Transport systems : Railway Interlocking system

Interlocking: arrangment of signals for safe movement of trains over tracks

From mechanical interlocking (route settings by levers)
to electrical (electro-mechanical) intelocking
to electronic/computer-based interlocking

Computer-based interlocking:

- software logic running on special-purpose control hardware
- logic is implemented by software rather than hard-wired circuitry
- facilitates modifications by reprogramming rather than rewiring

Signal blocks on a subway system (Toronto) : 4 signals , short blocks
If a train has just passed the most distant signal, the two most distant signals are red (*stop and stay* aspect);the next closest signal is yellow (*proceed with caution*), and the nearest signal shows green (*proceed*).

https://en.wikipedia.org/wiki/Signalling_of_the_Toronto_subway

Transport systems: Railway Interlocking system

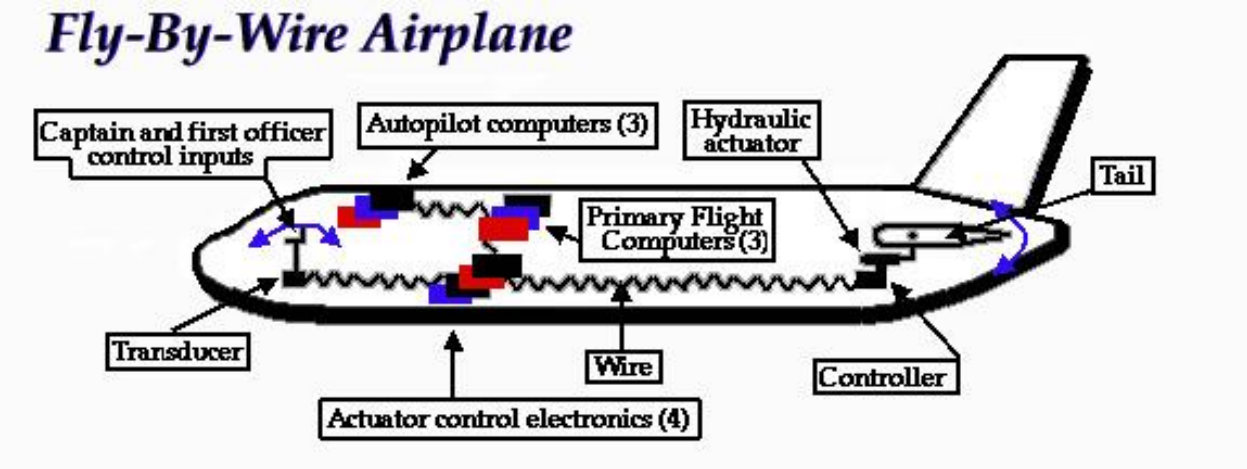
Mechanical control (leavers)

Computer-based controls

Electro-mechanical control

Supervisory control and data acquisition (SCADA) systems to view the location of trains and the display of signals.

Transport systems: Aerospace



Boeing's first attempt at a completely fly-by-wire commercial airplane.
Source:
https://www.mura.org/websites/me39c.me.berkeley.edu/Spring97/Projects/b777/flightdeck2.html

Earliest aircrafts: mechanical and hydro-mechanical control system; series of levers, rods, cables, ….

Fly-by-wire (FBW) system: all commands and signals are transmitted electrically along wires. The pilot uses a console.

These signals are sent to **flight-control computers (FCS)** that reconvert the electrical impulses into instructions for control surfaces like wing flaps or the tail.

Devices in the control surfaces measure their position and transmit that data back to the flight computer.
Flight computers can be programmed to carry out adjustments to control surfaces automatically.

Transport systems: Aerospace

Air traffic Control

Source:http://www.adp-i.com/en/our-solutions/airport-expert-appraisals/air-navigation

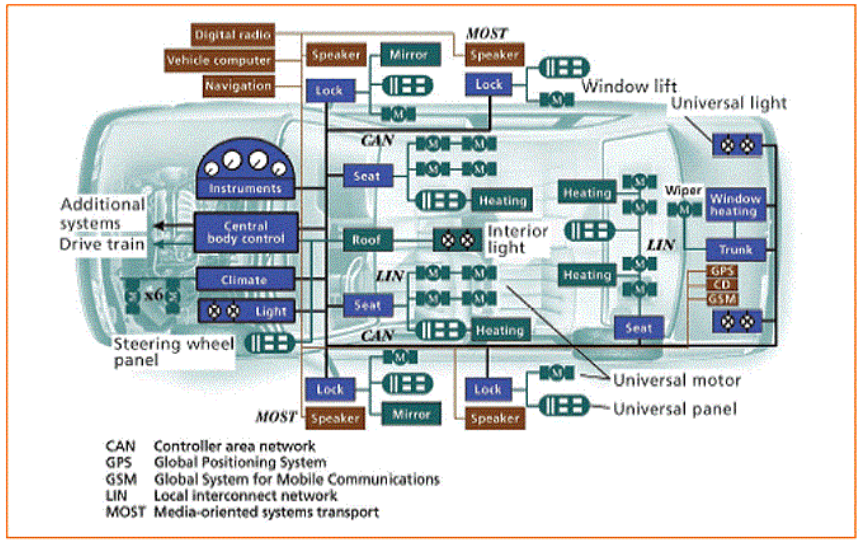
Air Traffic Control (ATC) is a service provided by ground-based controllers who are responsible for maintaining a safe and efficient air traffic flow.

ATC is transitioning to use of the Global Positioning System for Navigation and precision approaches

Future generation of ATC: **Airborne Self-Separation**
an operating environment where pilots are allowed to select their flight paths in real-time.

Main challenge:
coordination between aircrafts within a dynamic environment, where the set of surrounding aircraft is constantly changing

Transport systems: Automotive



Drive-by-wire

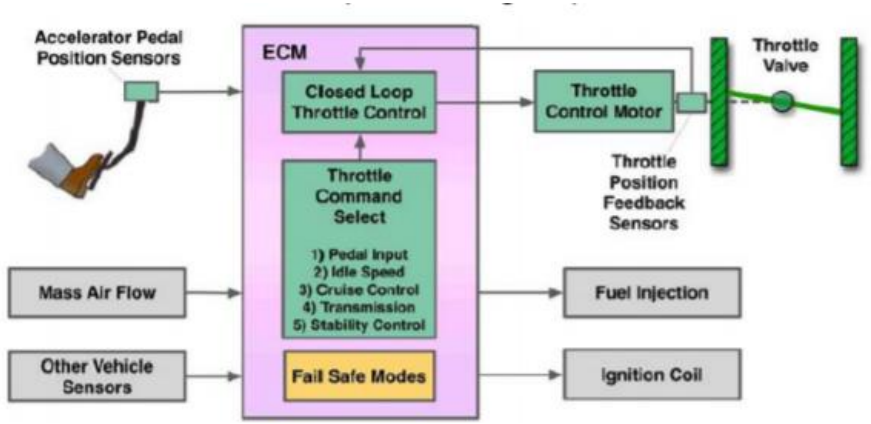
traditional mechanical control of vehicle functions replaced by ECUs

Over 80 different embedded processors, interconnected

Key ECUs (Electronic Control Unit):

- Engine Control Modul (ECM)
- Electronic Brake Control Module (EBCM)
- Transmission Control Module (TCM)
- Vehicle Vision System (VVS)
- Navigation Control Module (NCM)
- …

Trottle ECU



Source: P. Koopman. (2014) A case Study of Toyota Unintended Acceleration and Software Safety.

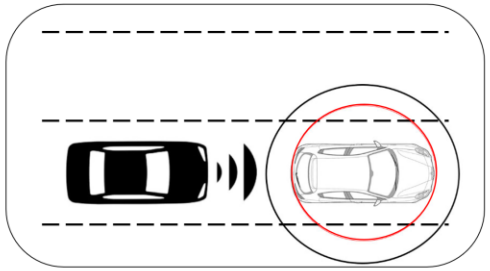
https://users.ece.cmu.edu/~koopman/toyota/koopman-09-18-2014_toyota_slides.pdf

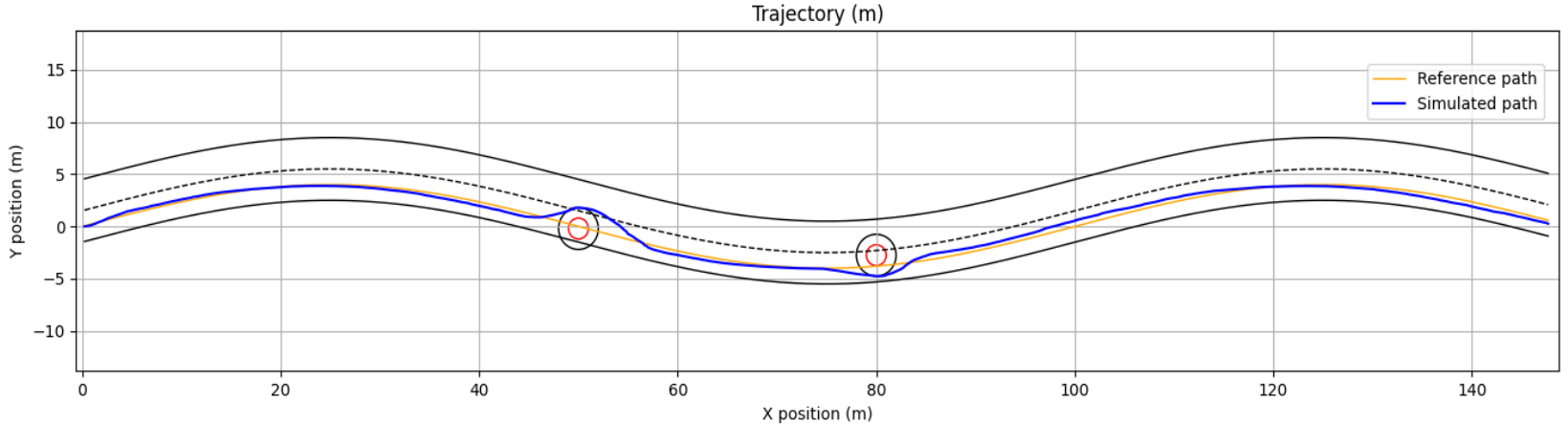
Transport systems: Automotive

Autonomous driving:
vehicles capable of sensing its environment and navigating without human input

Array of sensors needed to provide the autonomous system with situational awareness about the physical world. Embedded processors use this information to make appropriate decisions about what actions the autonomous system should perform.

The Advanced Driver Assistance Systems (ADAS)





Checkoway et al.
Comprehensive Experimental Analyses of Automotive Attack Surfaces. Usenix Symposium 2011

Digital Instrumentation and Control

A Digital Control System samples feedback from the system under control and issues commands to the system in an attempt to achieve some desired behaviour

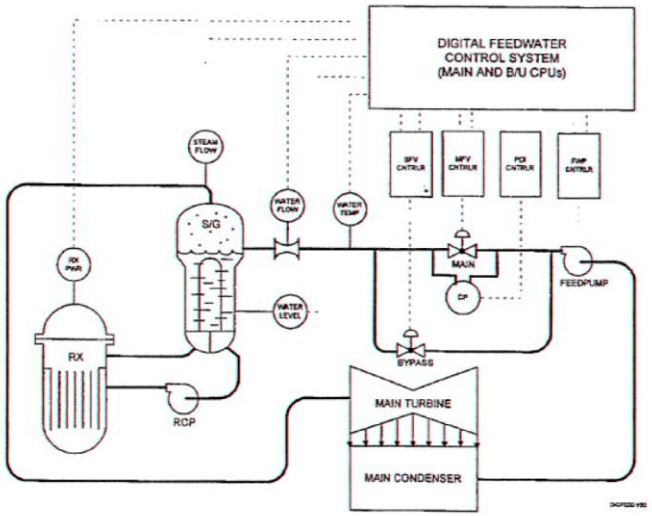
Digital I&C: analog and mechanical parts are replaced by CPUs and software

Nuclear Power Plant (NPP) has two units, each consisting of two reactor coolant loops

For each reactor coolant loop:
- Reactor coolant pump (RCP)
- Steam Generator (S/G)

Main components of the FeedWater Systems (FWS)
- FWPs (FeedWater Pumps)
- MFRVs (Main FeedWater Regulating Valves)
- BPFRVs (Bypass FeedWater Regulating Valves)

One of the reactor coolant loops with its associated Digital FeedWater Control System



Source: ''Traditional Probabilistic Risk Assessment Methods for Digital Systems'', U.S. Nuclear Regulatory Commission, NUREG/CR-6962, 2008

Healthcare: Medical systems

PCA devices

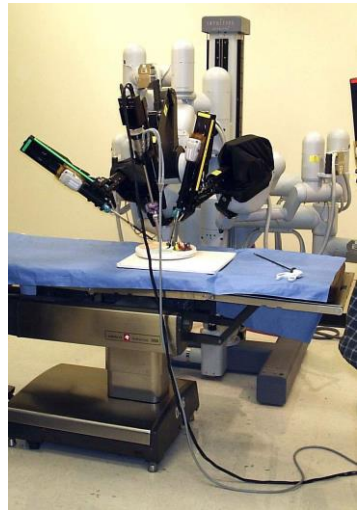
A patient-controlled analgesia (PCA) infusion pump, configured for intravenous administration of morphine for postoperative analgesia, programmable thorugh an interactive user interface

Cardiac Pacemakers

The bulk of the device contains its battery and electronic control systems. The leads detect the heart's electrical activity, transmit that information to the pacemaker's electronics for analysis and, if the natural activity is deemed irregular, deliver an electrical charge from the pacemaker's batteries that causes the cardiac muscle to contract, pacing the pumping of the heart.

Robotic Surgical Systems

Da Vinci Surgical System: Approved by the Food and Drug Administration (FDA) in 2000, it is designed to facilitate complex surgery using a minimally invasive approach and is controlled by a surgeon from a console.



Source: http://www.davincisurgery.com/da-vinci-surgery/da-vinci-surgical-system/