Lecture 2 — Software Correctness

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Software Correctness

RECOMMENDATIONS
To Builders and Users of Software

Make the most of effective software development technologies and formal methods. A variety of modern technologies — in particular, **safe programming languages**, **static analysis**, and **formal methods** — are likely to reduce the cost and difficulty of producing dependable software. Elementary best practices, such as source code control and systematic defect tracking, should be universally adopted, . . .

–Software for Dependable Systems

Patriot Missle

- **1991, Dhahran**
  - Iraqi Scud missile **hits barracks** killing 28 soldiers
  - Patriot system was activated, but **missed target** by over 600m
  - Floating point **representation of 0.1** was cause (rounding error over time, required 100 hours of continuous operation)
- **See:** “Engineering Disasters”
  `https://www.youtube.com/watch?v=EMVBLg2MrLs`

(Image by Darkone - Own work, CC BY-SA 2.5)

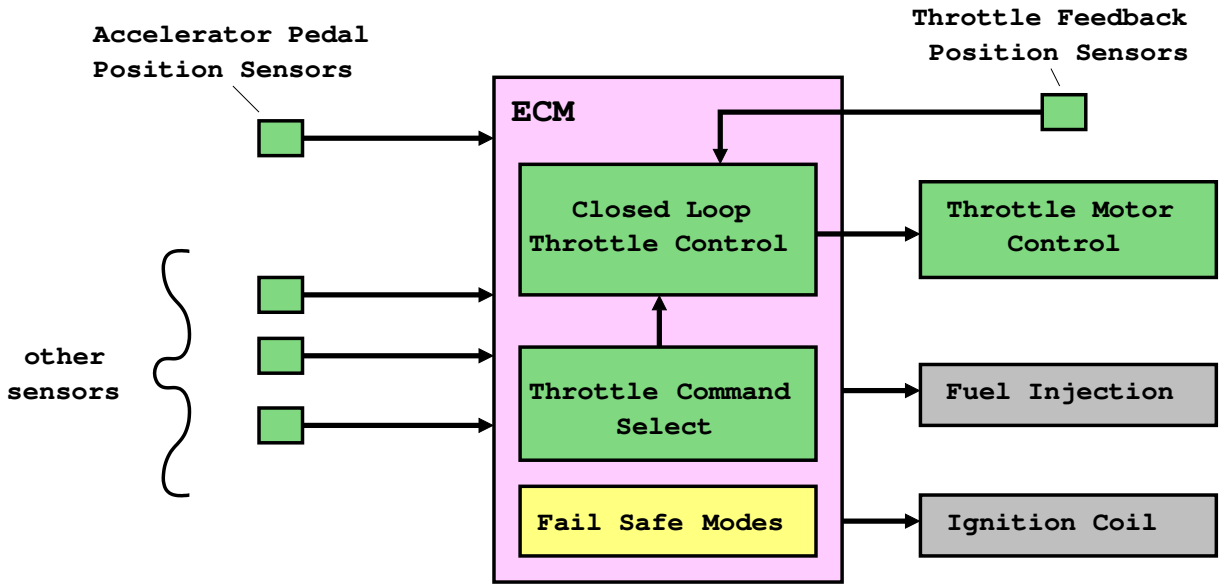
Unintended Acceleration? (Overview)

- Braking Problems (Toyota Prius)
  - Drivers reported **"sudden acceleration"** when braking
  - By 2010, over **seven million** cars recalled
  - **NASA experts** called into investigate
    Specialists in **static analysis**
    Their report had significant redactions though
  - Bookout vs Toyota, 2013
    Victim's awarded $1.5million each
    Barr provided **expert testimony**

See "Unintended Acceleration and Other Embedded Software bugs", Michael Barr, 2011

See "An Update on Toyota and Unintended acceleration"

Unintended Acceleration? (NASA Analysis)



"*The initial focus in analyzing the Camry MY 2005 source code has been on a thorough static source code analysis of the ECM source code to find possible coding defects and potential vulnerabilities in the code.*"

See "National Highway Traffic Safety Administration Toyota Unintended Acceleration Investigation"

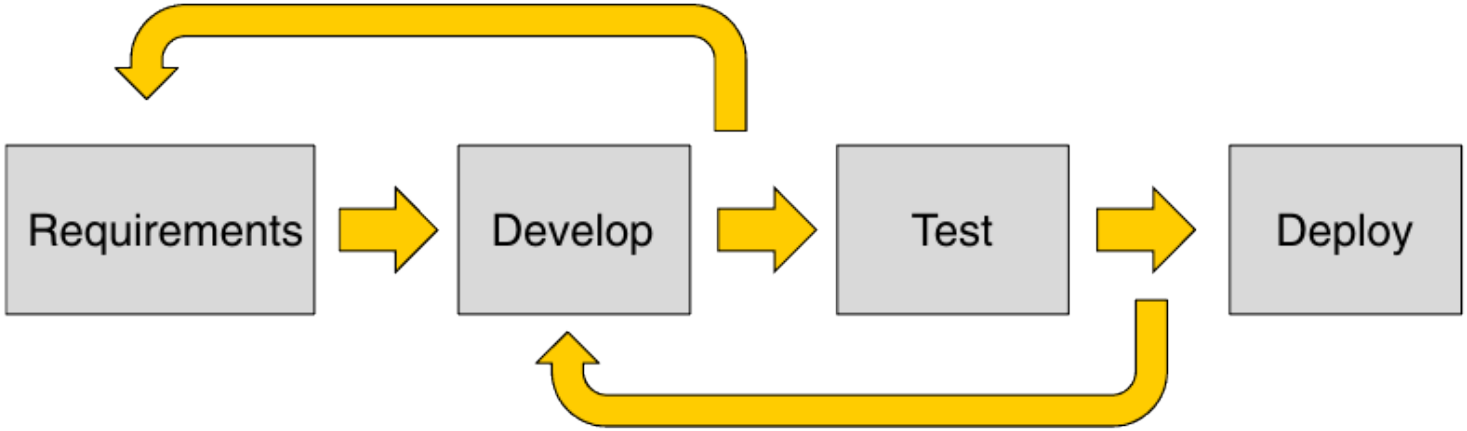
Unintended Acceleration? (Barr's Analysis)

"*Toyota's ETCS source code is of unreasonable quality. Toyota's source code is defective and contains bugs including bugs that can cause unintended acceleration*" –Michael Barr

- ECM main-cpu is V850E1 microcontroller (a 32-bit RISC CPU core)
- Code written in English following proprietary coding standard, sharing **similarities with MISRA-C**
- Redacted text indicates that compiler and static analysis tools produced large numbers of **warnings and errors**
- Code contained **243+ violations** of the "Power of 10-Rules"

See "An Update on Toyota and Unintended Acceleration", Michael Barr, 2013.

When to Catch Errors?



- Can we prevent errors in the **software requirements** themselves?
- Can we prevent errors being **introduced** during development?
- Can we prevent errors **through testing?**
- Is it **too late** to prevent errors at deployment time?

Example: *Type Checking*

```
/**
 * Type check an assertion statement. This requires checking that the
 * expression being asserted is well-formed and has boolean type.
 *
 * @param stmt
 *            Statement to type check
 * @param environment
 *            Determines the type of all variables immediately going into
 *            this block
 * @return
 */
private Environment propagate(Stmt.Assert stmt, Environment environment) {
    stmt.expr = propagate(stmt.expr, environment, current, null);
    checkIsSubtype(Type.T_BOOL, stmt.expr);
    return environment;
}
```

- **Aim:** Prevent type errors during development
- **Limitations:** Casting in Java means cannot catch all type errors
- **When:** During development, as *compile-time* or *static activity*

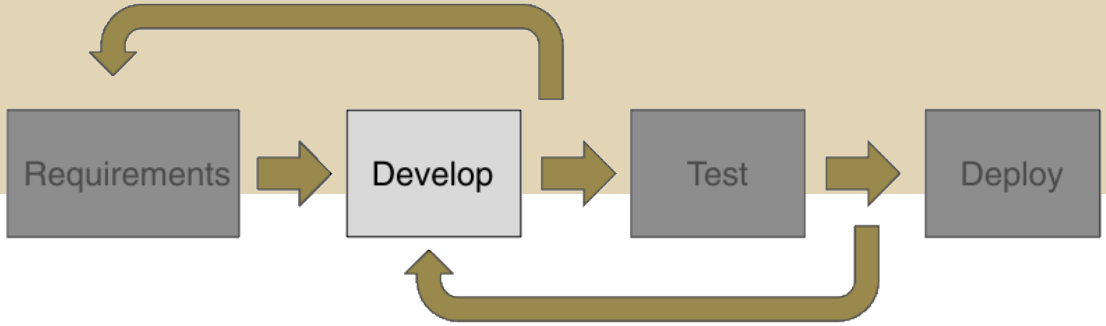
Type Checking is “Conservative”

```
public class Test {
    public static void fun(Test t) {
        // ...
    }

    public static void main(String[] args) {
        Object o = new Test();
        fun(o);
    }
}
```

- Type checking prohibits programs **with type errors**
- ... but also prohibits some programs **without type errors**
- ... and is also conservative (i.e. admits **false positives**)

“Compile Time”

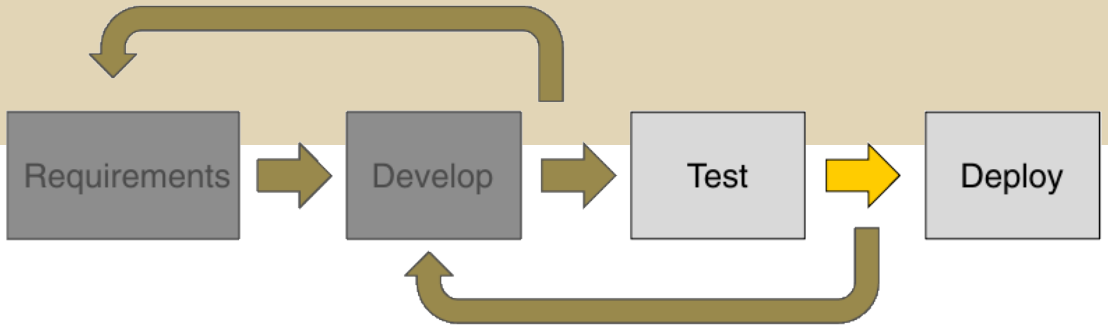


In computer science, **compile time** refers to either the operations performed by a compiler (the “compile-time operations”), programming language requirements that must be met by source code for it to be successfully compiled (the “compile-time requirements”), or properties of the program that can be reasoned about during compilation.

–Wikipedia

- Error Checking at Compile-Time
  - Occurs **before** program is run
  - Considers **all possible** execution traces
  - Possible to **guarantee** absence of certain errors
  - E.g. type checking in Java

“Run Time”



In computer science, **run time**, runtime or execution time is the time during which a program is running (executing), in contrast to other program lifecycle phases such as compile time, link time and load time.

–Wikipedia

- Error Checking at Runtime
  - Occurs during an **actual** program execution
  - Considers only **single** execution trace
  - Cannot guarantee absence of errors
  - E.g. runtime assertions in Java

Exercise: *Spot the Bug!*

```
// return largest of three numbers
int max3(int x, int y, int z) {
  int r;
  if(x > y) {
    if (x > z) { r = x; }
    else { r = z; }
  } else if (y > z) {
    r = z;
  } else {
    r = y;
  }
  //
  assert r >= x && r >= y && r >= z;
  return r;
}
```

- What are the **downsides** here?

Is it a Bug or a Feature?

A **functional specification** (also, functional spec, specs, functional specifications document (FSD), functional requirements specification) in systems engineering and software development is a document that specifies the functions that a system or component must perform (often part of a requirements specification) (ISO/IEC/IEEE 24765-2010).

–Wikipedia

```
int max(int[] items) {
  int max = items[0];
  for(int i=1;i<items.length;++i) {
    if(max < items[i]) { max = items[i]; }
  }
  return max;
}
```

- **Q)** is this function implemented **correctly?**