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2010 Emissions from an Electronics Perspective

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Agenda

- Objective
- A perspective of processing power
  - Evolution of an ECU
  - Comparison to the gaming industry
- 2010 engine control challenges
  - Combustion feedback
  - Virtual NOx sensor
  - Model-based controls for OBD-II
- Effects on the ECU
- A happy ending for 2010?

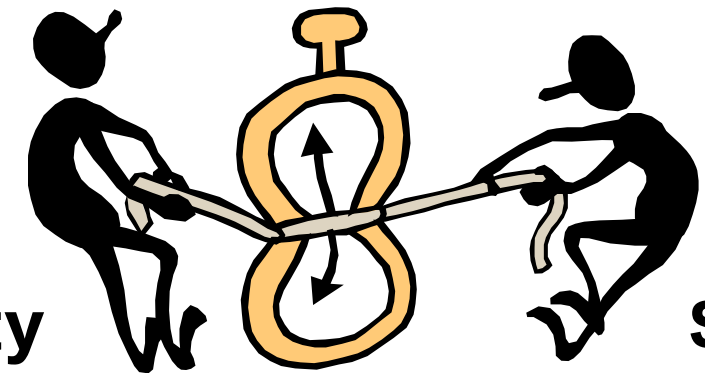
Objective

- Acquaint engine designers & testers with the electronic ramifications of controlling the systems they create.
- In general terms, I'd like to explain why the electrical engineers in your life look like this...

How are we ever going to design the 2010 controller?

Objective

- Historically engine control units (ECU's) have always been caught between cost and capability.
- The less time allowed for system integration, the more it costs to add or change electronic functionality.

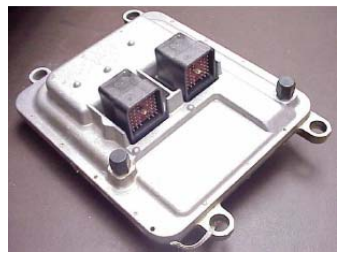


Capability **$$ Cost $$**

Evolution of an ECU

- **ADEM ~ introduced in 1990**
  - Dual 8-bit processors @ 2MHz
  - 64K flash memory, 8K RAM

- **ADEM2 ~ introduced 1992**
  - Dual 8-bit processors @ 4MHz
  - 256K flash memory, 32K RAM

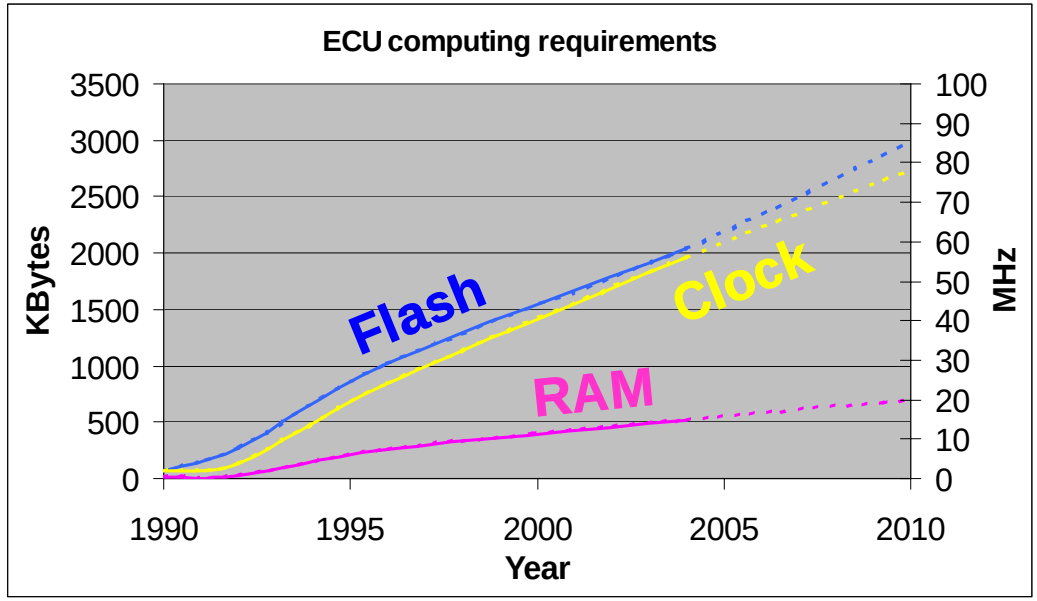


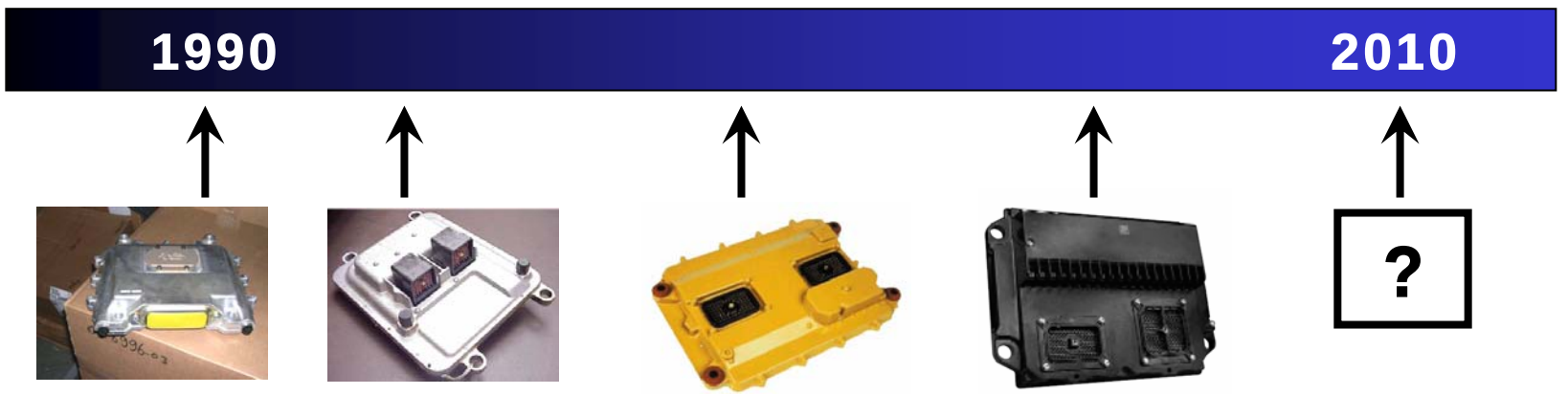
- **ADEM3 ~ introduced 1996**
  - 32-bit + 8-bit processor @ 24MHz
  - 1M flash memory, 256K RAM

- **ADEM4 ~ introduced 2004**
  - 32-bit RISC processor @ 56MHz + FPGA
  - 2M flash memory, 512K RAM

Evolution of an ECU

- Regression modeling & extrapolation says 2010 ECU will have 3M flash, 690K RAM and be running @ 78MHz





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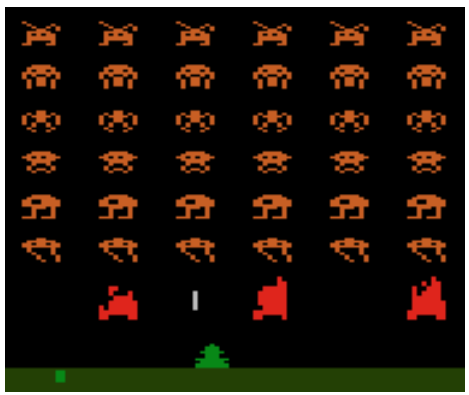
A comparison to the gaming industry

- Gaming system ‘A’ – debut in 1977
  - MOS Technologies 6507 4-bit processor @ 1.19MHz
  - 6K ROM, 128 bytes RAM
  - separate chip for TV interface & sound
  - ins: joystick interface (four directions & one button)
  - outs: draws those groovy graphics...



source: http://www.atariage.com/2600/archives
originally printed IEEE Spectrum, March 1983, Perry & Wallich

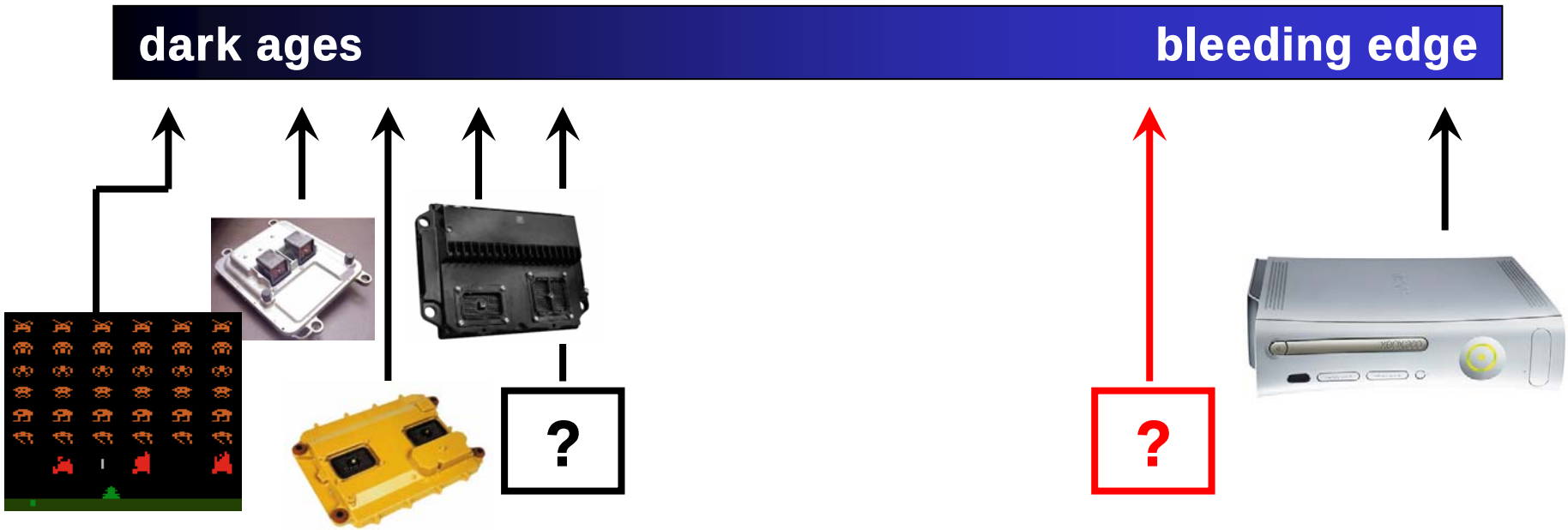
A comparison to the gaming industry

- Gaming system ‘X’ – available holiday 2005
  - 3 IBM PowerPC cores on single chip
    - 3.2GHz each w/ floating point extension unit
  - separate graphics & audio processors
  - overall system performance @ 1 trillion FLOPS/sec
  - 20GB hard drive option, 10MB embedded DRAM
  - ins: 4 wireless controllers, internet, USB devices
  - outs: high-resolution video, surround sound audio

source: http://www.xbox.com/en-US/xbox360/factsheet.htm

How do engine controllers measure up?

- It's not really a fair comparison
  - environment (heat, vibration, general nastiness)
  - lifetime (million-mile warranties)
- We're taking incremental steps in the engine industry…this time we need a break-through

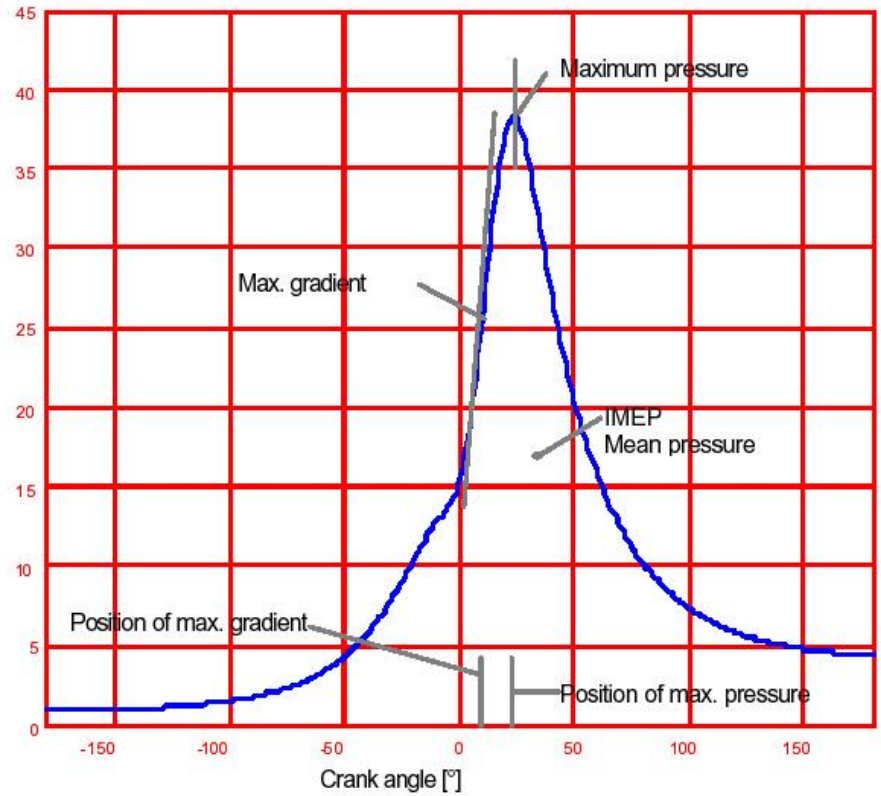


Why do we need the extra power?

- The diesel engine industry is researching multiple paths for 2010 emissions compliance
  - HCCI combustion requires:
    - Precise control of in-cylinder combustion over full operating range of the engine
    - We'll probably need combustion sensor feedback
  - NOx aftertreatment requires:
    - Keep engine & catalysts operating such that tailpipe-out NOx emissions are always compliant with 0.2g/bhp*hr
    - We'll probably need a NOx feedback sensor
  - OBD-II requires:
    - Model-based controls approach for fault detection

Combustion pressure requirements

- Cost-effective small sensor that matches lab-grade instrumentation within 0.1% over engine operating range. And it has to last for 500 million cycles.
- Correlate with cylinder position @ 0.2° crank resolution
- 6 channels of high-speed analog input ~1.5MHz
- Calculate stuff really fast…not a conventional engine



source: Schiefer, Maennel & Nardoni SAE 2003-01-0364

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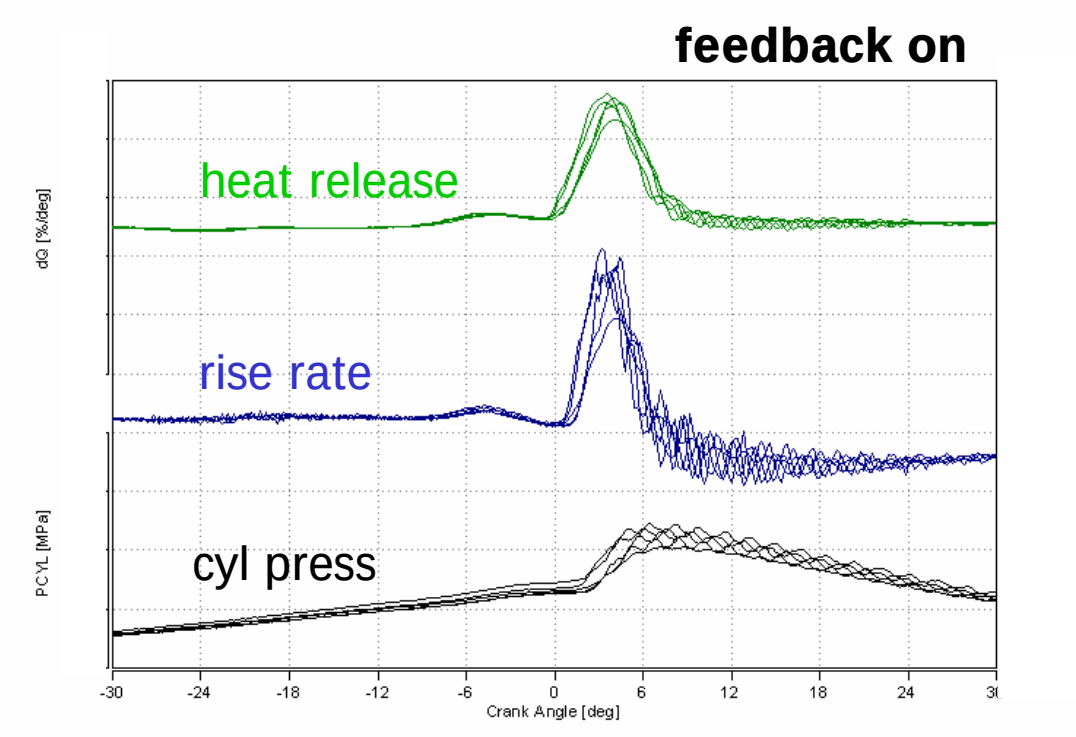
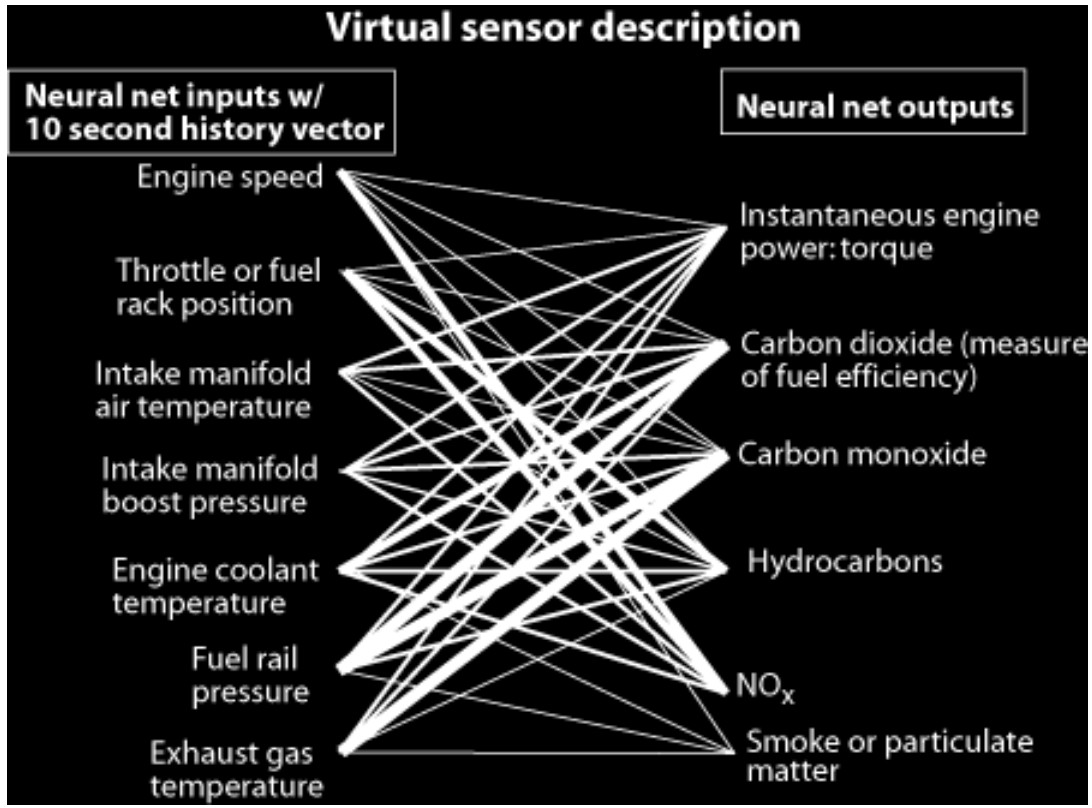
Some results with our electronics

– Varying valve actuation conditions to balance cylinder-to-cylinder out variation utilizing combustion sensor feedback.



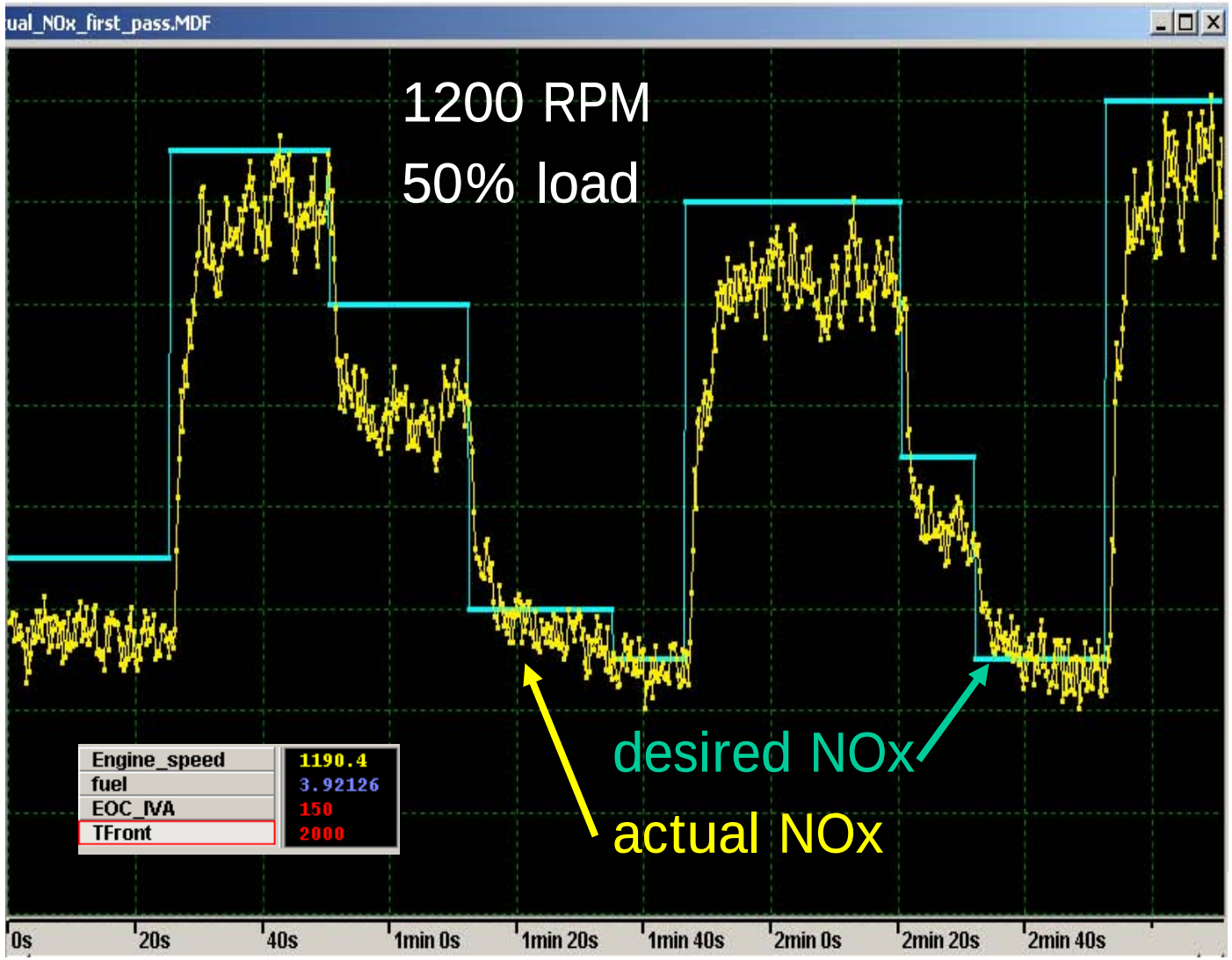
Virtual NOx sensor requirements

- Monitor existing engine sensors & operating conditions to extrapolate emissions info
- Neural networks are set up like the human brain: lots of small processing cells with many interconnects
- The network can adjust its own gains to “learn” how to describe the system



source: Atkinson, Traver, Long, Hanzevack
published @ http://www.isa.org/Content/ContentGroups/InTech2/Features/20023/June15/20020632.pdf

Some results with our electronics



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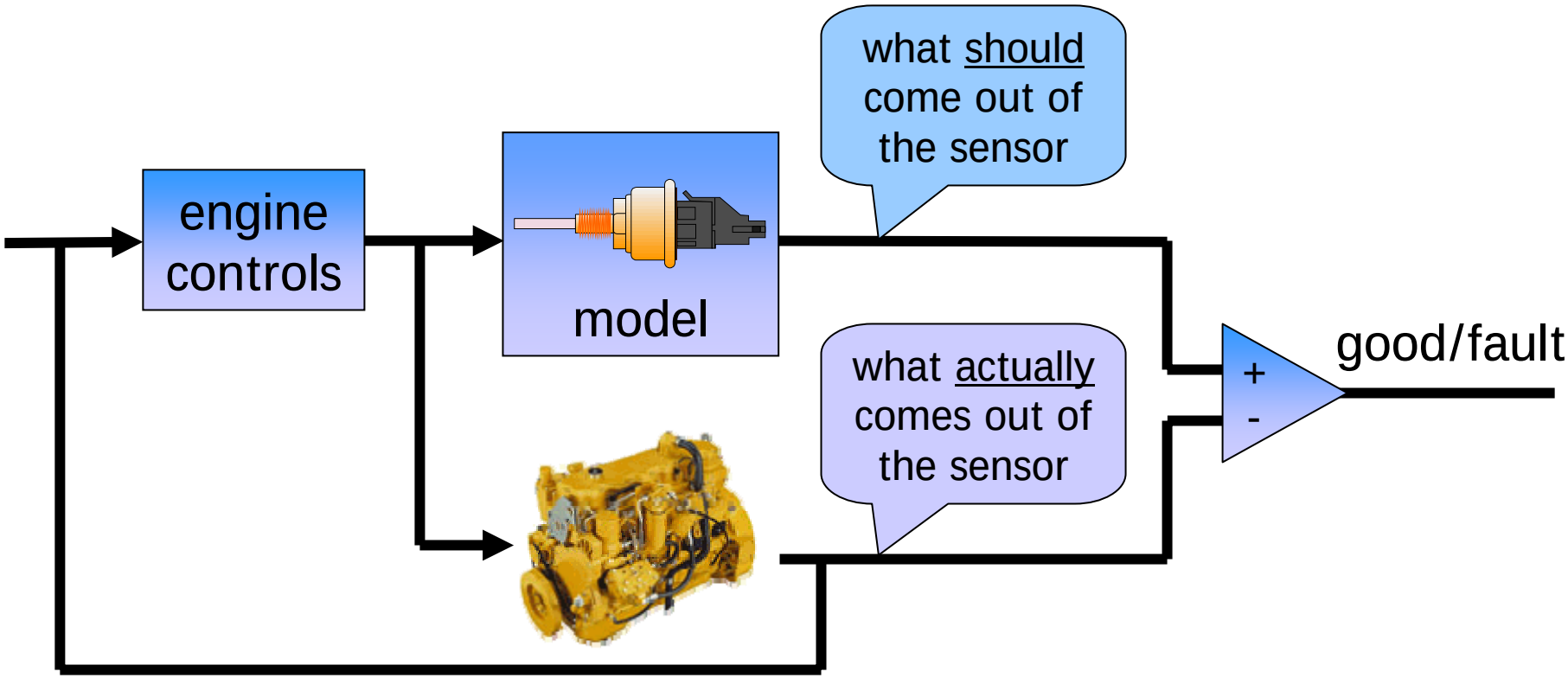
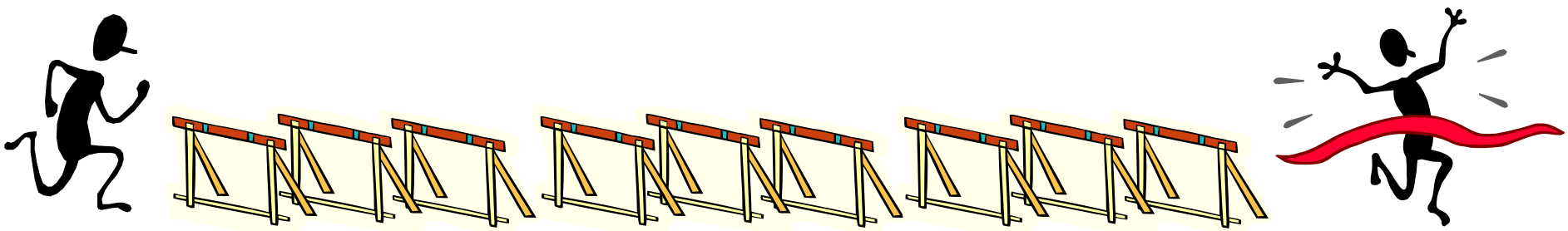
Model-based controls for OBD-II



- One of these models will exist for every sensor, actuator and subsystem on a 2010 engine.

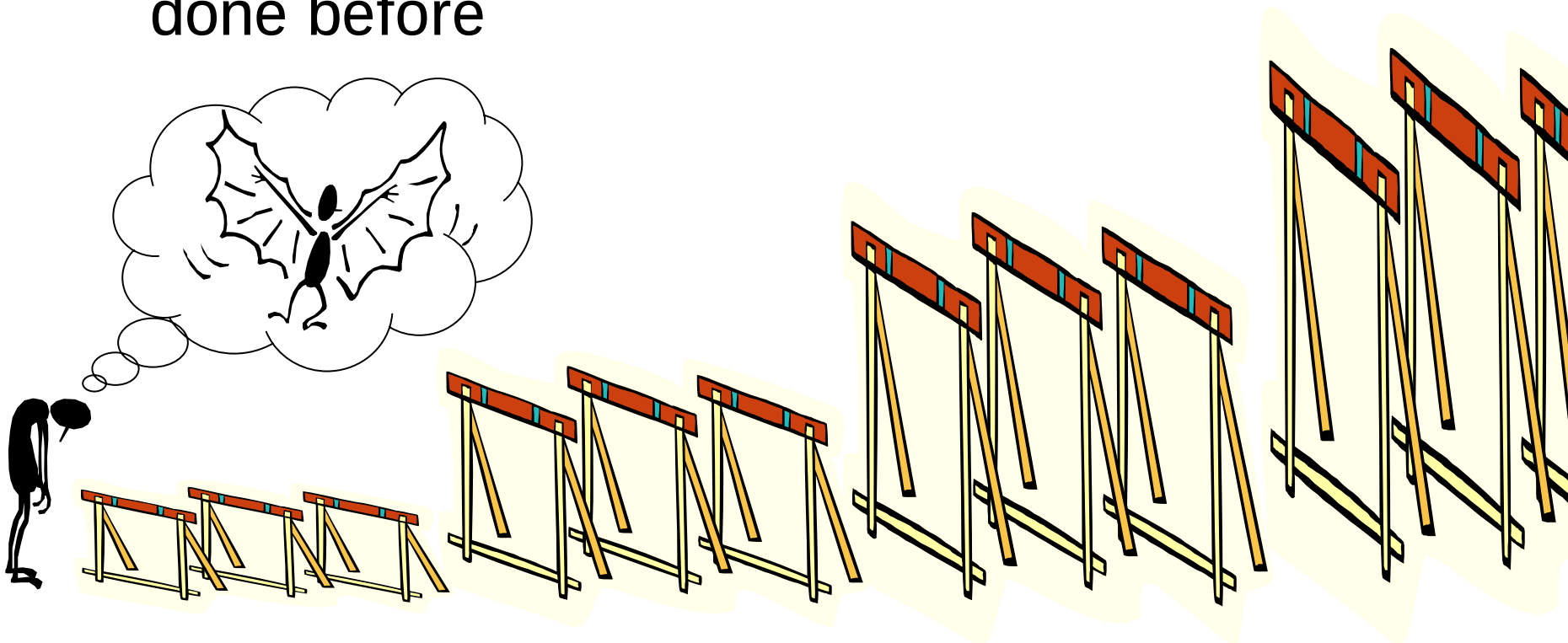
So what do these do to our future ECU?

- Today's ECU has been tuned for today's requirements
  - hardware filters and converts sensor signals & appropriately drives actuators
  - every loop, software reads input sensors, performs control algorithms & writes output values to actuators (15msec to 120msec)
  - the ECU wins its race against the clock every time



So what do these do to our future ECM?

- When we add in cylinder pressure, virtual NOx sensing & model-based controls, we're asking the ECM to do something it's never done before



Will there be a happy ending?

- **Get a bigger hammer!**
  - Bigger, faster electronic components are available such as components for the gaming industry
  - Start investigating packaging/cooling solutions to put consumer-grade electronics in the heavy-duty environment
- **Distribute the electronics!**
  - Multiple, smaller, more specialized ECM's connected over a datalink should be more effective than one giant box