

# CPS Education: *a practical perspective?*

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The cartoon depicts a man's life milestones on a timeline from age 20 to old age. Above the timeline are four thought bubbles filled with technical terms and question marks, suggesting the man is overthinking or questioning his life path. The milestones include: go to college, meet soulmate in college, finish college, go to grad school, get married, pass quals, choose thesis topic, defend thesis, write thesis, land academic dream job, buy house, publish book(s), get tenure, have kids, win prestigious career award, and live happily ever after.

**LIFE PLAN**

Age	Milestone
age 20	go to college
age 20	meet soulmate in college
age 22	finish college
age 22	go to grad school
age 24	get married
age 24	pass quals
age 24	choose thesis topic
age 26	defend thesis
age 26	write thesis
age 28	land academic dream job
age 28	buy house
age 30	publish book(s)
age 32	get tenure
age 34	have kids
old age	win prestigious career award
old age	live happily ever after

Where and how do we insert CPS?

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## Some Key Elements for CPS Education



- Terminology
- Graduate vs. undergraduate students
- Topics of focus
- Learning materials
- Labs
- Placement
- Course examples @ Carnegie Mellon

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## Some Questions to be Addressed

- Appropriate for **undergraduates**?
  - For seniors, juniors or earlier?
  - Or seminar courses for grads?
- **Core** courses? Or which **prerequisites**?
- **Co-teaching** or Sole instructor?
- **Academic time constants** for introducing new courses
  - What about CPS-centric curricula?
- **Textbooks**?



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## Terminology

- “CPS” is a term **recognized** by many faculty and graduate students at CMU Engg. College
- CPS is a term **not yet recognized** by undergraduate engg. students
- How about the **world at large**?
- What is **assumed** in a CPS course?
- What will be **taught**?



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## Graduate Courses

- Cover **breadth and a lot of depth**
- Tension between **cutting-edge research** and **established principles**
- Need a **set of textbooks** to choose from
  - Which engineering departments?
  - Computer science cross-pollinated with whom?
- Projects
  - **Group projects vs individual projects**
- **Papers, discussions and guest lectures**



PLEASE DO  
NOT FEED THE  
SENIOR  
GRADUATE  
STUDENT

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## Undergraduate Courses

- Need **standard text**
  - Lots of **exercises**
  - Powerpoint **slides**
  - Instructor **guides**
  - Possibly **voluminous**
- Need **long-term commitment** from faculty and parent department(s)



FOR UNDERGRADUATE  
STUDENTS

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## CPS Course Topics

- Embedded systems
- **Wireless sensor networks**
- Real-time systems
- **Energy grids**
- Safety
- **Security**
- Subjects:
  - Formal methods
  - **Fault-tree analysis**



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## CPS Project Topics

- Agriculture
- **Manufacturing**
- Transportation (Parking)
- **Health and activity monitoring**
  - Coupled with social networks
- Energy management
- **Infrastructure and environmental monitoring**
- Controls
- Common **system infrastructure** across domains and apps



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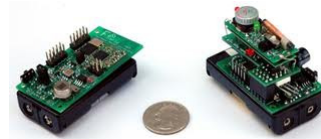
## CPS: An Embedded RT Variant

- **Embedded** concepts:
  - I/O and microcomputers
  - Hardware interrupts, timers, soft interrupts
  - OS notions of tasks and context switching
  - Real-time scheduling policies and analysis
  - Power management
- **Application-level** concepts:
  - Feedback control theory (P/I/D controllers)
  - Signal processing (sampling, Nyquist, noise, filters, ...)
  - Sensor fusion (multiple sensors, ...)
- **Glamorous** projects:
  - Android smartphones
  - Android tablets
  - iCreate robots?



# CPS Course: A WSN Variant

- **Wireless Sensor Network Layering**
  - Sensors and principles
  - Actuators and principles
  - Complete network stack
  - Wireless medium characteristics
  - OS issues
  - Localization
  - Distributed database issues
- Multiple **WSN nodes** per group
- Freedom and **flexibility** to buy sensors and actuators
- **Monitoring and control of physical environments**



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# Smartphone Add-Ons



## Optical Add-Ons



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## More Add-Ons



Blood sugar meter



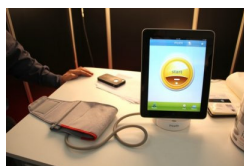
Heart rate belt



Pedal meter



Sleep meter



Blood pressure monitor



Personal Genome Sequencer CarnegieMellon

## Even More Add-ons



FM localcast for car



Video game arcade



Video console



Remote control



Mobile piano



Wall projector



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## Android

- Open source
- Cheap (“free”)
- OS extensions for adding new capabilities



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## Exit One's Comfort Zone

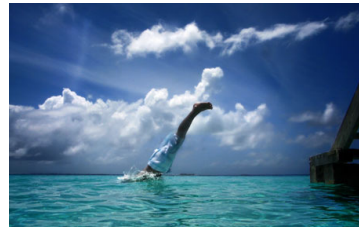
- ECE and CS departments may have faculty working on
  - Controls
  - Energy
  - Embedded Systems
  - Software Systems
  - Hardware
  - Theory
  - AI
  - Formal Methods
  - Languages
  - Security
  - ...



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## Really Leave the Comfort Zone...

- How about topics in
  - Structures
    - Buildings
    - Bridges
    - Transportation infrastructure
  - Materials
    - Sensors
  - Chemicals, Energy
    - Batteries



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## ... and keep going



### – Manufacturing

- CNC → CPS, Networks, Wireless, Coordinated
- Not “subtractive” fabs → “Additive” fabs

### – Bio-medical systems

- Computer-assisted surgery
- Nano-bio materials

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## Talking to Civil Engineers

- Recently, gave invited lecture to junior and senior Civil engineering students
- ... at a neighboring university
- Students knew very little about software and essentially nothing about networks
- Topic was Vehicular Networks and how they will affect traffic and traffic engineering!

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## Motivate!

- Which appealing **applications that students can relate to** can motivate CPS principles and concepts?



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## Experimentation



- What lab **equipment and facilities** can be used?
- Can we have some **prototypical labs** that institutions can reuse?
- Can we have **“virtual” labs for CPS** experimentation?
  - Even 3-D options may be possible

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## Placement

- How to **showcase CPS courses** as being attractive to employers?
  - Many students, particularly at the M.S. level, will go where the employers are
- A **clearinghouse for employers and potential CPS grads?**



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## Roles of Federal Agencies

- How can federal agencies **stimulate the creation of courses and textbooks?**
- How can **practitioners** be exposed to these courses and teaching/training materials?
- Can **labs be seeded?**
- Can **(remote) testbeds** be made accessible to grad students?



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## The Challenge



- Information and communication technologies permeating every aspect of life
- Every engineer ought to know how to use computers and perhaps what writing software is about (at some level of abstraction)
- Every programmer ought to know how and where *physical constraints* play a role
- A **CPS major that spans engineering disciplines**
  - The CPS version of Harvey Mudd's General Engineering Degree

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