Secure Your Programming Future!

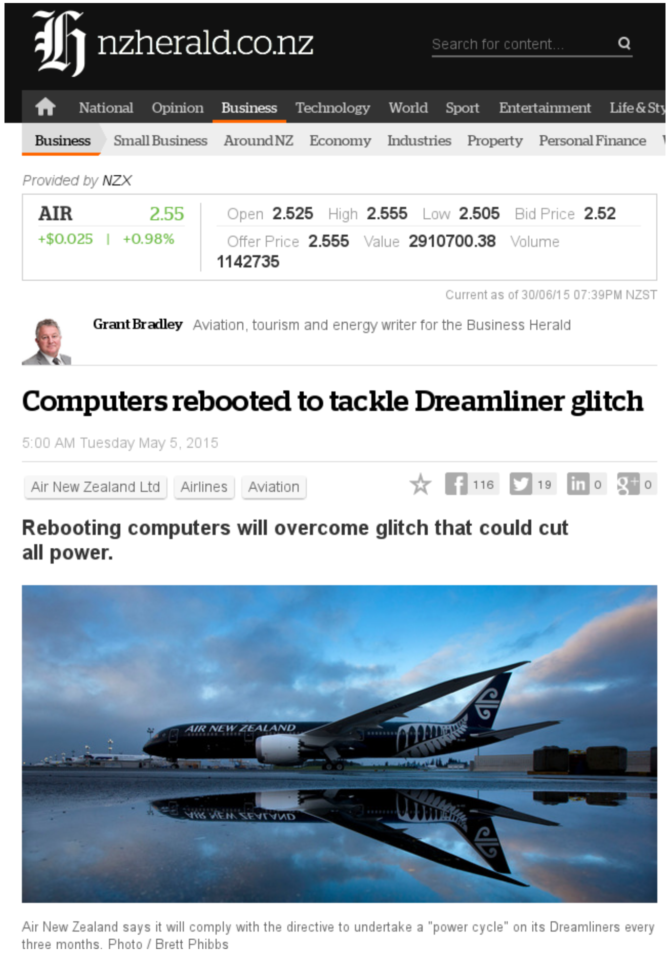
David J. Pearce

School of Engineering and Computer Science
Victoria University of Wellington

@WhileyDave
http://whiley.org
http://github.com/Whiley

Background

Verification: Who Cares?



nzherald.co.nz

National Opinion Business Technology World Sport Entertainment Life & Sty

Business Small Business Around NZ Economy Industries Property Personal Finance

Provided by NZX

AIR 2.55	Open 2.525	High 2.555	Low 2.505	Bid Price 2.52
+$0.025 | +0.98%	Offer Price 2.555	Value 2910700.38	Volume 1142735	

Current as of 30/06/15 07:39PM NZST

Grant Bradley Aviation, tourism and energy writer for the Business Herald

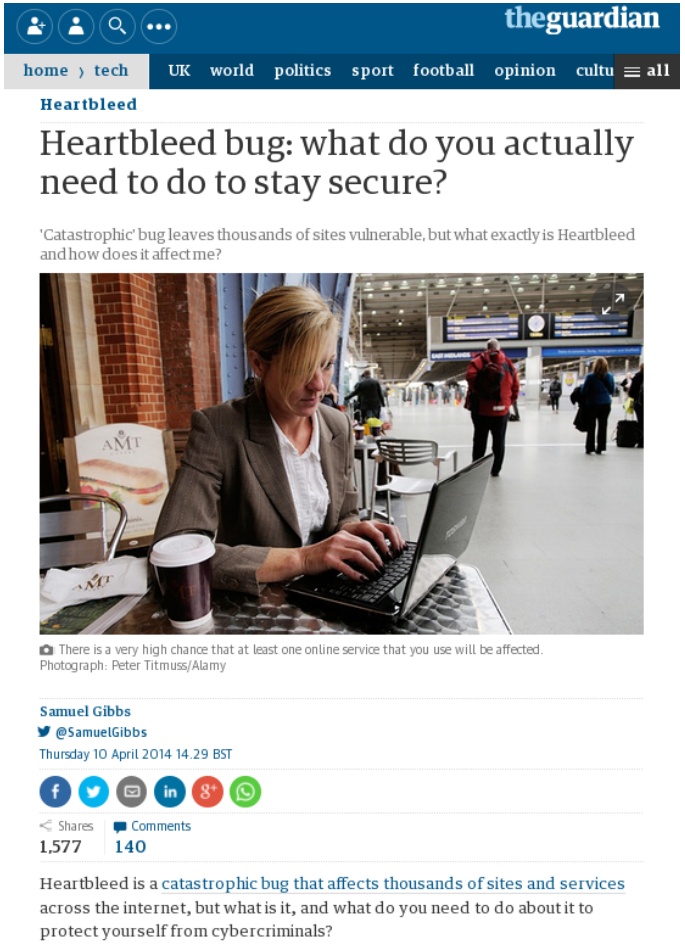
Computers rebooted to tackle Dreamliner glitch

5:00 AM Tuesday May 5, 2015

Air New Zealand Ltd
Airlines
Aviation
116
19
0
0

Rebooting computers will overcome glitch that could cut all power.

Air New Zealand says it will comply with the directive to undertake a "power cycle" on its Dreamliners every three months. Photo / Brett Phibbs



theguardian

Heartbleed

Heartbleed bug: what do you actually need to do to stay secure?

'Catastrophic' bug leaves thousands of sites vulnerable, but what exactly is Heartbleed and how does it affect me?

There is a very high chance that at least one online service that you use will be affected. Photograph: Peter Titmuss/Alamy

Samuel Gibbs
@SamuelGibbs
Thursday 10 April 2014 14.29 BST

Shares 1,577 | Comments 140

Heartbleed is a catastrophic bug that affects thousands of sites and services across the internet, but what is it, and what do you need to do about it to protect yourself from cybercriminals?

Verification: A Challenge for Computer Science

“A **verifying compiler** *uses automated mathematical and logical reasoning methods to check the correctness of the programs that it compiles”*

–Hoare’03

Whiley

Overview: What is Whiley?

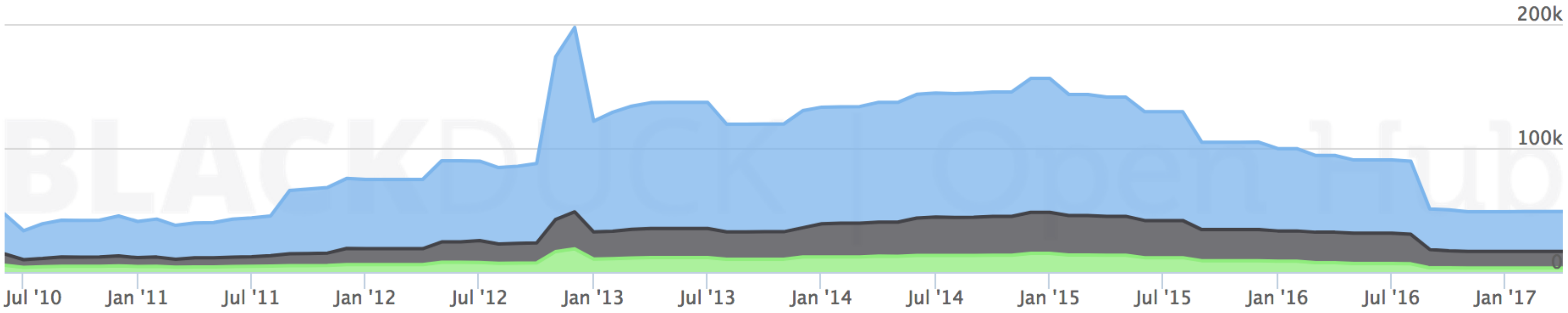
```
function max(int x, int y) → (int z)
// result must be one of the arguments
ensures x == z || y == z
// result must be greater-or-equal than arguments
ensures x <= z && y <= z:
    ...
```

- A language designed specifically to simplify **verifying software**

- Several trade offs e.g. **performance for verifiability**
  - *Unbounded Arithmetic, value semantics, etc*

- **Goal**: to statically verify functions meet their specifications

History of Whiley



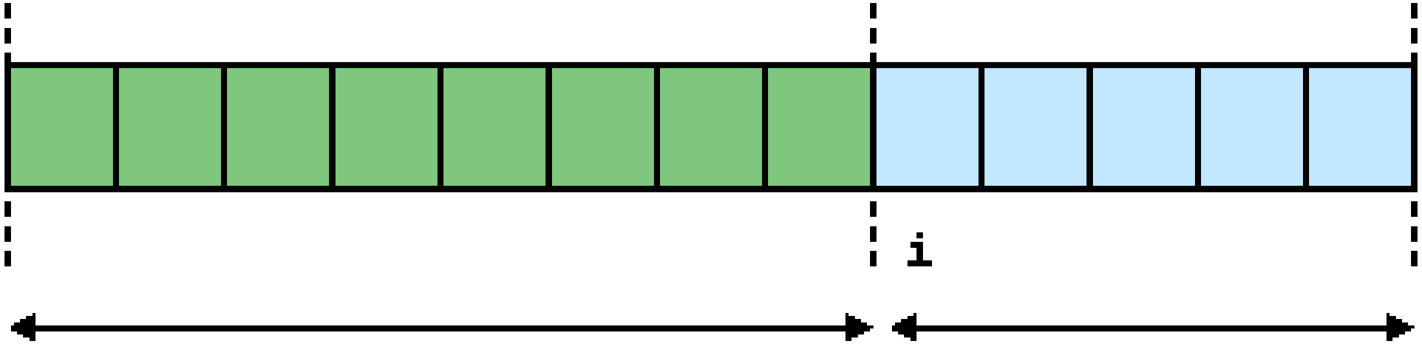
- 2009 — **Initial** version of Whiley released (GPL Licence)
- 2010 — **GitHub** repository and **`http://whiley.org`** go live
- 2010 — **Version 0.3.0** released (BSD Licence)
- 2016 — **Version 0.4.0** released
- 2017 — **Version 0.4.1** released

Demo Time…

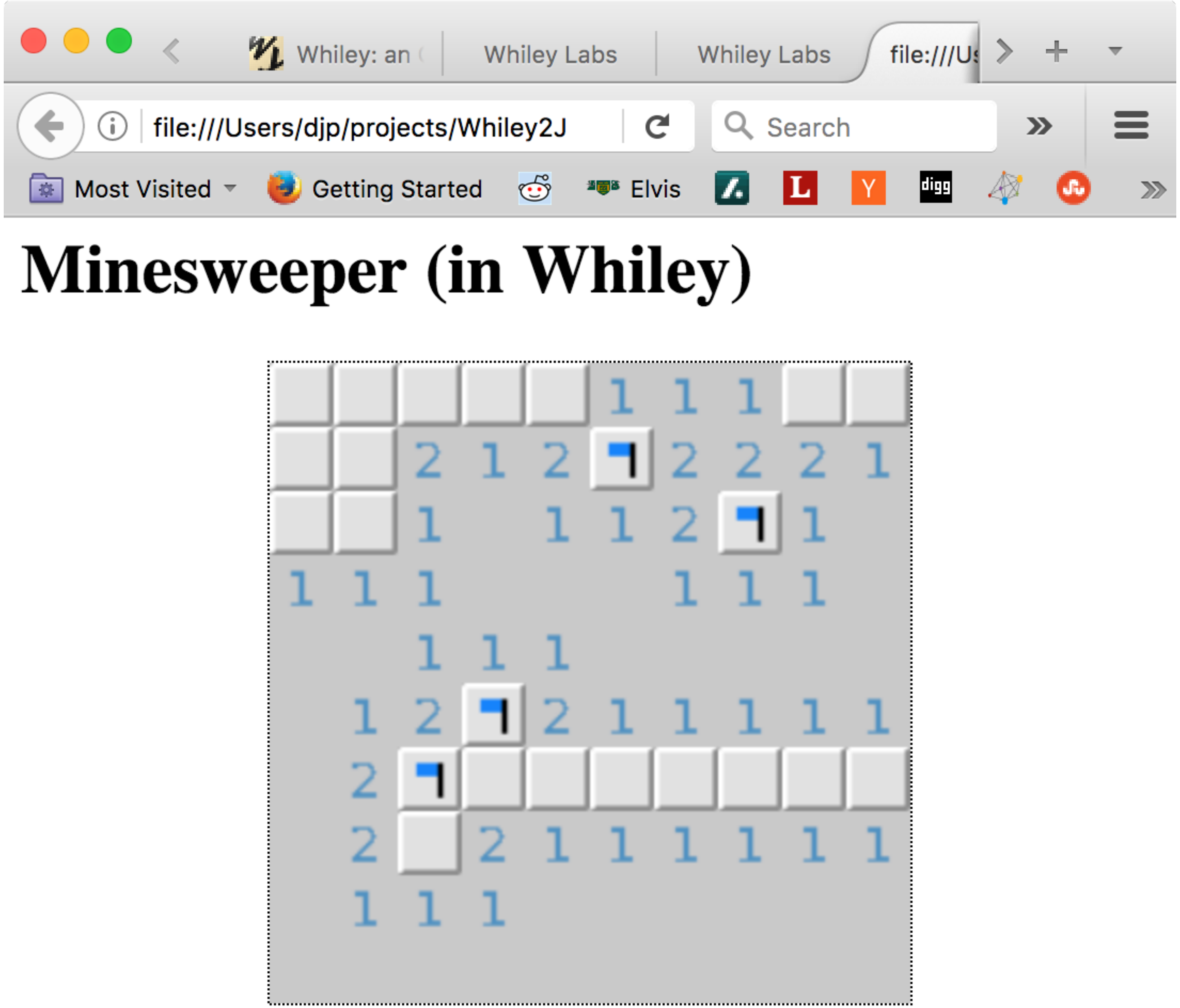
Example: max(int[])

```
// Returns index of largest item in array
function max(int[] items) → (int r)
```

Diagram!



Diagram!



Minesweeper (in Whiley)

□	□	□	□	□	1	1	1	□	□
□	□	2	1	2	⚑	2	2	2	1
□	□	1		1	1	2	⚑	1	
1	1	1				1	1	1	
		1	1	1					
	1	2	⚑	2	1	1	1	1	1
	2	⚑	□	□	□	□	□	□	□
	2	□	2	1	1	1	1	1	1
	1	1	1						

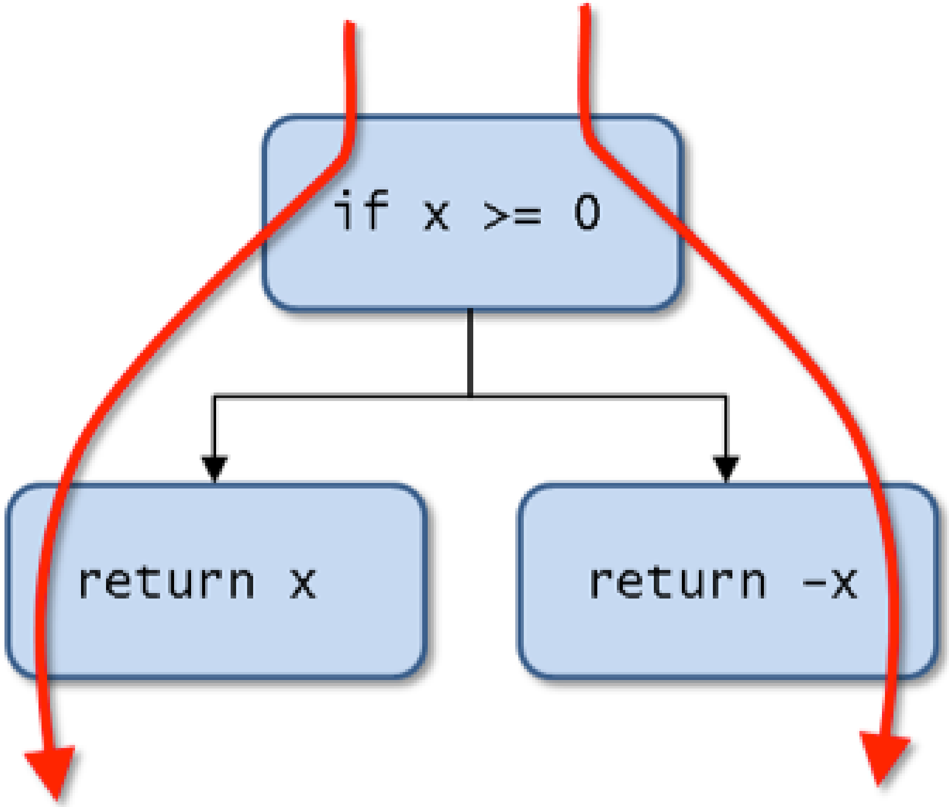
How does it work?

Verification: How does it work?

```
function abs(int x) => (int r)
// return value cannot be negative
ensures r >= 0:
    //
    if x >= 0:
        return x
    else:
        return -x
```

- To verify above function, compiler generates **verification conditions**
- Verification conditions are (roughly) **first-order logic formulas**

Verification: Verification Condition Generation



$\underbrace{x >= 0}_{\text{Assumptions}} \longrightarrow \underbrace{x >= 0}_{\text{Assertion}}$

$x < 0 \longrightarrow -x >= 0$

Verification: Assertion Language

- Whiley compiler emits verification conditions in **assertion language**

```
assert:
  forall (int x):
    x >= 0 ==> x >= 0

assert:
  forall (int x):
    x < 0 ==> -x >= 0
```

- Verification conditions from `abs()` example shown above

- In principle, can hook up different **automatic theorem provers**

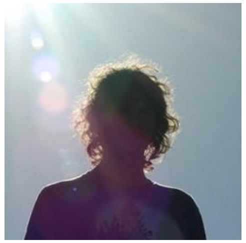
People (so far)

Art

(built C backend, 2012)

Melby

(built GPGPU backend, 2013)



Daniel

(helping with WhileyWeb)

Matt

(compiling for a QuadCopter, 2014)

Henry

(improving verification, 2014)

Sam

(started PhD on Parallelisation, 2014)

Lindsay

(A/Prof, Victoria University)

Mark

(A/Prof, University of Waikato)

http://whiley.org

@WhileyDave
http://github.com/Whiley

Verification: Constrained Types

```
type N is (T x) where e
```

- Above defines **constrained type**
- **Invariant:** for any variable of type `N`, follows that `e` always holds
- Constrained types can **simplify** specifications / invariants
- **Example:** *natural numbers*

```
type nat is (int n) where n >= 0
```

Verification: Structural Typing

```
type nat is (int n) where n >= 0

function cut(int x) → (nat y):
    if x >= 0:
        return x
    else:
        return 0
```

- Variable types in Whiley are **ephemeral** ...

  ... and determined by what is **known** (not what was declared)

Verification: Flow Typing

```
function indexOf(int[] items, int item) → (int|null r)
// If integer value returned, must be index of item
ensures r is int ==> items[r] == item
// No element before integer r matches item
ensures r is int ==> all { k in 0..r | items[k] != item }
// If null returned, no matching item
ensures r is null ==> all { k in 0..|items| | items[k] != item }:
    //
    int i = 0
    //
    while i < |items|
    where i >= 0 && i <= |items|
    where all { j in 0..i | items[j] != item }:
        if items[i] == item:
            return i
        i = i + 1
    //
    return null
```