape Quality Feedback Agent has captured information that Netscape needs to help improve Communicator's quality.

Enter your email address (optional), describe how you were using Communicator (optional), then click Send.

Your Email Address (optional):

Andreas Zeller <zeller@cs.uni-sb.de>

☐ Send me information about updates to Netscape products

If failure occured within the browser please provide URL/location address of the page you were browsing

about:config

Describe what you were doing when communicator failed (optional):

Printing "about:config" crashes.

Netscape Quality Feedback Agen

Talkback is a Trademark of Full C

Details

Application Information
- Agent Configuration Version
- Agent Library Version
- Application Launch Time
- Build Identifier
- Deployment Identifier
- Interface Version
- Monitor Configuration Version
- Platform Identifier
- Product Identifier

Description

Identifier used to uniquely identify which application was running at the time information was captured.

☐ include item selected above

```
NetscapeGecko1.4LinuxIntel2003061711
```

Talk Back + Privacy

- **Be sure what to collect and include in an automated report:**
  - **Pages visited**
  - **Text entered**
  - **Images viewed…**
- ***Privacy* is an important issue here!**

All these Problems

001 It's too big and too slow. [This one will never get fixed]

003 (Motif 1.1) The command window is scrolled whenever obscured.

021 (DBX) Using SunOS DBX, attempting to dereference a `(nil)' pointer results in an error message and no new display. However, the expression is entered as an ordinary display.

026 (DBX) Using SunOS DBX with PASCAL or Modula-2, selected array elements are not counted from the starting index of the array.

041 Starting a multi-window DDD iconified under vtwm and fvwm causes trouble with group iconification.

272 (LessTif) The `select' font selection method works only once.

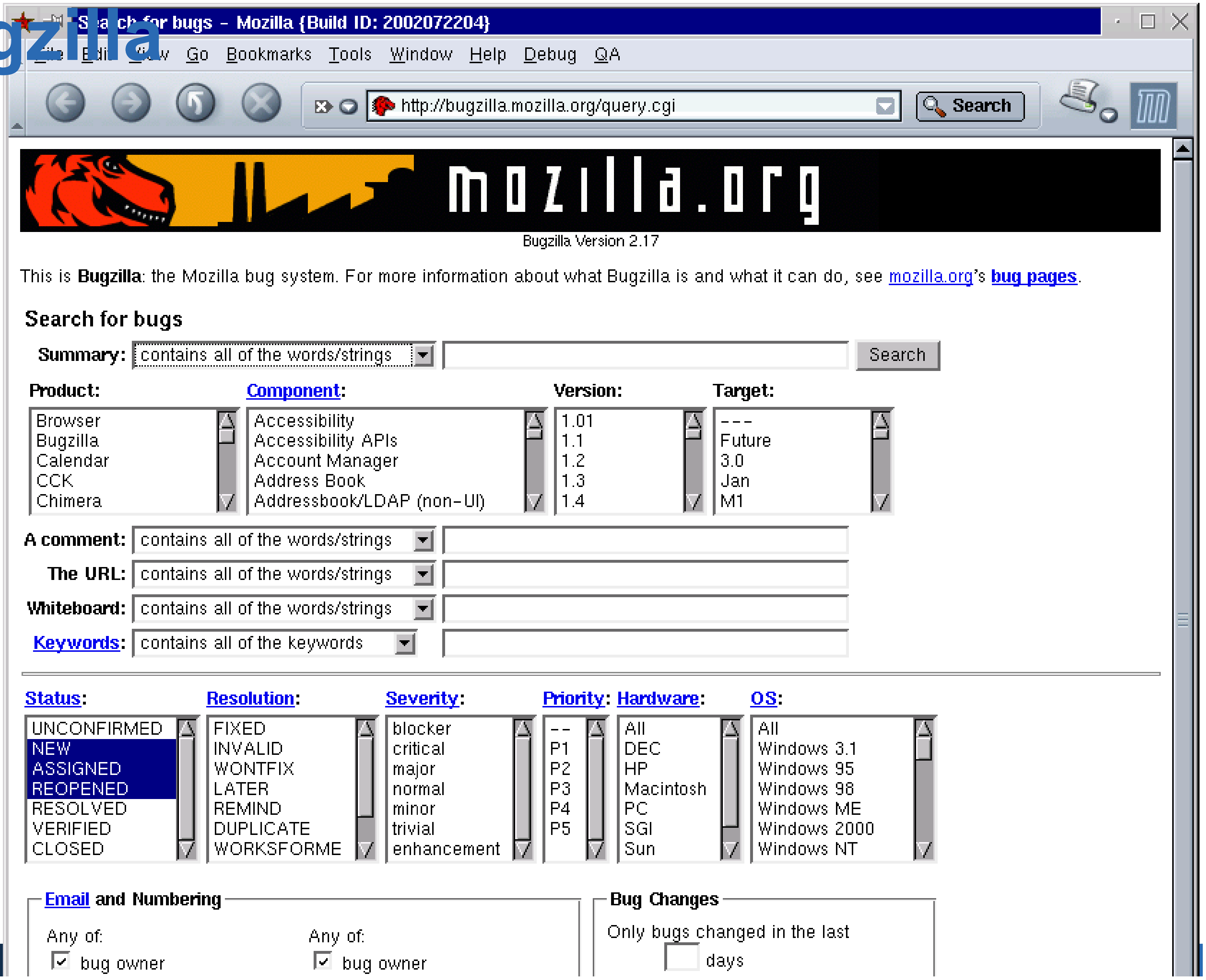
281 In auto deiconify mode, the Debugger Console uniconifies even if other DDD windows are already there.

286 (Motif) Changing Cut/Copy/Paste accelerators at runtime does not work.

Managing Problems

- Alternative #1: *A Problem File*
  - Only one person at a time can work on it
  - History of earlier (fixed) problems is lost
  - Does not scale
- Alternative #2: *A Problem Database*

Bugzilla


Search for bugs - Mozilla {Build ID: 2002072204}
File Edit View Go Bookmarks Tools Window Help Debug QA
http://bugzilla.mozilla.org/query.cgi
Search
mozilla.org

Bugzilla Version 2.17

This is **Bugzilla**: the Mozilla bug system. For more information about what Bugzilla is and what it can do, see mozilla.org's **bug pages**.

Search for bugs

Summary: contains all of the words/strings [ ] Search

Product:	**Component:**	**Version:**	**Target:**
Browser	Accessibility	1.01	---
Bugzilla	Accessibility APIs	1.1	Future
Calendar	Account Manager	1.2	3.0
CCK	Address Book	1.3	Jan
Chimera	Addressbook/LDAP (non-UI)	1.4	M1

A comment: contains all of the words/strings

The URL: contains all of the words/strings

Whiteboard: contains all of the words/strings

Keywords: contains all of the keywords

Status:	**Resolution:**	**Severity:**	**Priority:**	**Hardware:**	**OS:**
UNCONFIRMED	FIXED	blocker	--	All	All
NEW	INVALID	critical	P1	DEC	Windows 3.1
ASSIGNED	WONTFIX	major	P2	HP	Windows 95
REOPENED	LATER	normal	P3	Macintosh	Windows 98
RESOLVED	REMIND	minor	P4	PC	Windows ME
VERIFIED	DUPLICATE	trivial	P5	SGI	Windows 2000
CLOSED	WORKSFORME	enhancement		Sun	Windows NT

Email and Numbering

Any of: [✓] bug owner

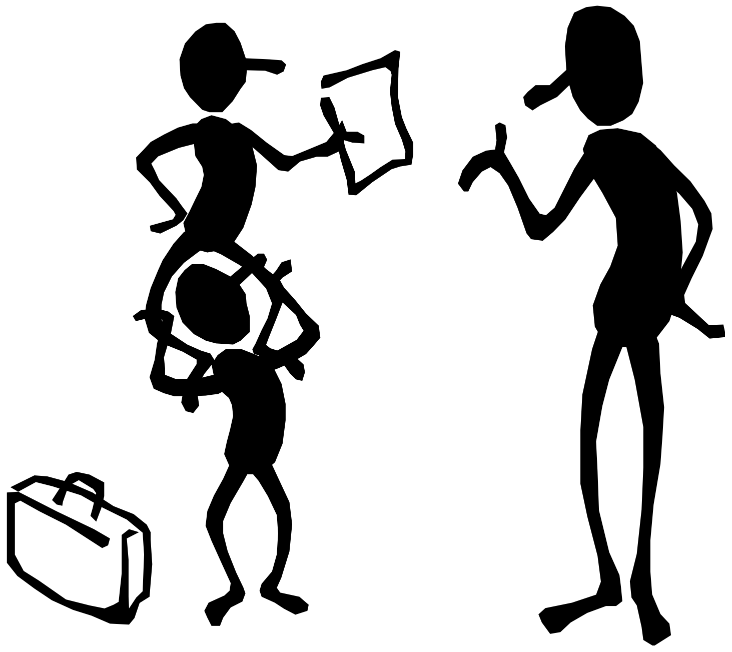
Any of: [✓] bug owner

Bug Changes

Only bugs changed in the last [ ] days

Classifying Problems

- Severity
- Priority
- Identifier
- Comments
- Notification



Severity

- **Enhancement.** A desired feature.
- **Trivial.** Cosmetic problem.
- **Minor.** Problem with easy workaround.
- **Normal.** “Standard” problem.
- **Major.** Major loss of function.
- **Critical.** Crashes, loss of data or memory
- **Showstopper.** Blocks development.

Priority

- Every new problem gets a *priority*
- The higher the priority, the sooner the problem will be addressed
- Priority is independent from severity
- Prioritizing problems is the main tool to control development and problem solving

Identity

- Every new problem gets an *identifier*
- (also known as *PR number* or *bug number*)
- The identifier is used in all documents during the debugging process:
  - Subject: PR #3427 is fixed?

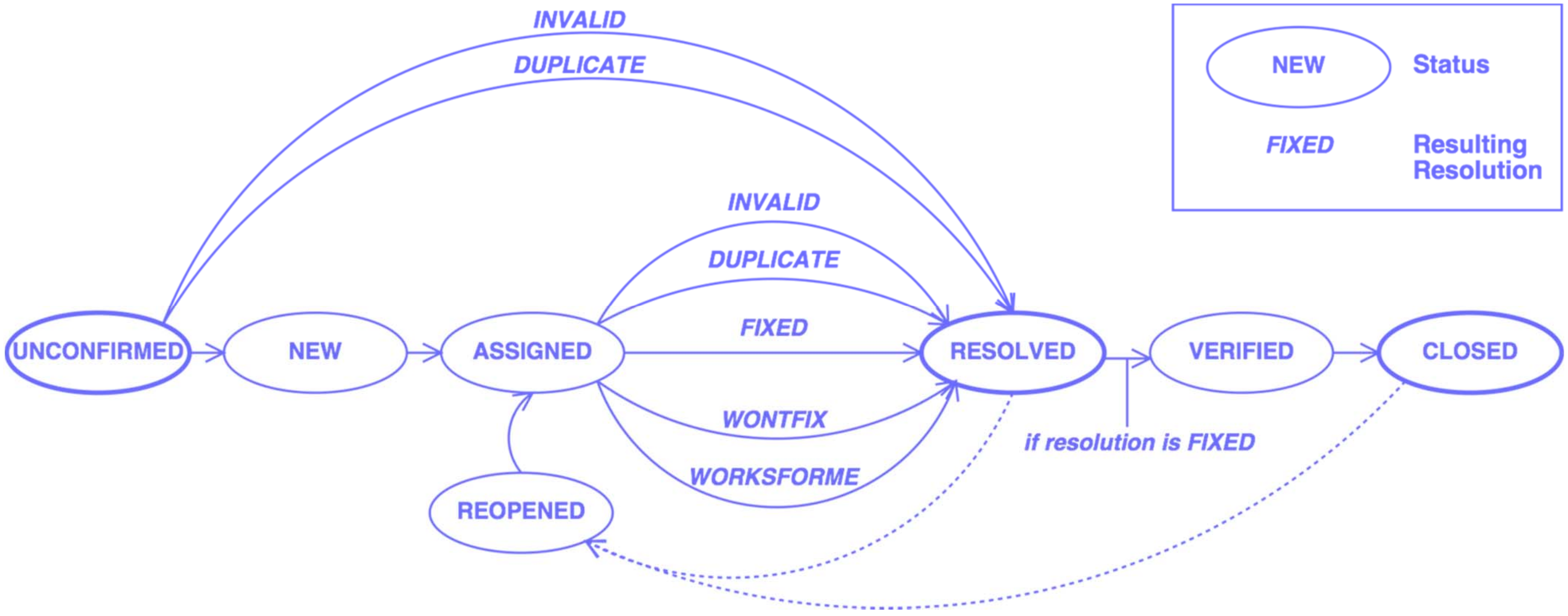
Comments

- Every developer can attach *comments* to a problem:
    - I have a patch for this. It's just an unititialized variable but I still need a review.
- Comments may also include files, documents, etc.

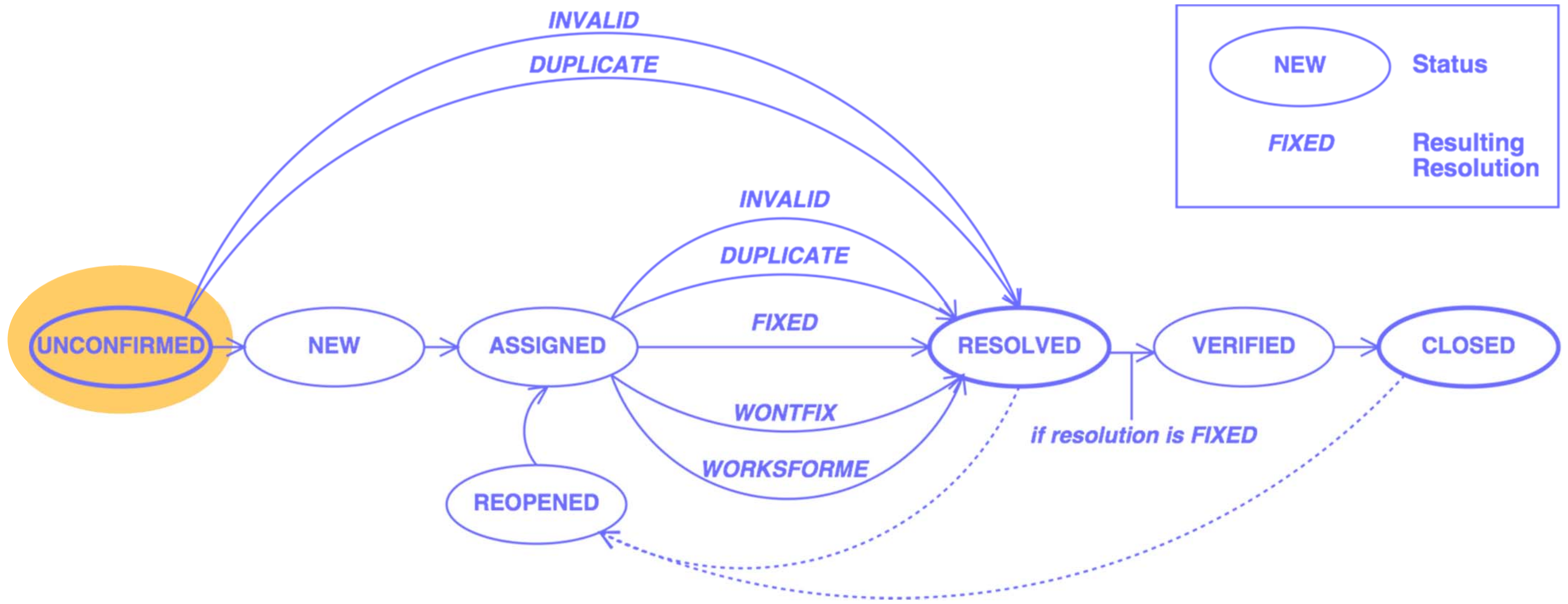
Notification

- Developers can attach an e-mail address to a problem report; they will be notified every time the report changes.
- Users can do so, too.

The Problem Lifecycle

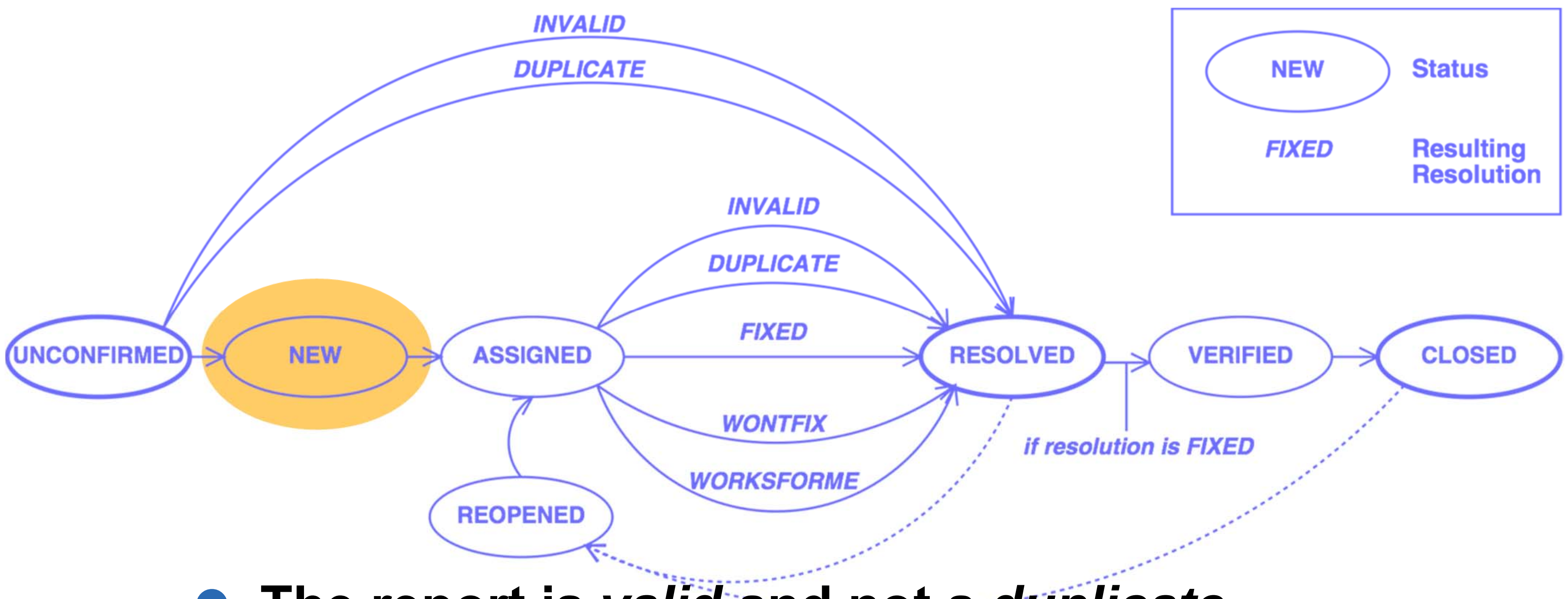


Unconfirmed Problem



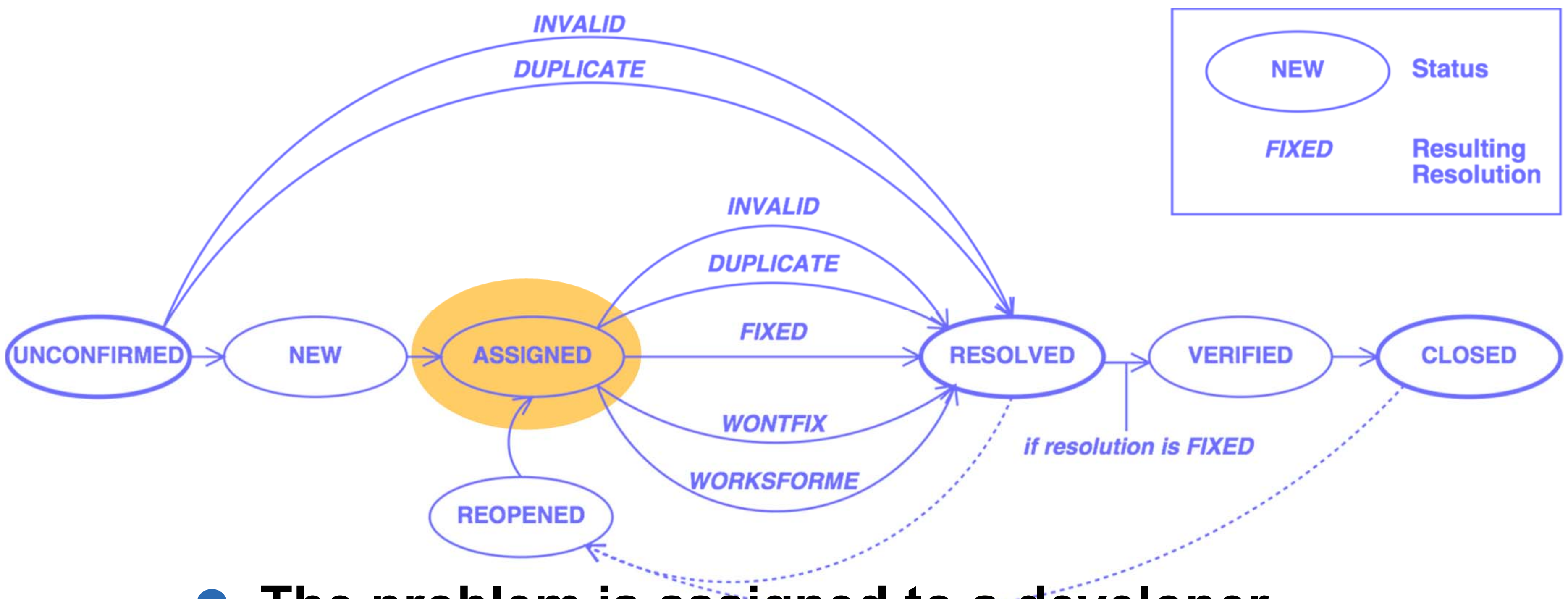
- **The problem report has just been entered into the database**

New Problem



- The report is *valid* and not a *duplicate.*
- (If not, it becomes *resolved.*)

Assigned Problem



- The problem is assigned to a developer

Resolution

FIXED: The problem is fixed.

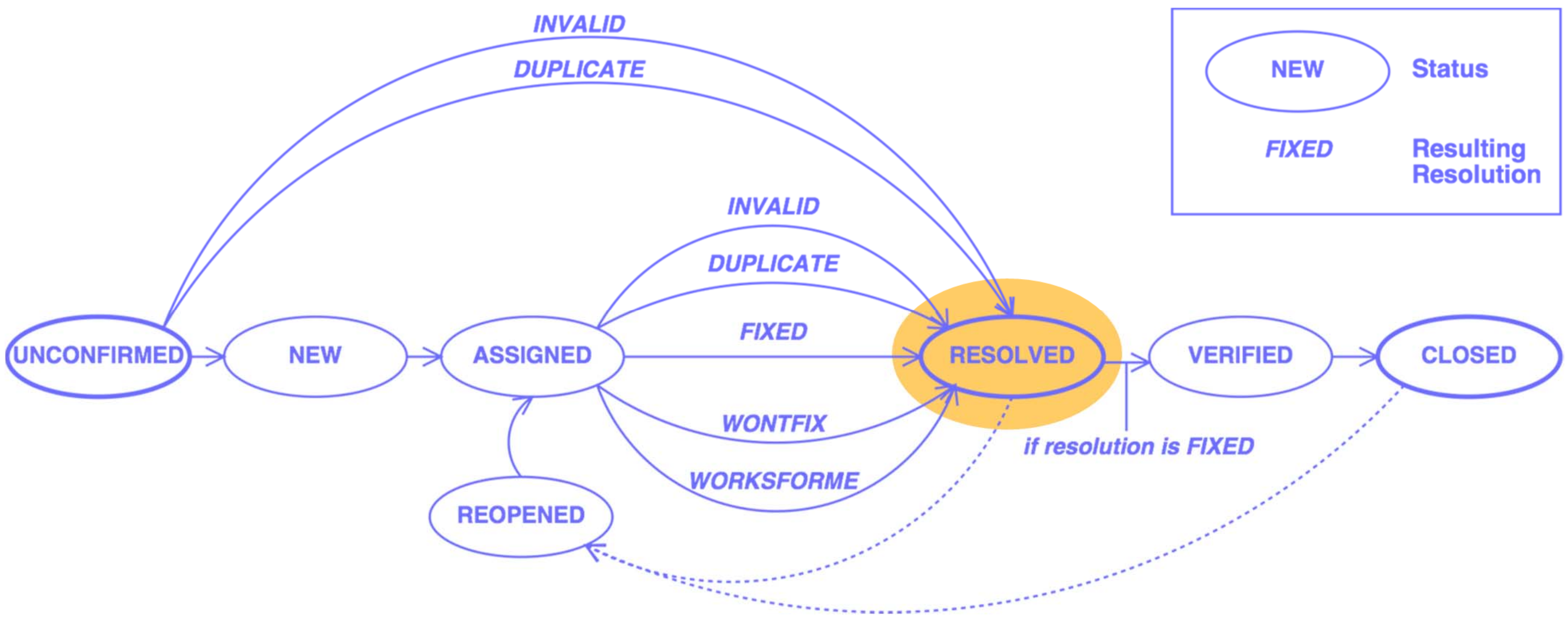
INVALID: The problem is not a problem.

DUPLICATE: The problem already exists.

WONTFIX: Will never be fixed (for instance, because the problem is a feature)

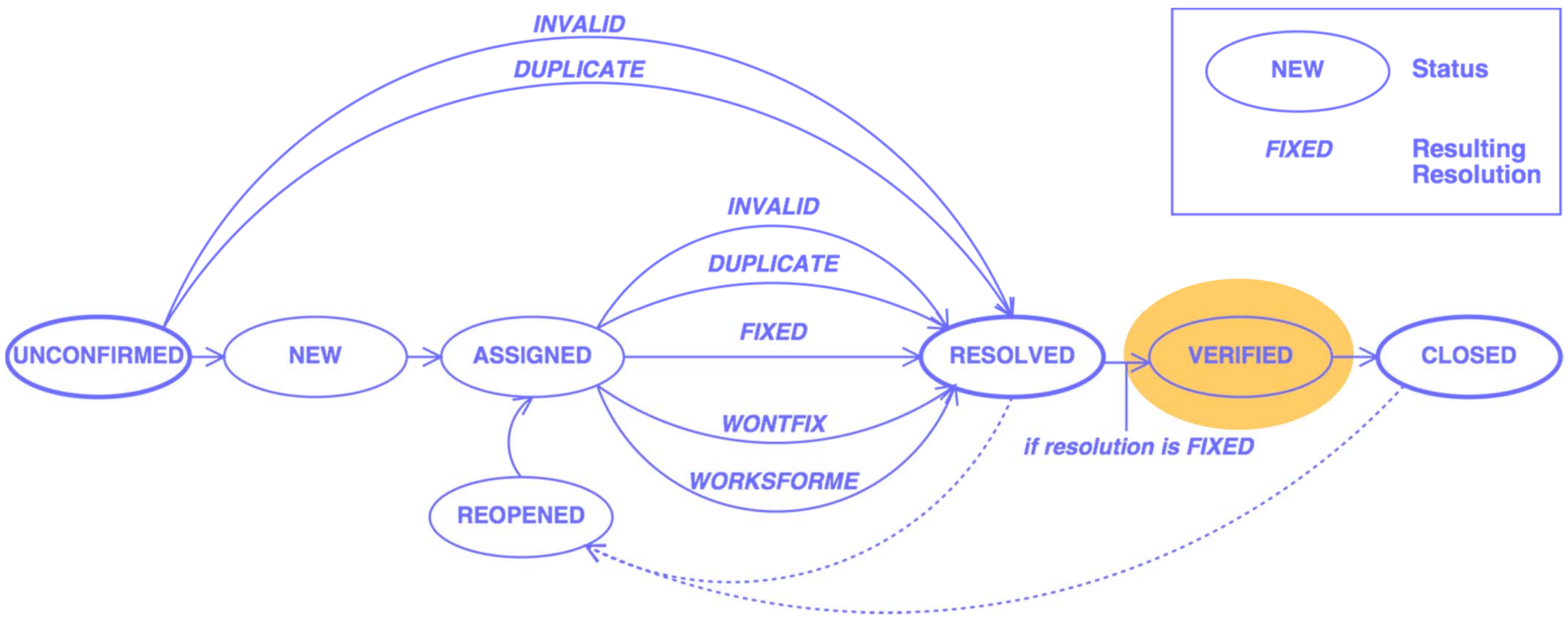
WORKSFORME: Could not be reproduced.

Resolved Problem



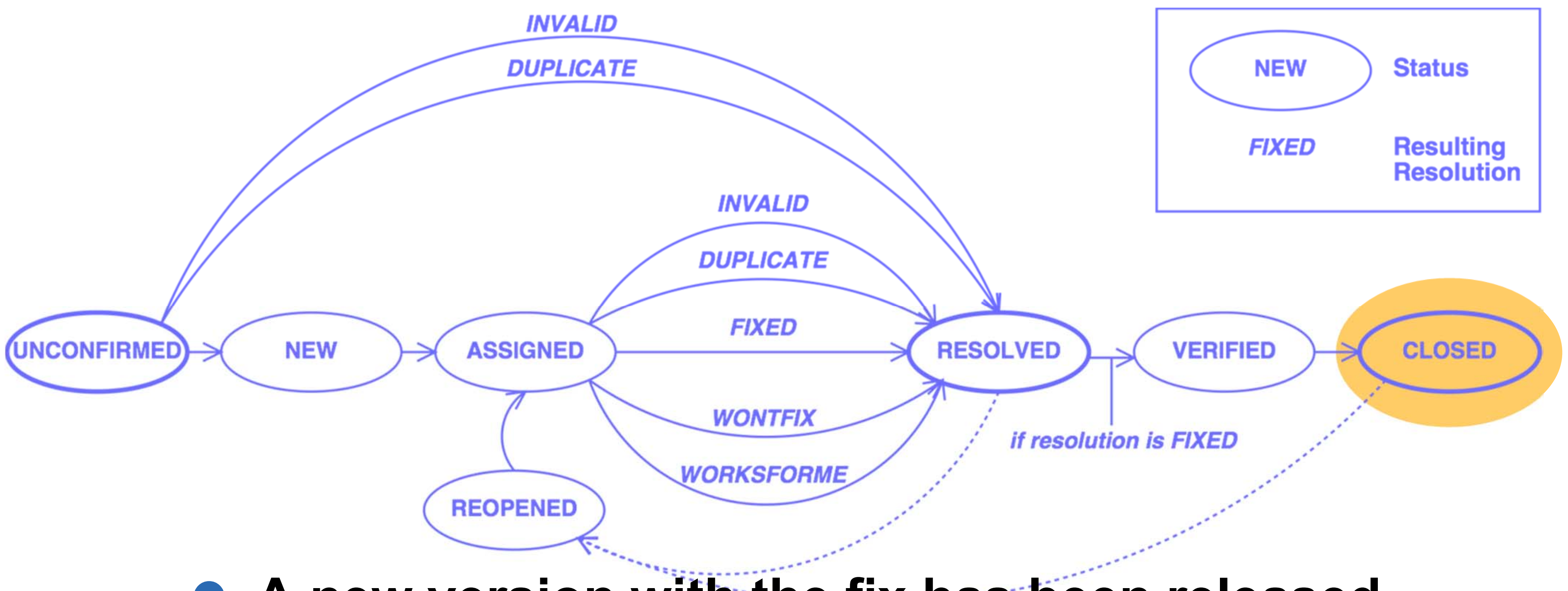
- The problem report has been processed.

Verified Problem



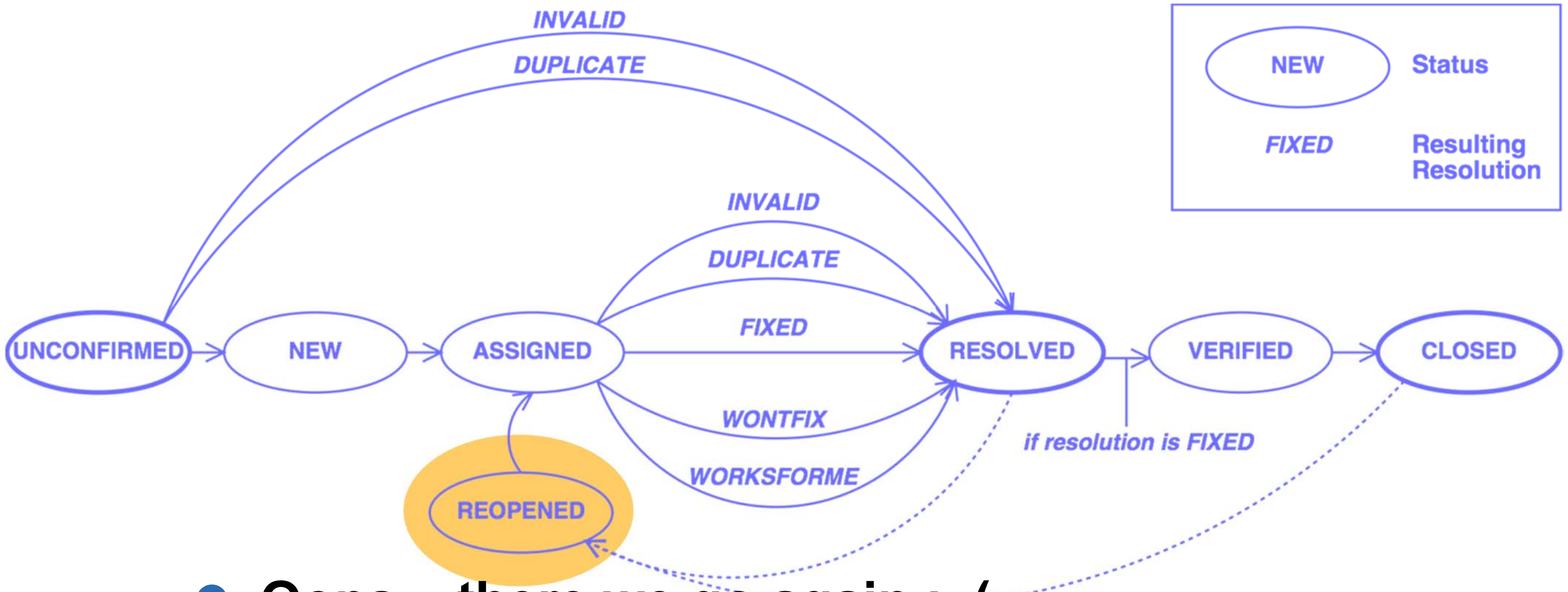
- The problem is fixed; the fix has been successful.

Closed Problem



- **A new version with the fix has been released.**

Reopened Problem



- **Oops – there we go again :–(**

Management

- Who *enters* problem reports?
- Who *classifies* problem reports?
- Who sets *priorities*?
- Who takes care of the problem?
- Who *closes* issues?

The SCCB

- At many organizations, a *software change control board* is in charge of these questions:
  - Assess the *impact* of a problem
  - Assign tasks to developers
  - Close issues…

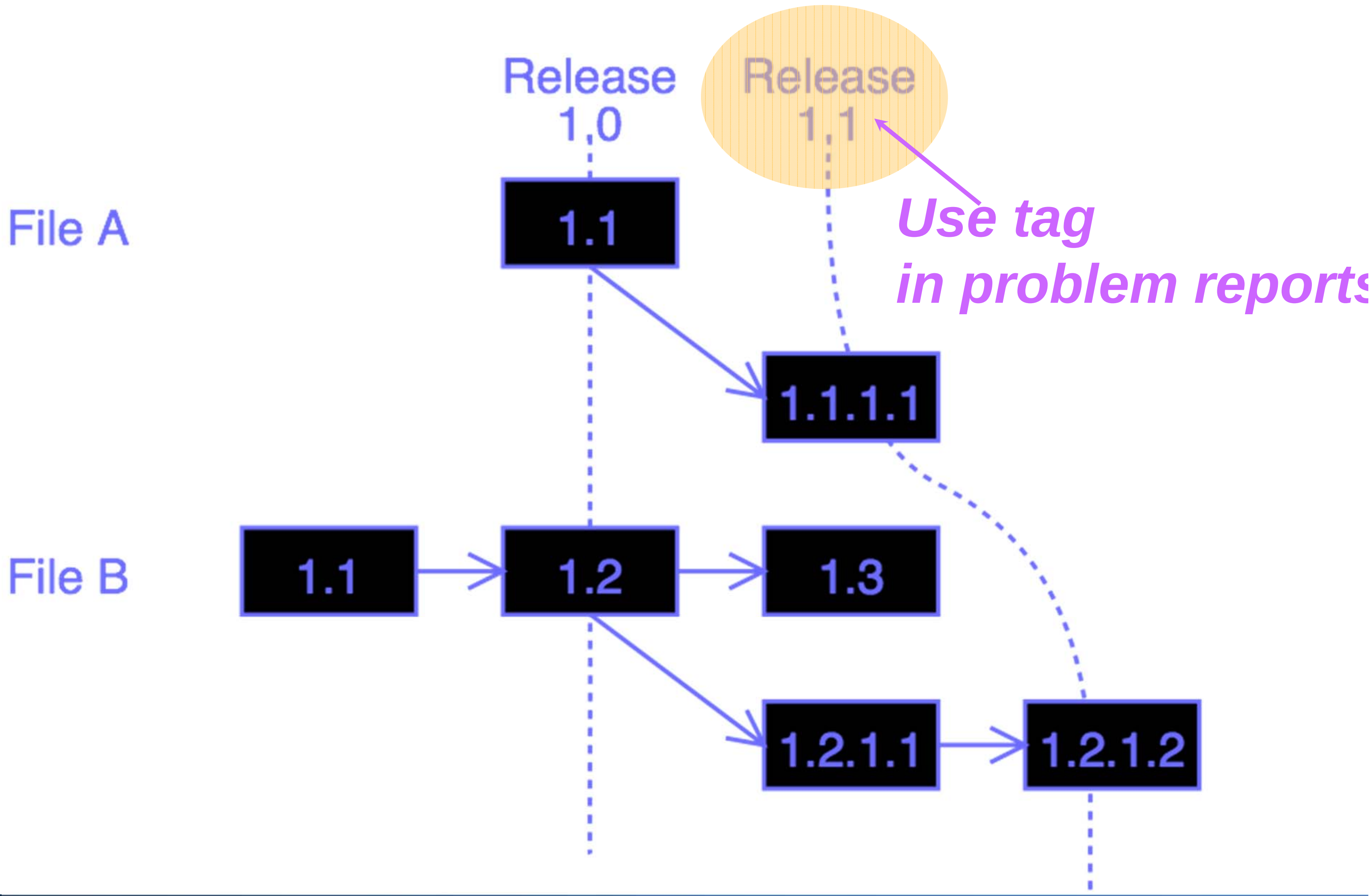
Problem-driven Development

- The whole development can be organized around the problem database:
  - Start with one single problem:
  - “The product isn’t there”
  - Decompose into sub-problems
  - Ship when all problems are fixed

Managing Clutter

- Large problem databases contain *garbage*
- Get rid of *duplicates* by
  - simplifying bug reports
  - asking submitters to search first
- Get rid of *obsolete* problems by searching for old ones that rarely occurred

Problems and Fixes



Problems and Tests

- **Some test fails. Should we enter the problem into the database?**
- ***No*, because test cases make problem reports obsolete.**
- **Once we can repeat a problem at will, there is no need for a database entry**

Concepts

- Reports about problems encountered in the field are stored in a *problem database*.
- A problem report must contain everything relevant to reproduce the problem.
- It is helpful to set up a standard set of items that users must provide (product release, operating environment…)

Concepts (2)

☆ **An effective problem report…**

- **is *well-structured***
- **is *reproducible***
- **has a descriptive *one-line summary***
- **is as *simple* and *general* as possible**
- **is *neutral* and stays with the facts.**

Concepts (3)

- A typical problem life cycle starts with an *unconfirmed* status
- It ends with a *closed* status and a specific *resolution* (such as *fixed* or *worksforme*)
- Typically, a *software change control board* organizes priorities and assignments

Concepts (4)

- Use *version control* to separate fixes and features during development.
- Establish conventions to relate *changes* to *problem reports* and vice versa.
- Make a problem report *obsolete* as soon as a test case exists.