ECE 471 – Embedded Systems
Lecture 28

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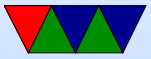
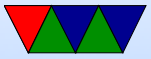
Announcements

- Don't forget HW#9
- Midterm next Friday
- Release of Apple Silicon M1 ARM chip

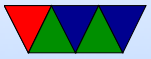


HW#9 – Modular Code

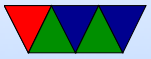
- What is modular code?
- In C you can compile each C file into its own object file, link together at end
- Each C file can act as self-contained module
- Can make code-reuse easier, can treat like a library
- API defined in a header .h file



- Can be easier to follow code than in one huge program
- Easier when working in shared git repository

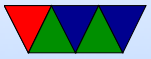


Another Few Software Disaster Case Studies



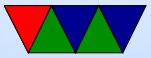
Financial

- Knight Capital. Upgrade 7 of 8 machines, missed last. Re-used a flag definition with new software. Caused massive selloff, $440 million

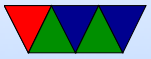


Power

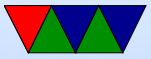
- 2003 Blackout
  - Power plant fail. Cause more current down transmission lines in Ohio. Heat, expand, touch tree, short out.
  - Race condition in Unix XA/21 management system, so alarms not go off
  - Eventually primary system fail as too many alarms queue up
  - Backup server also fail



- During failure, screens take 59s (instead of 1s) to update
- Blackout of most of NY and a lot of north east.

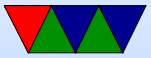


Good Design Practices



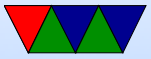
Code Safety Standards

- Avionics: DO-178C (1992 for B)
- Industrial: IEC 61508 (1998)
- Railway: CENELEC EN 50128 (2001)
- Nuclear: IEC 61513 (2001)
- Medical: IEC 62304 (2006)
- Automotive: ISO 26262 (2011)



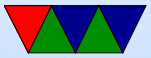
Aviation

- DO-178B / DO-178C
- Software Considerations in Airborne Systems and Equipment Certification
  - Catastrophic: fatalities, loss of plane
  - Hazardous: negative safety, serious/fatal injuries
  - Major: reduce safety, inconvenience or minor injuries
  - Minor: slightly reduce safety, mild inconvenience
  - No Effect: no safety or workload impact

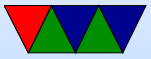


Automotive ISO 26262

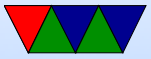
- What is a document like this like?
- Vocab and definitions
- Management
- Safety Life Cycle
- Supporting processes
- Safety Analysis
- Risk Strategy
- Severity
  - S0 – No injuries



  - S1 – No injuries
  - S2 – Severe injuries
  - S3 – Not survive-able
- Exposure
  - E0 – Unlikely to Happen
  - ...
  - E4 – High probability
- Controllability
  - C0 – Controllable
  - ...
  - C3 – Uncontrollable

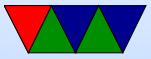


- Look up those in a matrix so you know how to assess risk, know how important to fix, know what resources to apply



Medical Response

- IEC 62304 – medical device software – software lifecycle
  - Quality management system – establish the requirements needed for such a device, then design methods to be sure it meets these
  - Avoid reusing software of unknown pedigree (don't just cut and paste from stackoverflow)
  - Risk management – determining what all the risks involved are, then determine ways to avoid or minimize them



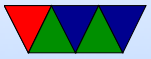
- Software safety classification

  Class A: no injury possible

  Class B: Nonserious injury possible

  Class C: serious injury or death possible

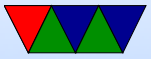
  Software sorted into these areas. Class A do not require the same precautions as the others.



Other notes

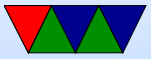
- Top down vs Bottom up Design
  Spec out whole thing and how they work first
  Start with core part and just keep adding to it until it works

- Requirements/Specifications?

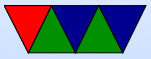


Writing Good (Embedded) C Code

- Various books
- Comment your code!
- Strict, common code formatting (indentation)
- More exact variable types (int32_t not int) Size can vary on machine, and on operating system
- Subset to avoid undefined behavior

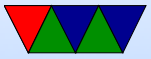


- Tool that enforces the coding standards
- Good to write safe code even if it isn't meant for a safe application. Why? Good practice. Also who knows who or when your code might be copied into another project.



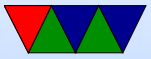
MISRA

- **MISRA: Guidelines for the Use of the C Language in Critical Systems**
- Motor Industry Software Reliability Association
- Guidelines: Mandatory, Required, Advisory
- Some sample guidelines
  - Avoid compiler differences int (16 or 32 bit?) `int32_t`
  - Avoid using functions that can fail (malloc()) allocate memory at beginning of program not throughout
  - Maintainable code, comments, coding style (see

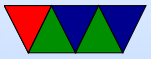


below)

- Compliance
  - All mandatory rules must be met
  - All required rules must have formal deviation
- Deviation
  - Must make a format explanation for why deviation is necessary
  - Prove you've thought about the issue
- MISRA 2012 has 143 rules, 16 directives
- NOTE: YOU CAN STILL WRITE BAD CODE EVEN WHEN FOLLOWING THIS

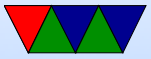


It just makes it easier to write good maintainable code.



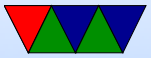
C Style

- What can C look like?
  IOCCC (International Obfuscated C Code Competition)
- Variable style, `CamelCase`, `under_score`, Hungarian Notation (arru8NumberList)
- Indentation (tabs vs spaces)
- Curly braces on same or next line
- Comment style
- Auto-generated documentation from comments



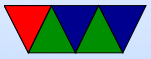
Good Test Practices

- Unit testing
- Test Driven Development – tests written before the code happens, needs to pass the tests before done
- Fuzzing
- Device Hardening?



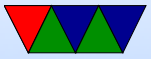
Good Documentation Practices

- Comment your code
- Write documentation! Make sure it matches code! There are some tools that can auto-generate documentation from special code comments
- Use source control (git, subversion, mercurial)
- Use good commit messages in your source control



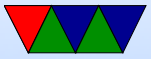
Space Shuttle Design

- https://www.nasa.gov/mission_pages/shuttle/flyo flyfeature_shuttlecomputers.html
- Issues normal embedded systems don't have: Vibration at liftoff, Radiation in Space
- If computer stopped for more than 120ms, shuttle could crash
- "Modern" update in 1991: 1MB Ram, 1.4MIPS. Earlier was 416k and 1/3 as fast and twice as big
- Change to code, 9 months testing in simulator, 6 months



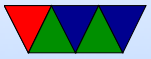
more extensive testing

- 24 years w/o in-orbit SW problem needing patches
- 12 year stretch only 3 SW bugs found
- 400k lines of code
- HAL/S high-order assembly language (high-level language similar to PL/I)
- PASS software – runs tasks. Too big to fit in memory at once
- BFS – backup flight software. Bare minimum to takeoff, stay in orbit, safely land, fits in memory, monitors pASS during takeoff/landing Written by completely different



team.

- 28 months to develop new version
- IBM
- Extensive verification. One internal pass, one external
- 4 computers running PASS, one running BFS
- Single failure mission can continue; still land with two failures
- 4 computers in lock-step, vote, defective one kicked out



SpaceX Falcon 9

- Linux – on dual core x86 systems
- Three each, vote
- Flight software in C/C++
- Dragon displays in Chromium+JS