

# NSF Cyber-Physical Systems Principal Investigators' Meeting

Arlington, VA | October 31 – November 1, 2016

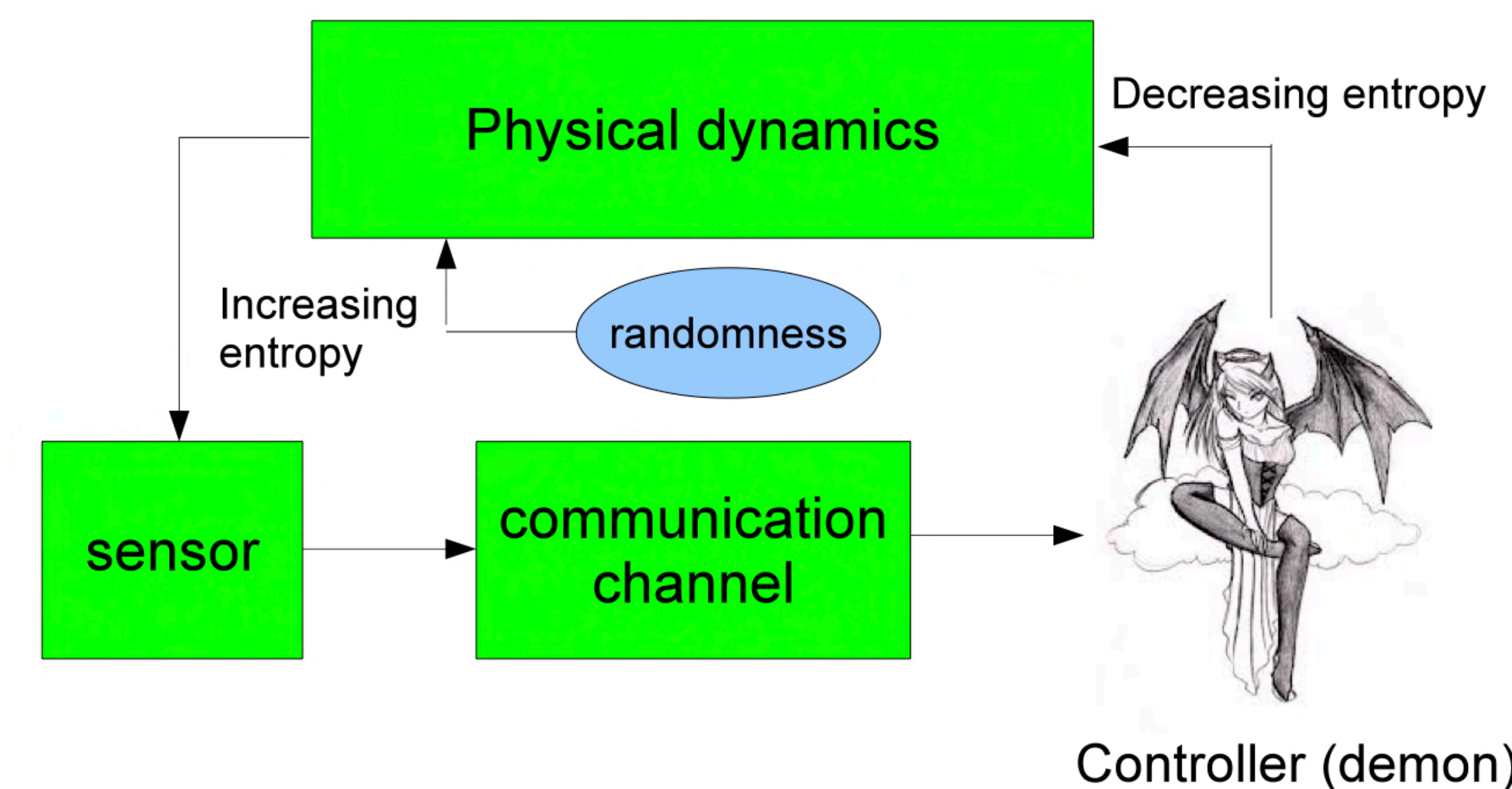
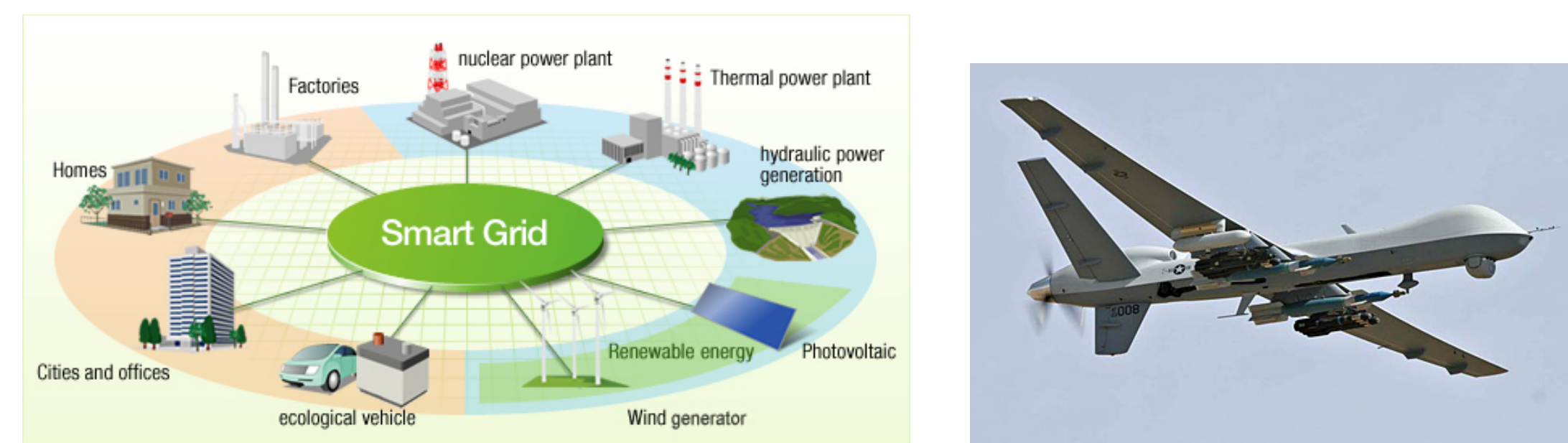
## NSF-1543830 CPS: Breakthrough: An Entropy Framework for Communications and Dynamics Interdependency in Cyber Physical Systems: Analysis, Design and Implementation (2015-2018)

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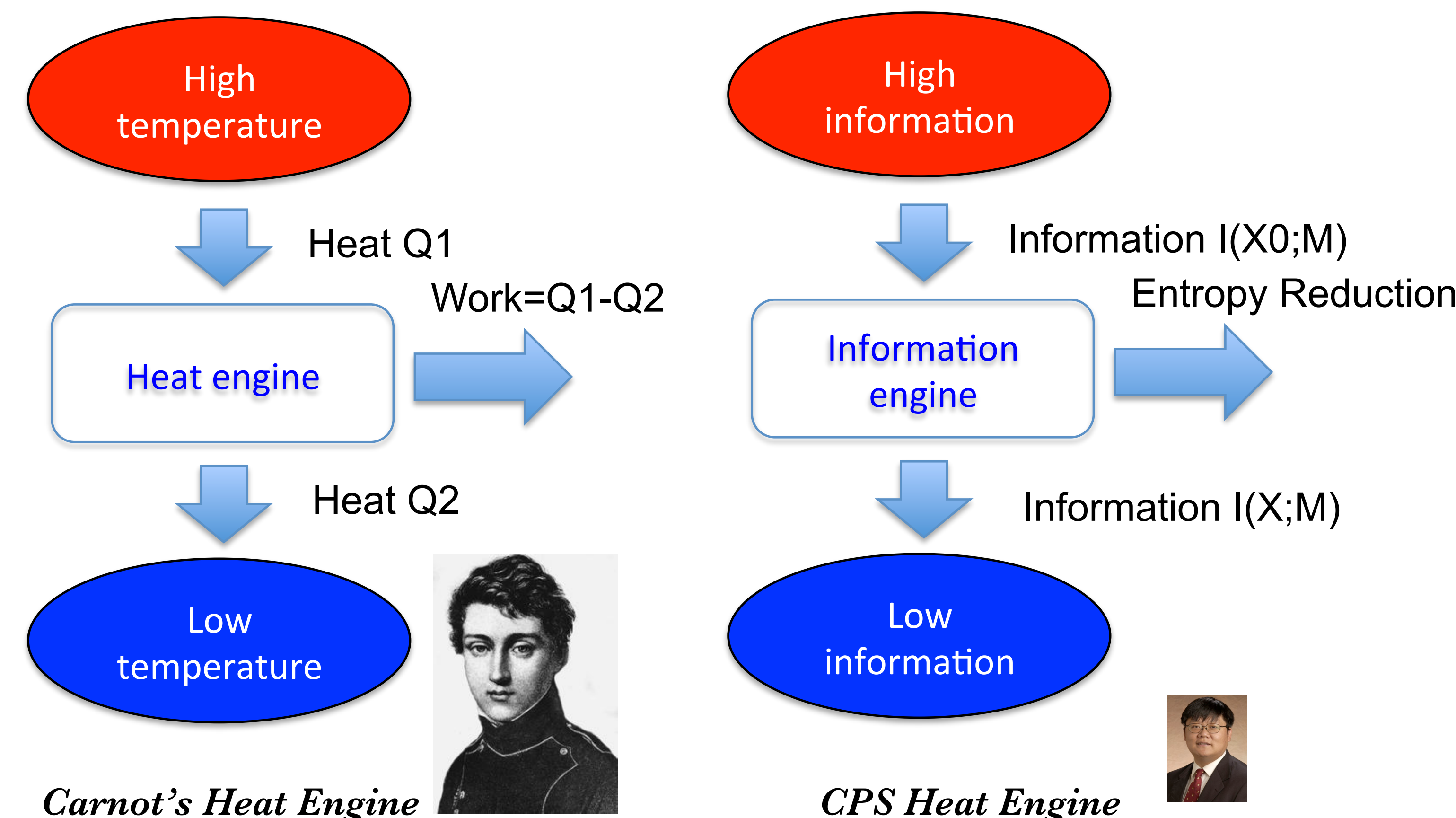
*The University of Tennessee*

### Challenge:

- Communications are needed for controlling physical dynamics in CPS.
- What is the communication requirement for the control?
- How to design the communication scheme?
- What if the physical dynamics is networked?



Entropy framework



Heat engine efficiency

Information engine efficiency (CDC'2016)

### Scientific Impact:

- The conclusion can be used to estimate the communication requirement for control systems in CPS, such as smart grids.
- It can be used to design the communication system, particularly the source coding, in CPS.
- The propagation of entropy and the information efficiency both bring new dimensions for physics.
- The mathematical framework also brings new challenges to math (say, a new partial differential equation never known before).



First order dynamics: Diffusion of entropy



Second order dynamics: Wave of entropy

$$\frac{\partial^4 u}{\partial t^4} - 2C \frac{\partial^2}{\partial t^2} \Delta u + C^2 \square u = 0,$$

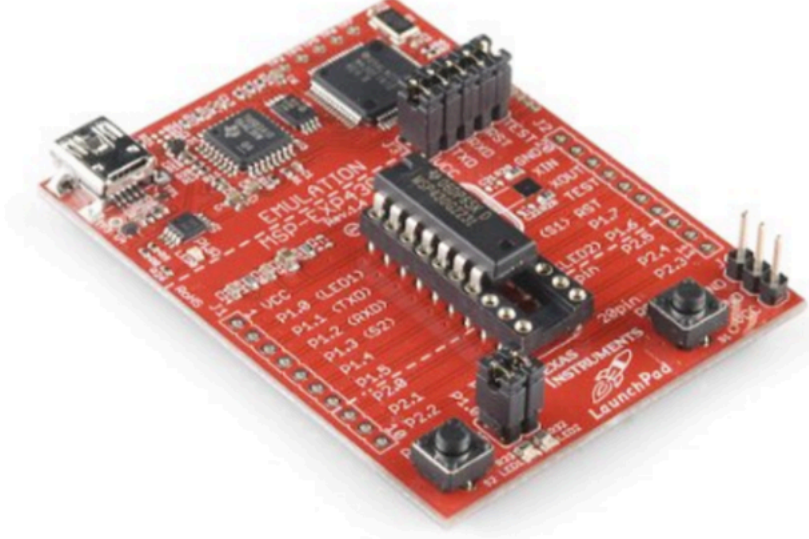
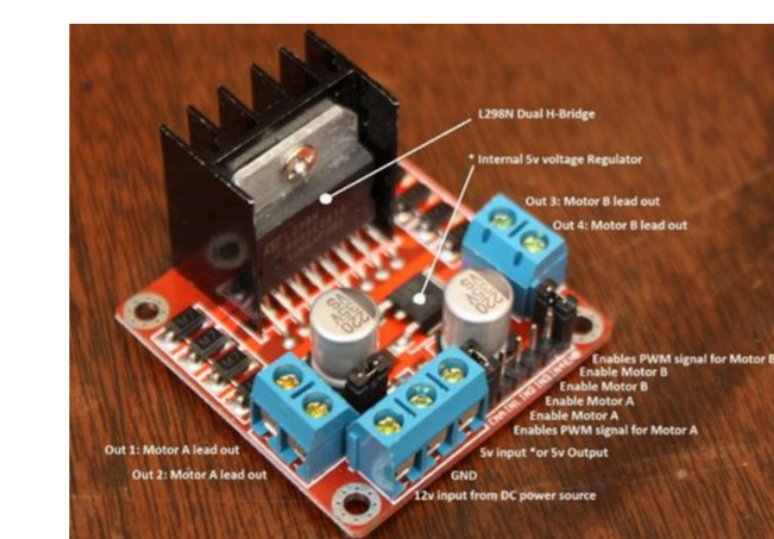
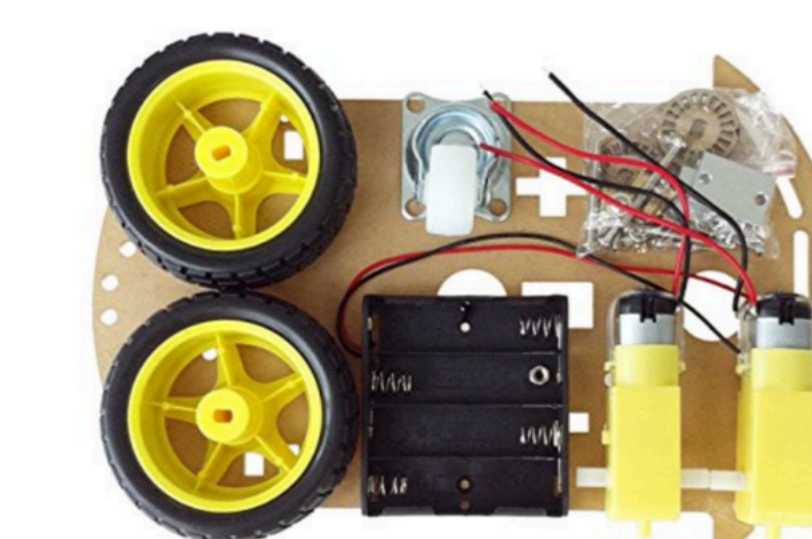
where  $\square = \left( \frac{\partial^2}{\partial x^2} - \frac{\partial^2}{\partial y^2} \right)^2$ .

### Solution:

- Entropy framework: We use entropy to measure the messiness of the physical dynamics. Communications can be considered as negative entropy to compensate the entropy increased caused by random noise (ISIT'2015).
- We also study the propagation of entropy.
- The novelty is the usage of entropy to bridge the communications and control.

### Broader Impact:

- The theoretical framework helps to better understand and quantify the communication requirement in CPS. Particularly, it enhances the design of communications in smart grids.
- Two PhD students are involved in the project.
- Three high school students are involved in the project, focusing on the implementation of controlling unmanned vehicles.



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