A 21st–Century Cyber–Physical Systems Education

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National Academy Study

- 3 years
- Industry and Academia
- 100 page report
- 21st Century CPS Education is critical
Observations:

- Emerging discipline with significant economic and societal implications

- Expansion of CPS will increase going forward

- Growing need for a workforce
  - Defense
  - Transportation, health, energy, agriculture, IT, ...
  - Subsuming IoT, Smart cities, ...
Observations:

- Cyber is central to all engineering disciplines
  - Must be treated on the same level as physical science and principles
  - Just taking 1–2 software classes is NOT sufficient

- Computer science must address the fact that more and more computing is tied to the physical

- CPS is breaking down barriers to stovepiped engineering disciplines
Core Knowledge

- Understand the basics of physical engineering and cyber design, but emphasize how these influence and impact each other

- Cannot just collect current courses
e.g., feedback control and cyber, including machine learning interactions not taught
CPS Education must:

- **Foundational Knowledge**: computing for the physical world; modeling heterogeneous systems, ...

- **System characteristics**: deep knowledge of the essential characteristics such as security, dependability, safety, ...

- **System integration**: effectively combine cyber and physical without undervaluing either
## Link Lab Approach

<table>
<thead>
<tr>
<th>Normalization Modules</th>
<th>In-Depth CPS Electives</th>
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<tbody>
<tr>
<td>• Embedded systems programming (Alemzadeh and Lach)</td>
<td>• Smart and connected health</td>
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<tr>
<td>• Formal methods and safety (Fleming and Feng)</td>
<td>• Smart and connected communities</td>
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<tr>
<td>• Signal processing and machine learning (Alemzadeh and Tian)</td>
<td>• Autonomous systems, robotics and drones</td>
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<td>• Feedback control (Stankovic and Lin)</td>
<td>• Internet of Things</td>
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<td>• Sensor networks and wireless (Stankovic and Lach)</td>
<td>• Smart fluidic systems</td>
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<tr>
<td>• Cyber-physical security (Bezzo and Tian)</td>
<td>• Smart infrastructure</td>
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<td>• Statics and dynamics (Quinn and Fleming)</td>
<td>• Optimization and uncertainty</td>
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<td>• Human-CPS interactions (Feng and Goodall)</td>
<td>• Dependability and risk</td>
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<td>• Infrastructure and the built environment (Goodall and Quinn)</td>
<td>• Model based design</td>
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<td>• Mobile computing</td>
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<td>• Real-time systems</td>
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<td>• Seminars on special topics</td>
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## Masters Program

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<tr>
<th>Semester 1</th>
<th>Semester 2</th>
<th>Semester 3</th>
<th>Semester 4 +</th>
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| • Bootcamp sessions  
  • 4 normalization modules (2 courses)  
  • Departmental course  
  • In-depth elective | • Bootcamp sessions  
  • 2 normalization modules (1 course)  
  • Departmental course  
  • In-depth elective | • 3 in-depth electives |  |

## PhD Program

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  • In-depth elective | • Bootcamp sessions  
  • 2 normalization modules (1 course)  
  • Departmental course  
  • In-depth elective | • 3 in-depth electives | • Independent research  
  • In-depth electives as needed  
  • Professional development and communication training |
Industrial Affiliates

- Real problems and constraints
- Teamwork
- Hands-on projects
  - Testbeds
- Evolving skill set

- Deliverables
  - Trained workforce
  - Pushing the boundaries of research
  - Keeping your company “ahead”