From Cooking to Advanced Manufacturing --Controls, Automation, and Beyond

Xu Chen

Department of Mechanical Engineering

University of Washington

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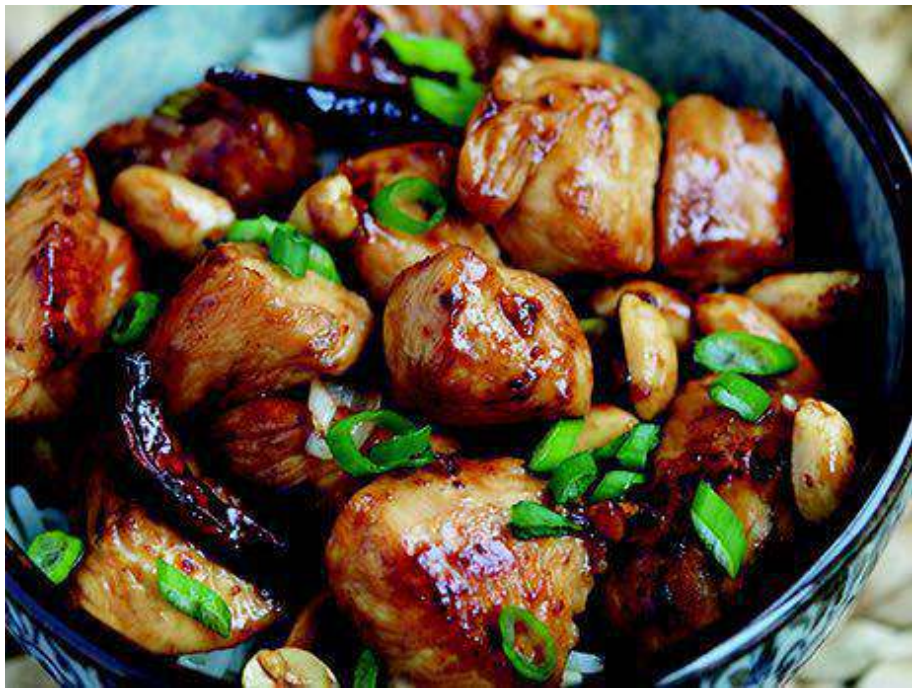
Ingredients of Kung Pao Chicken

Marinade

- 1 tablespoon soy sauce
- 2 teaspoons Chinese rice wine or dry sherry
- 1 1/2 teaspoons cornstarch
- 1 pound boneless, skinless, chicken breasts or thighs, cut into 1-inch cubes

Sauce

- 1 tablespoon Chinese black vinegar, or substitute good-quality balsamic vinegar
- 1 teaspoon soy sauce
- 1 teaspoon hoisin sauce
- 1 teaspoon sesame oil
- 2 teaspoons sugar
- 1 teaspoon cornstarch
- 1/2 teaspoon ground Sichuan pepper
- 2 tablespoons peanut or vegetable oil
- 8 to 10 dried red chilies
- 3 scallions, white and green parts separated, thinly sliced
- 2 garlic cloves, minced
- 1 teaspoon minced or grated fresh ginger
- 1/4 cup unsalted dry-roasted peanuts



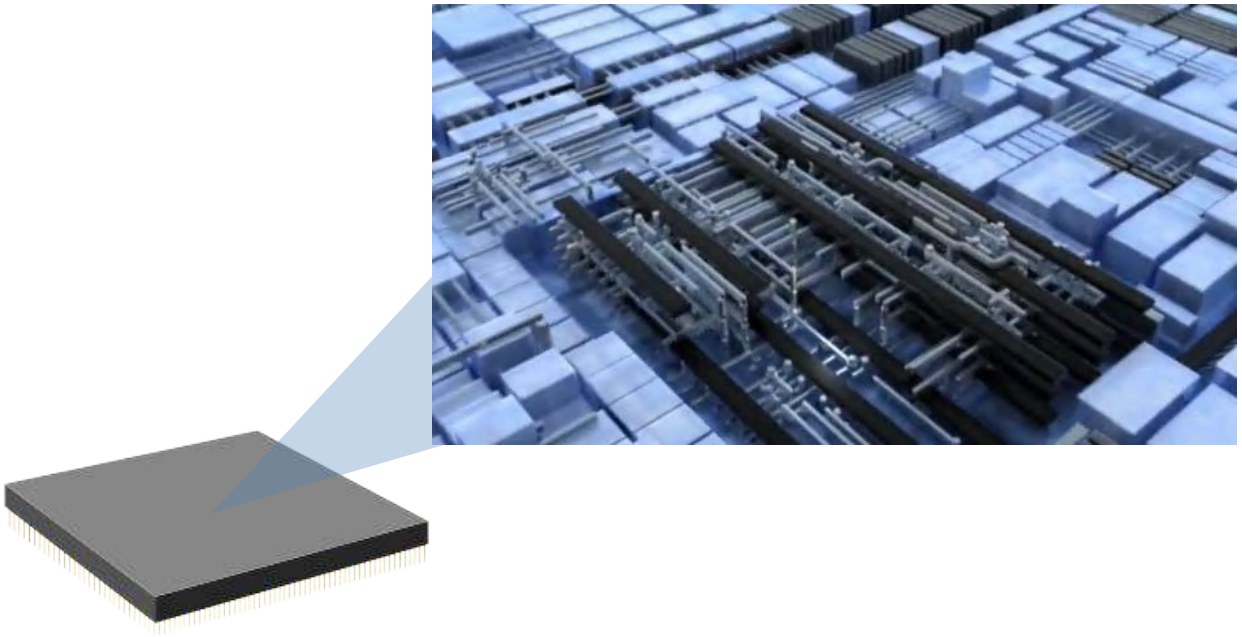
Courtesy of Diana Kuan

The Cooking Procedure

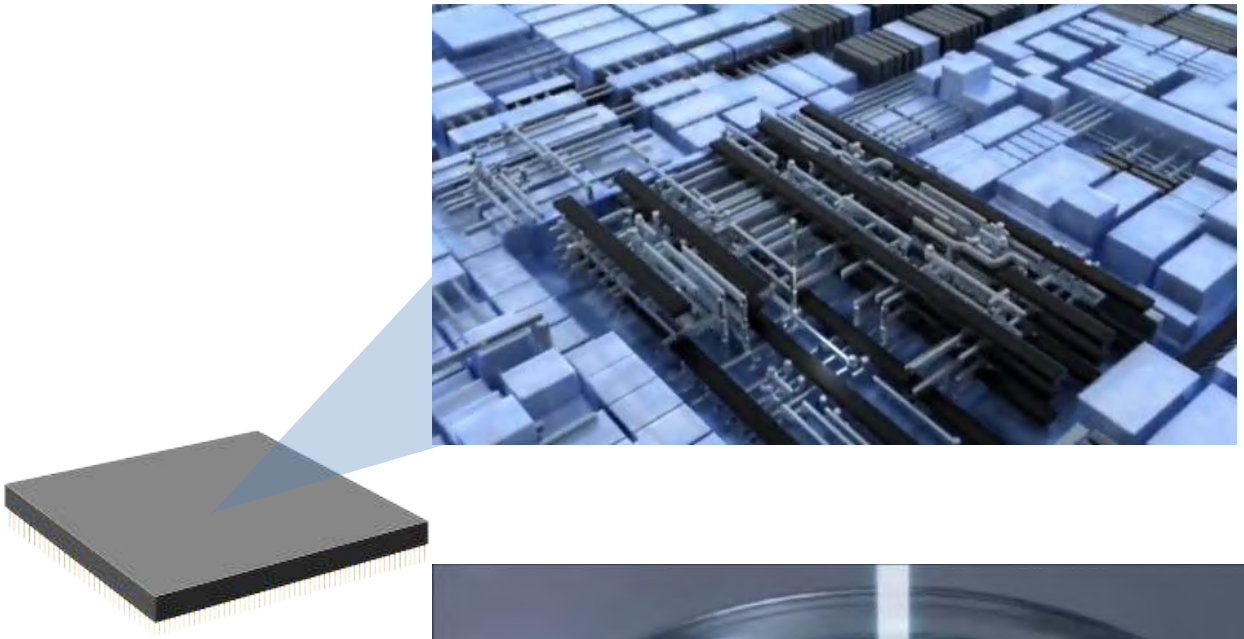
The Difference of Controls

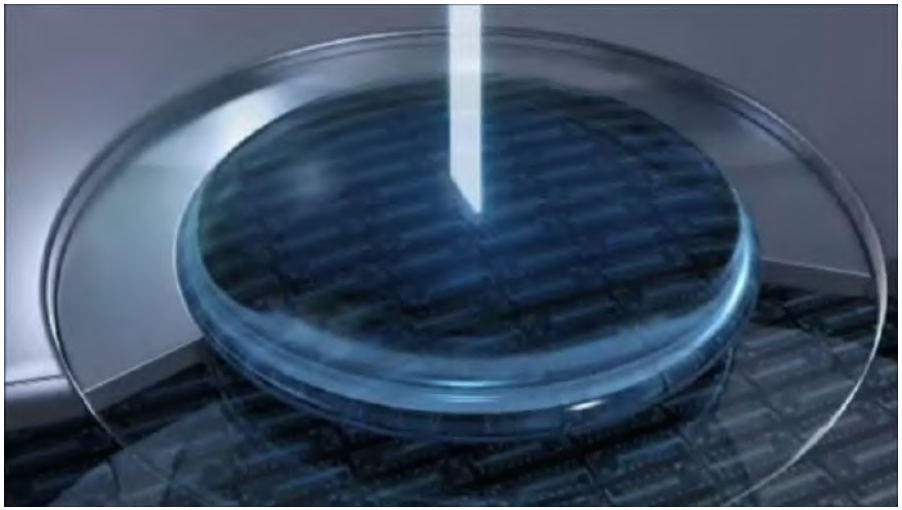
Courtesy of Diana Kuan

Semiconductor Manufacturing

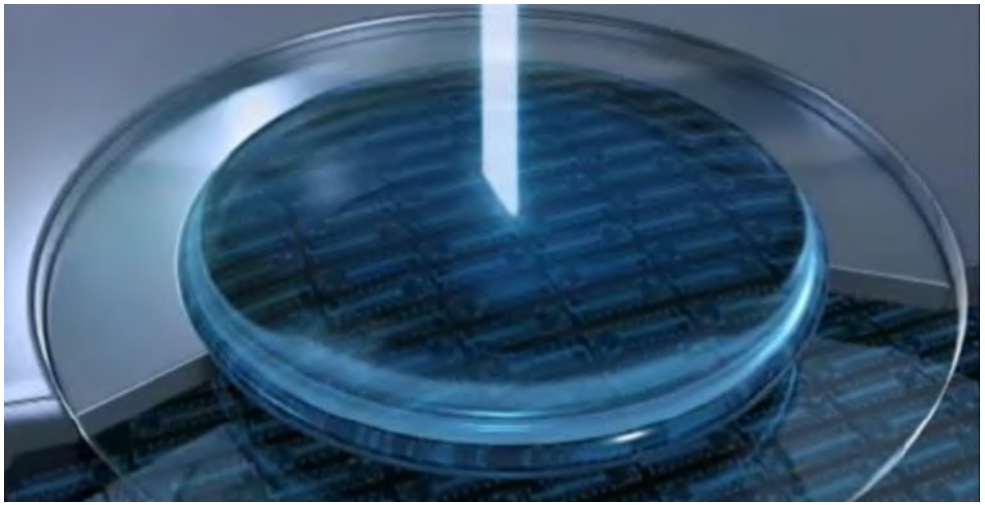


Semiconductor Manufacturing

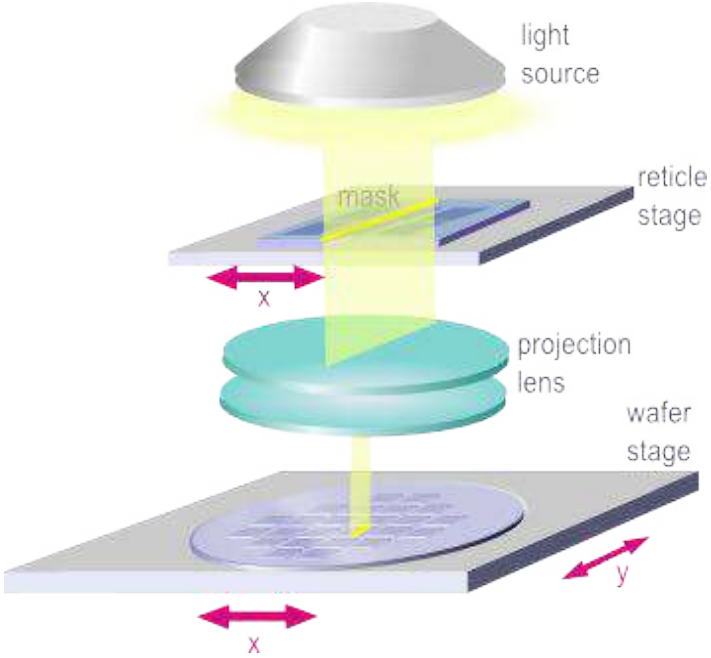




The Required Precision



Photolithography



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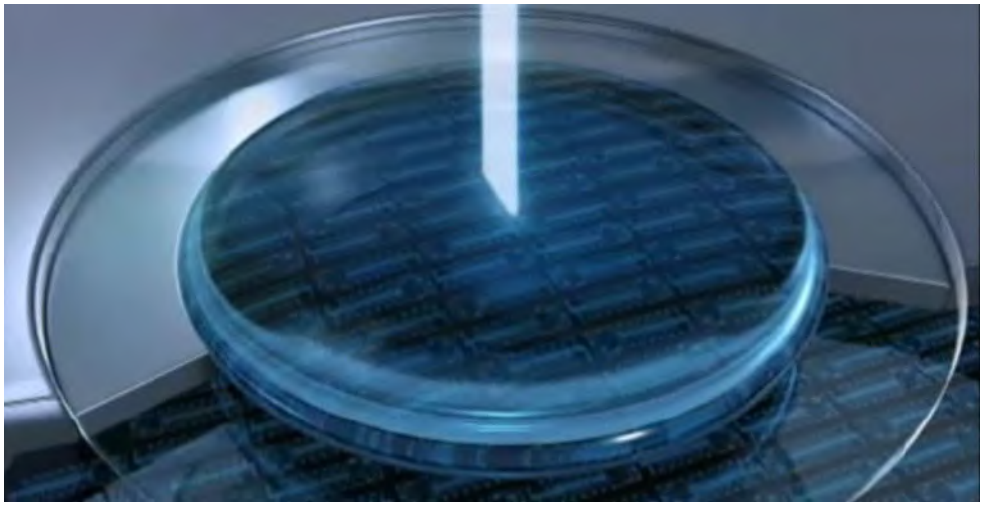

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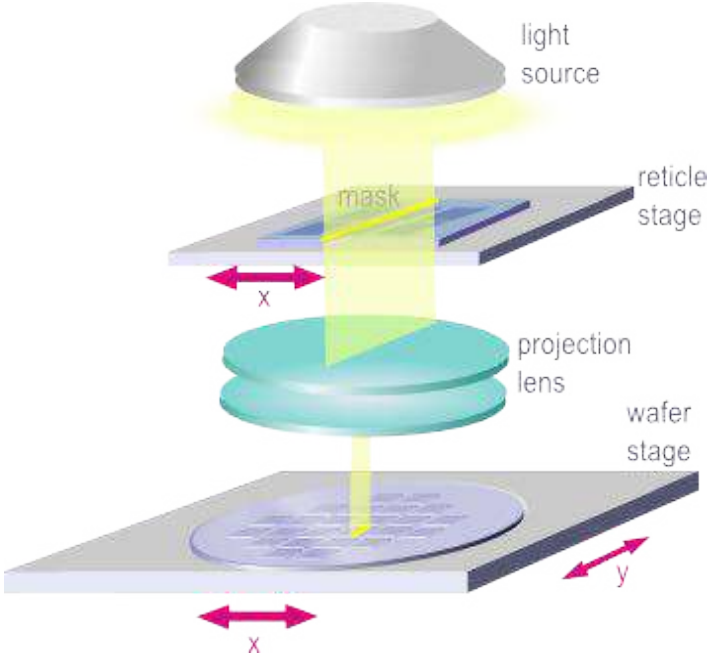
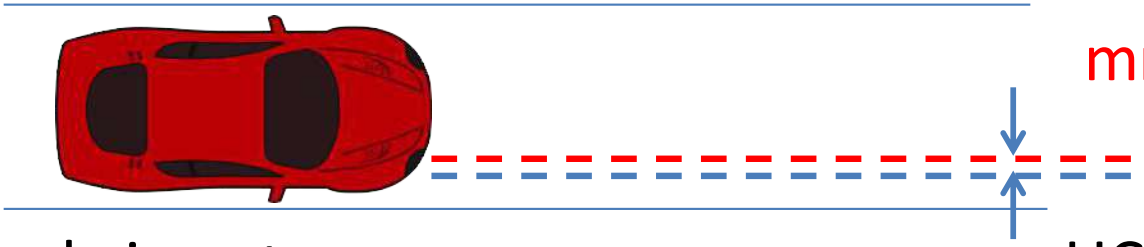


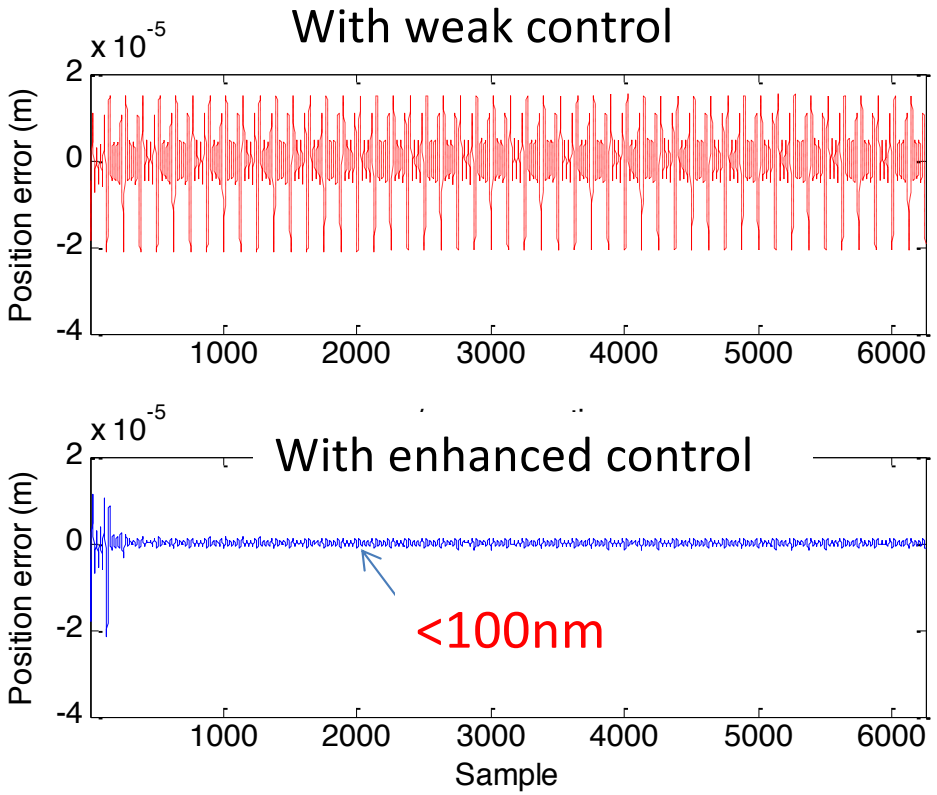


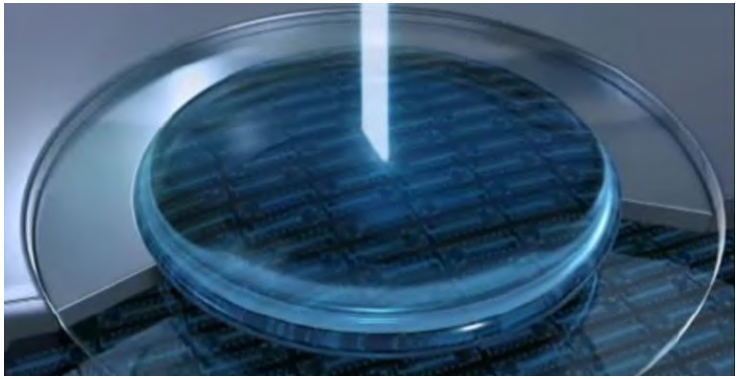
mm-scale error tolerance

Hartford airport

UCONN

The Role of Automation and Controls

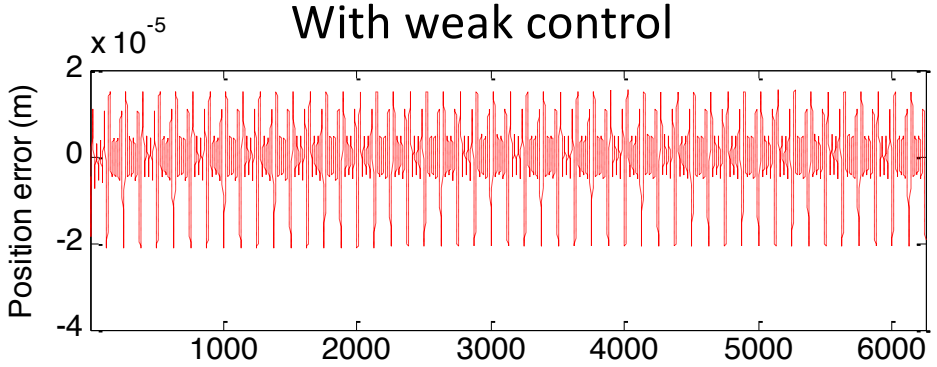


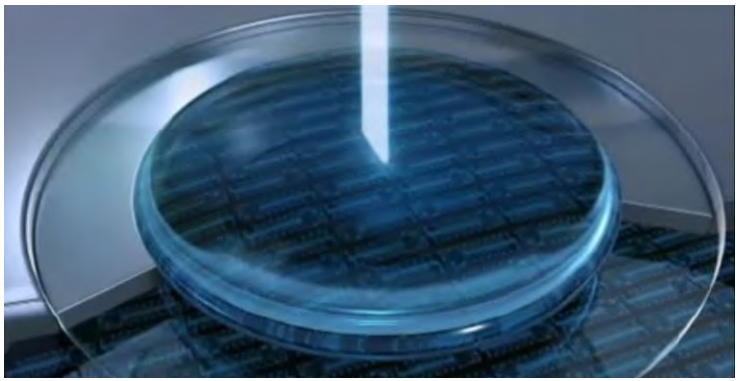


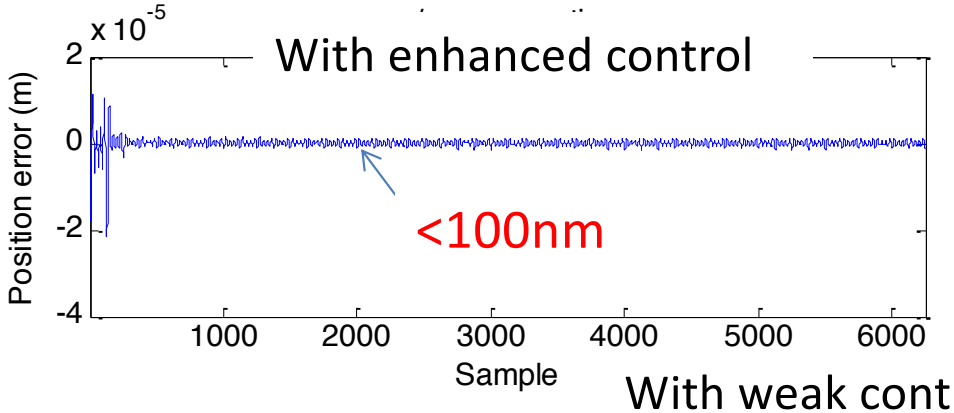
X. Chen and M. Tomizuka, "Control Methodologies for Precision Positioning Systems," in Proceedings of 2013 American Control Conference, Washington, DC, Jun. 17-19, 2013, pp. 3710-3717.

The Role of Automation and Controls

With weak control

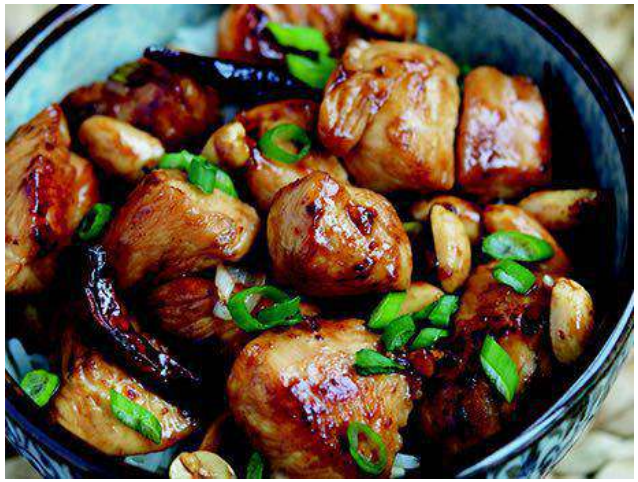






With good control

With weak control



Control Engineering

Control engineering or control systems engineering is the engineering discipline that applies control theory to design systems with desired behaviors.

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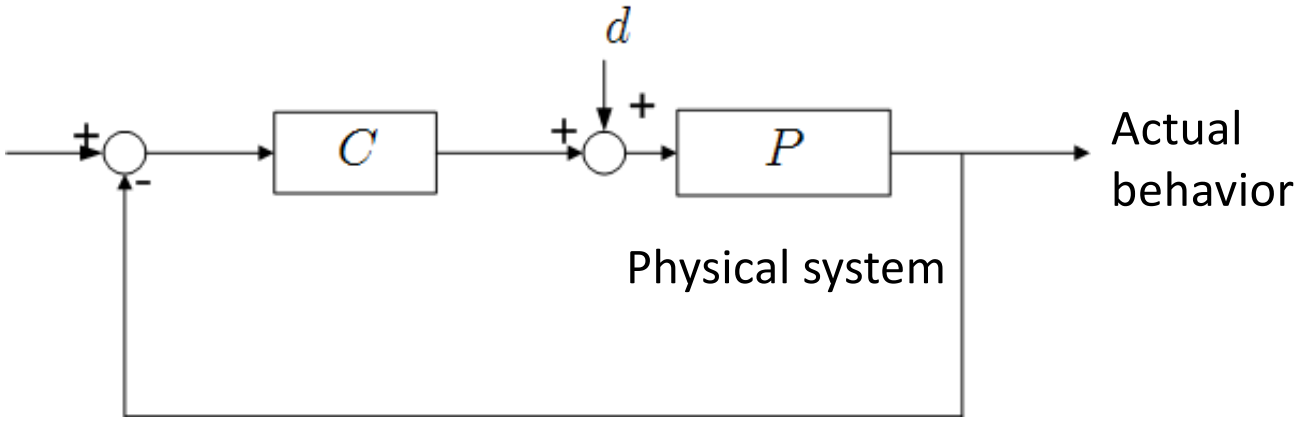

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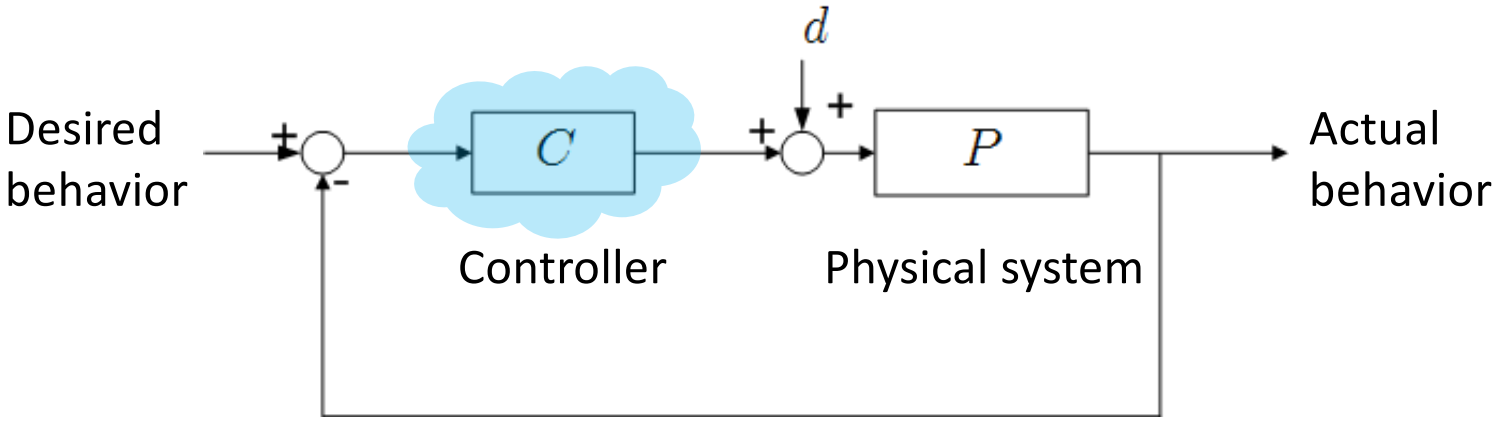

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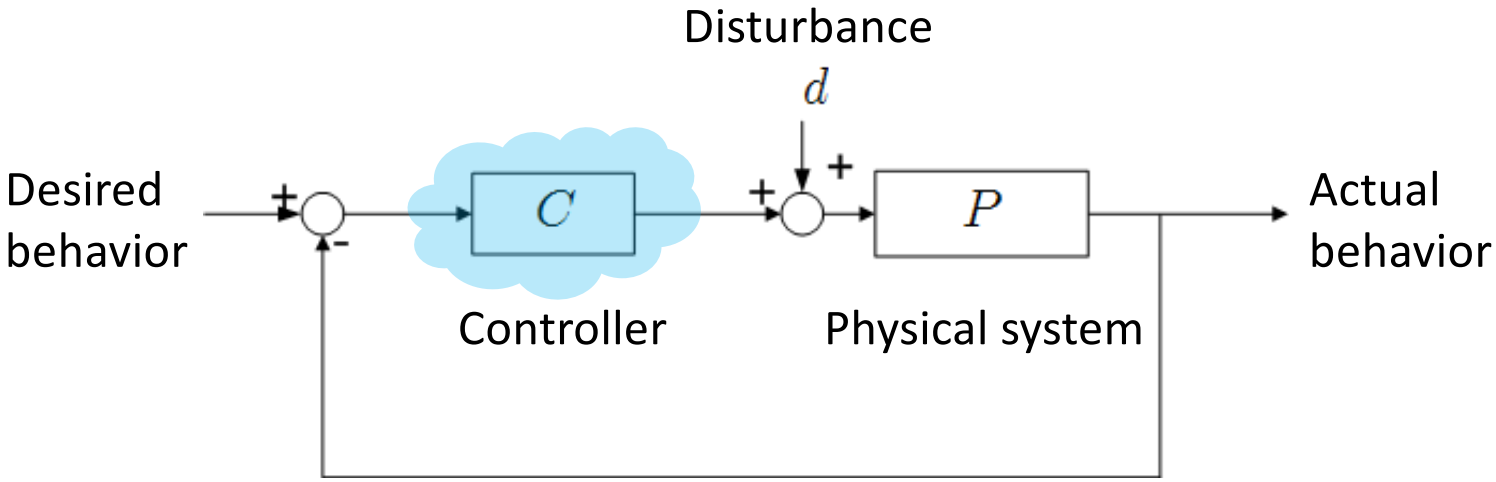

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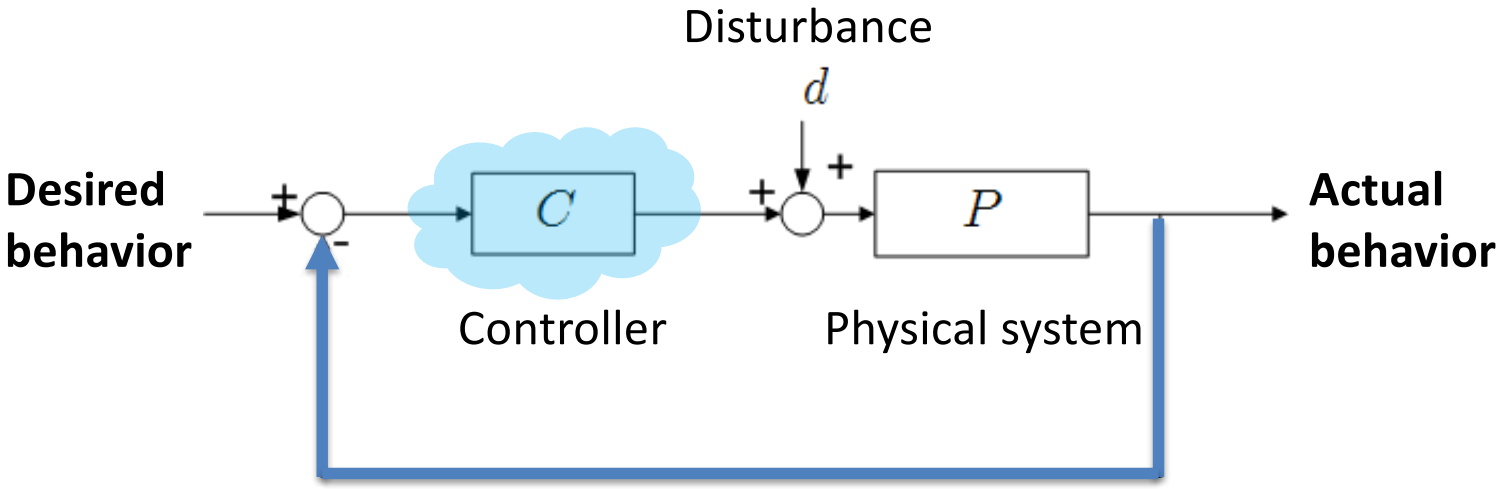
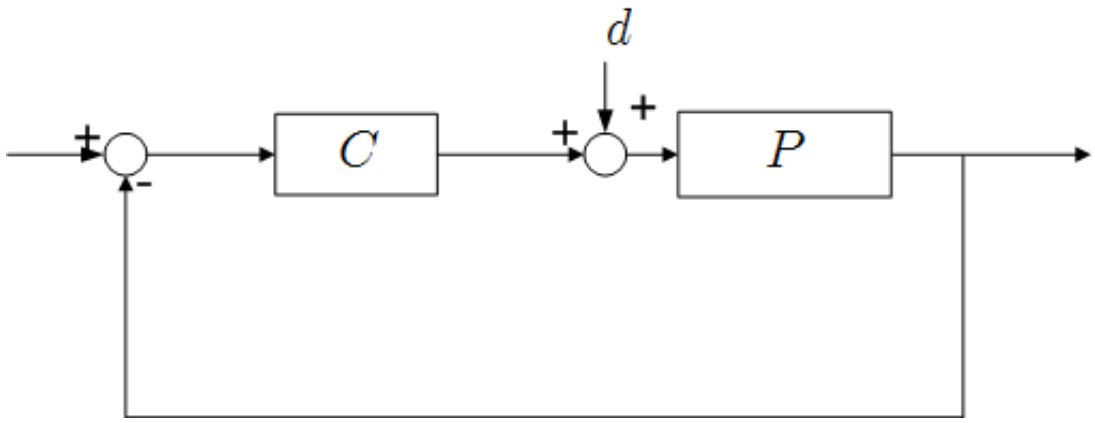


Why Automatic Control?



- **Stability/Safety**
  - Difficult/impossible for humans to control the process or would expose humans to risk
- **Performance**
  - Cannot be done "as well" by humans
- **Cost**
  - Humans are more expensive and bored

Example of Control Systems: HDDs

Example of Control Systems: HDDs

Sub-10nm position-error tolerance

Example of Control Systems: HDDs

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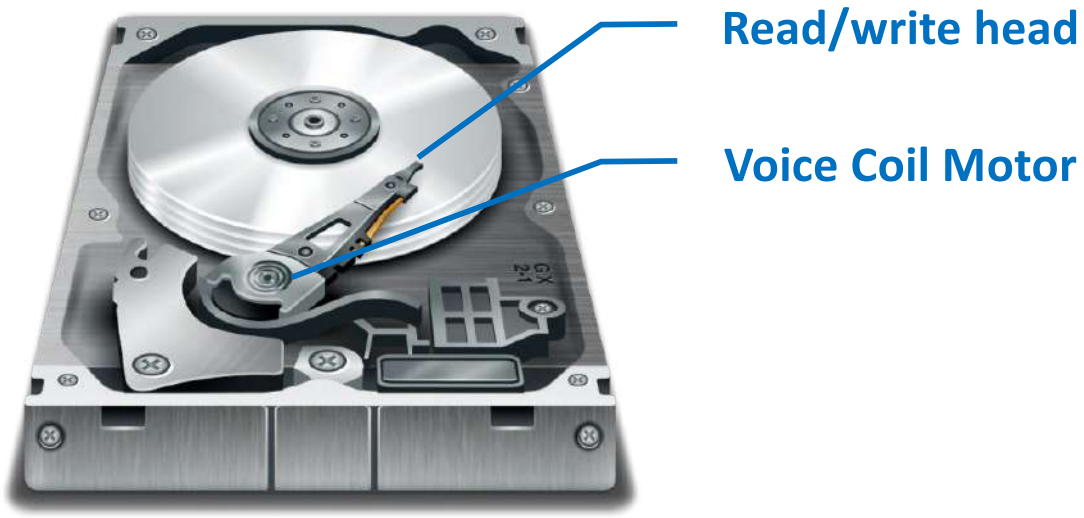
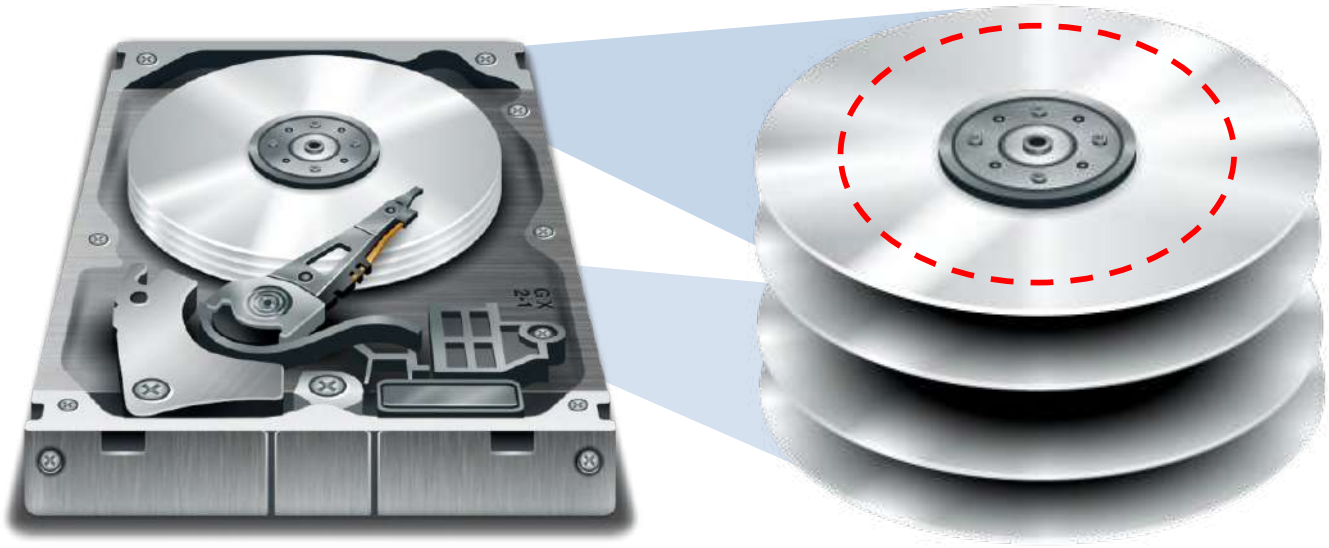
Example of Control Systems: HDDs



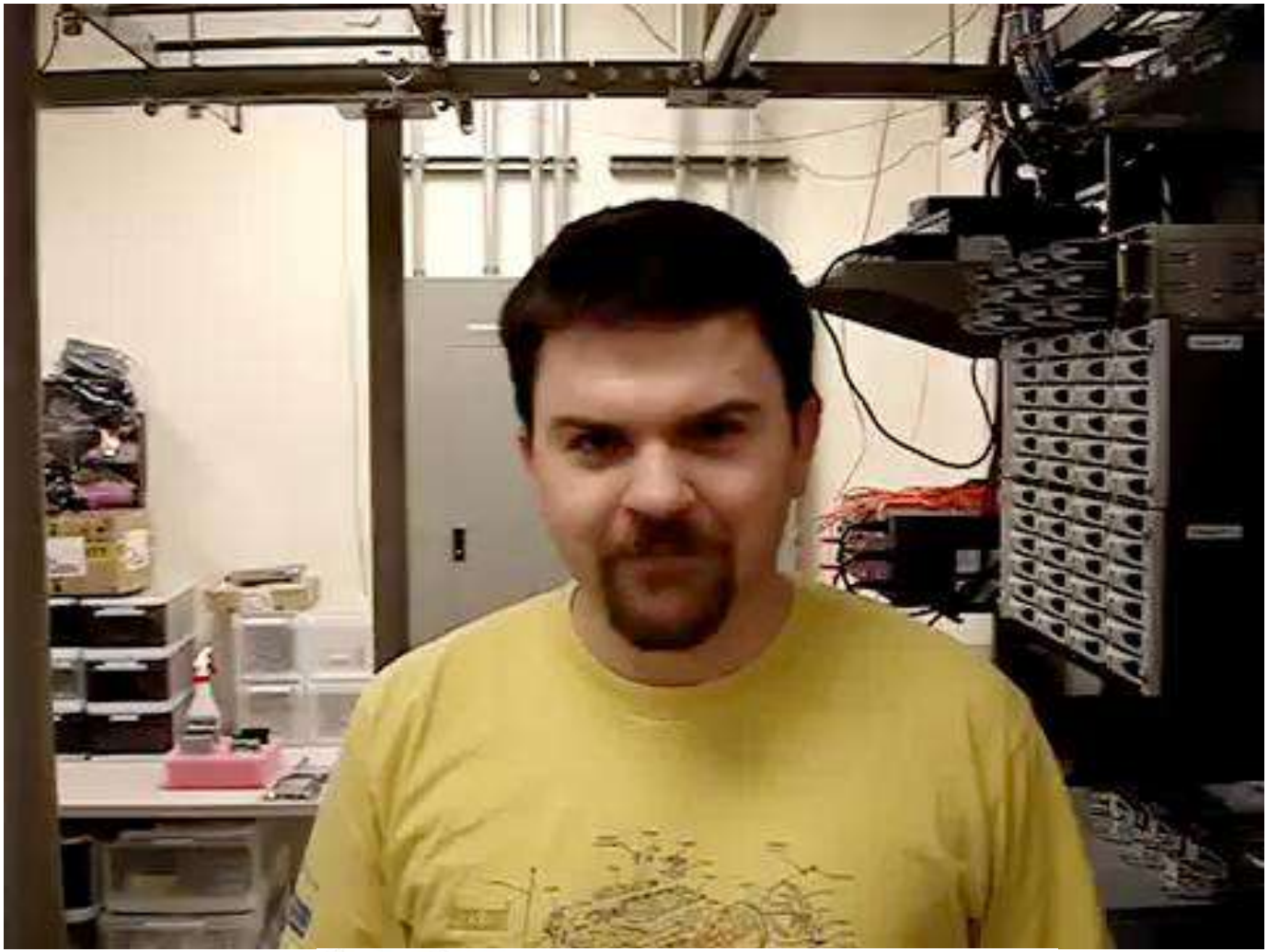
Example of Control Systems: HDDs



>900,000 tracks per inch (in a 2012 HDD)

~ ten thousand tracks on a human hair!

Importance of Control Systems in HDD



Shouting in the Datacenter

1,518,607 views DOWNLOAD 7K 97 SHARE

Bryan Cantrill
Published on Dec 31, 2008

SUBSCRIBE 945

Brendan Gregg from Sun's Fishworks team makes an interesting discovery about inducing disk latency. For more details, see Brendan's blog entry:
http://blogs.sun.com/brendan/entry/un...

Importance of Control Systems in HDD

A Loud Sound Just Shut Down a Bank's Data Center for 10 Hours

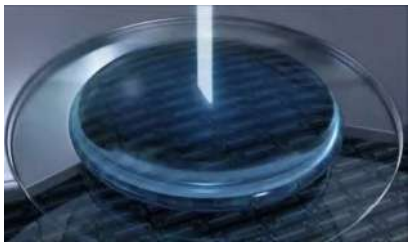
Dozens of hard drives were knocked down during a fire drill that involved inert gas deployment.

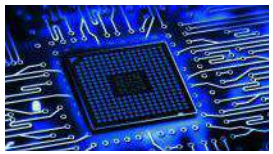
SHARE TWEET

Andrada Fiscutean
Sep 11 2016, 2:00pm

Image: Jeff Kubina/Flickr.

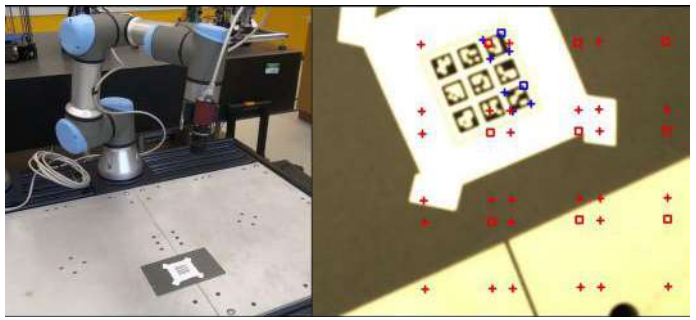
Recap and Outline



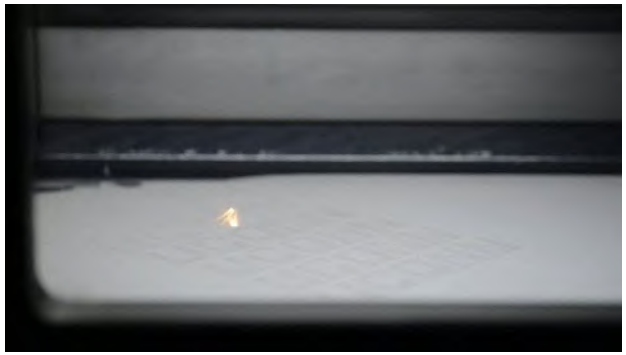


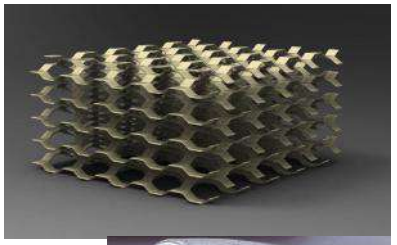
Semiconductor manufacturing

Information storage



Manufacturing inspection & automation





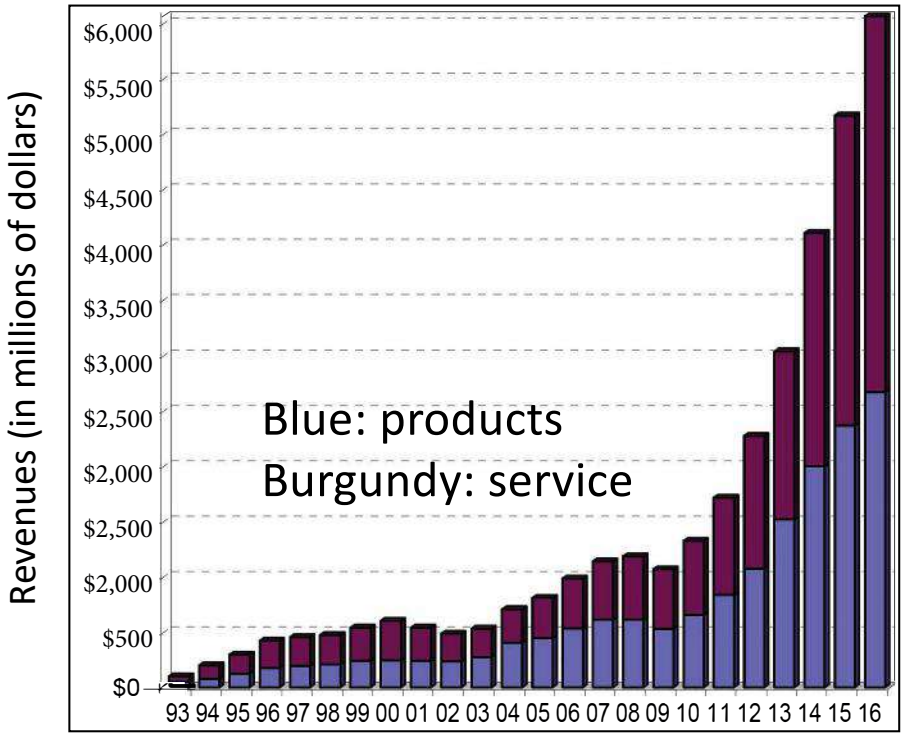
GE fuel nozzle

Additive manufacturing (3D printing)

Control engineering or control systems engineering is the engineering discipline that applies control theory to design systems with desired behaviors.

Examples of Control Systems: 3D Printing

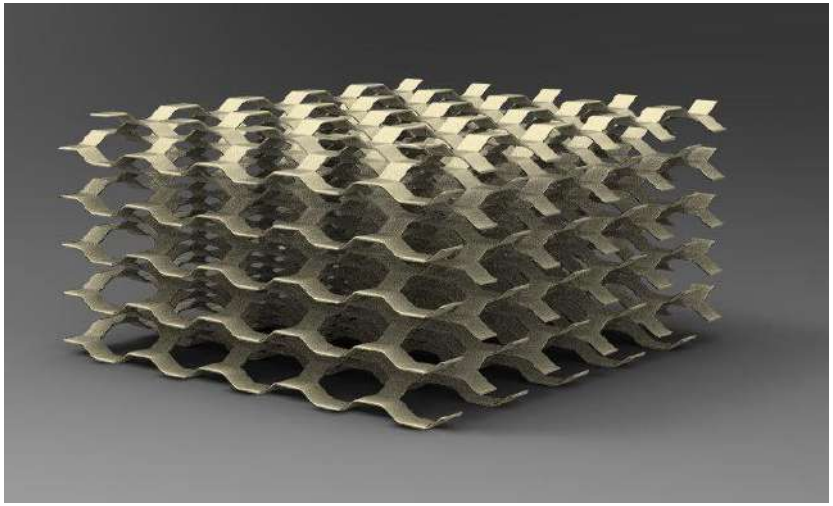
- Additive manufacturing (AM) / 3D Printing
  - Annual market recently topped $6 billion
  - Increased nearly 6-fold over the past 7 years

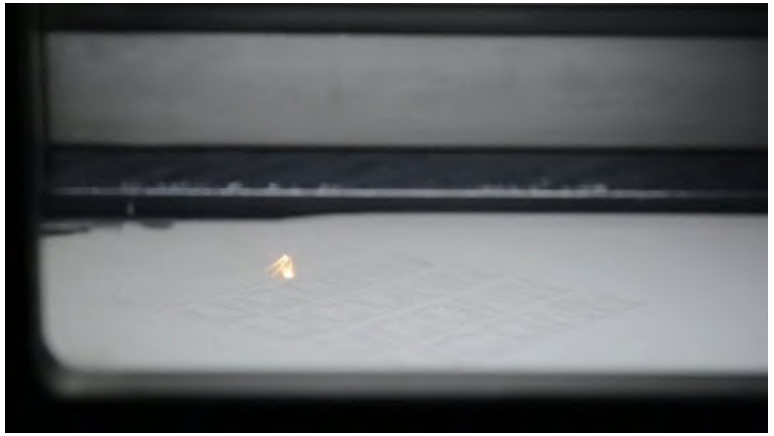


Source: Wohlers Associates, Inc.

40%: Powder bed processes

Background: Powder Bed Fusion (PBF)



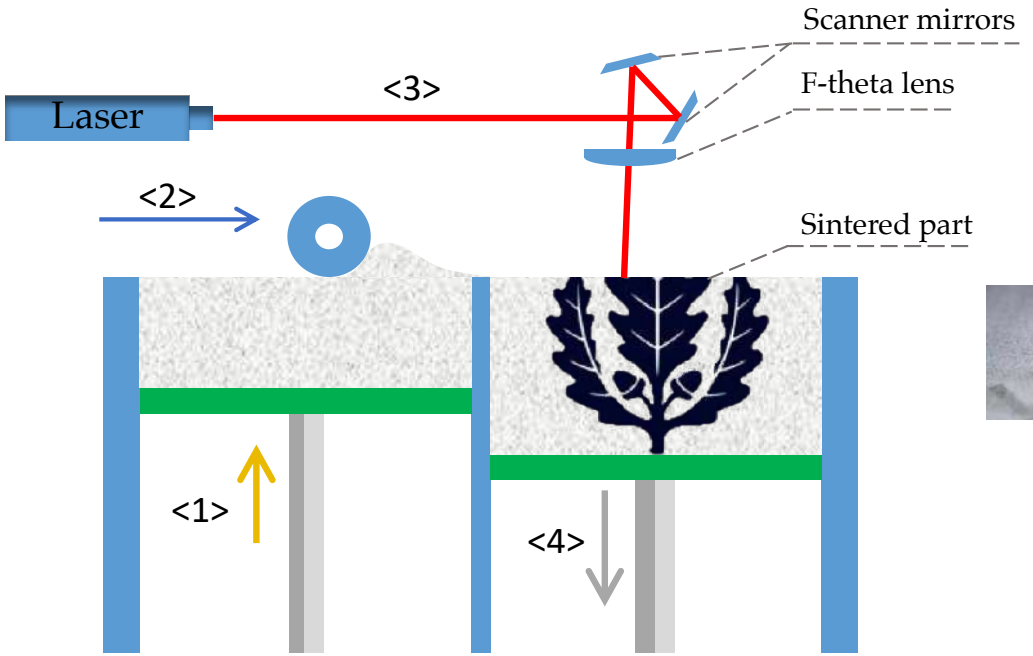


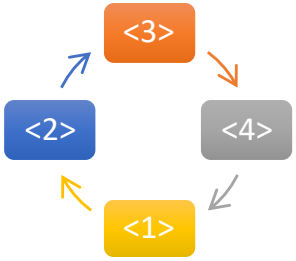
Source: UConn

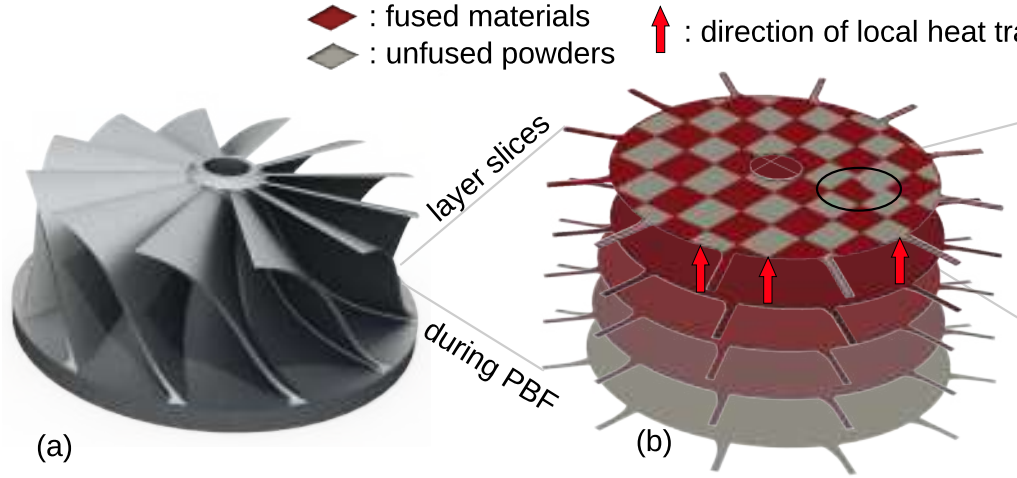
- ***Versatile***: works with a broad range of materials
- ***Effective***: high achievable shape complexity and accuracy
- ***Functional***: expanding applications from engine components to medical implants

The Control Problem to Meet the Quality Demand

Selective laser sintering/melting:







solid line: fused tracks.
dashed line: pending tracks to scan.

(a) part with complex geometries
(b) cross-layer thermodynamics
(c) in-layer precision energy deposition & thermointeractions (example: "island" raster scan)

Challenges in Sensing, Controls, and Platforms

REPORT TO THE PRESIDENT

ACCELERATING U.S. ADVANCED MANUFACTURING

Executive Office of the President

President's Council of Advisors on Science and Technology

October 2014

ANNEX 1

TRANSFORMATIVE MANUFACTURING TECHNOLOGY:

Manufacturing Technology Area 1 -

Advanced Sensing, Control, and Platforms for Manufacturing

Overview

"One of these high-priority MTAs is the broad area of **Advanced Sensing, Control, and Platforms for Manufacturing (ASCPM)**."

"Without a leadership position in these technologies the U.S. will run the risk of missing this next wave of manufacturing innovation."

Challenges in Sensing, Controls, and Platforms

Important Technology and Measurement Challenges for AM:

"*Process control:* Feedback control systems and metrics are needed to improve the precision and reliability of the manufacturing process and to increase throughput while maintaining consistent quality."

NIST National Institute of Standards and Technology U.S. Department of Commerce

Measurement Science Roadmap for Metal-Based Additive Manufacturing, 2013

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Additive Manufacturing: Pursuing the Promise

$7.5M UCONN-P&W Additive Manufacturing Innovation Center

Arcam A2X

LECO ONH 836, CS 744 for impurity analysis.
Camsizer XT for powder particle size analysis

3DSystems ProX300

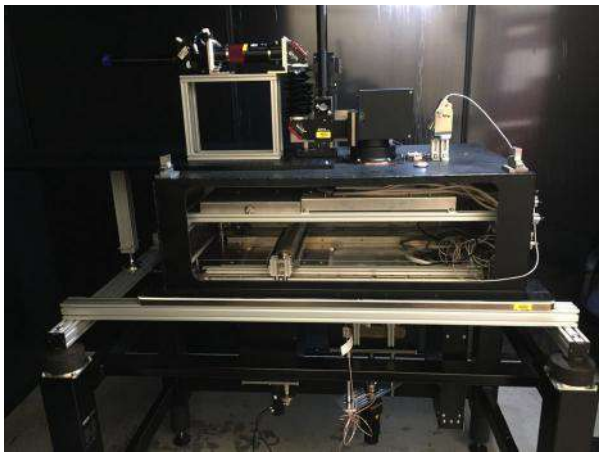
From alloy development to machine control and property analysis

EOS M270 (P&W owned)

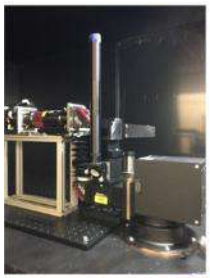
Anton-Paar rheometer

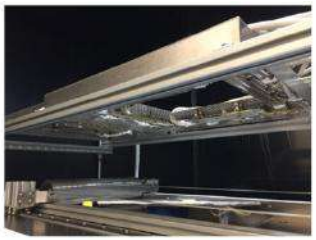
Gleeble 3500

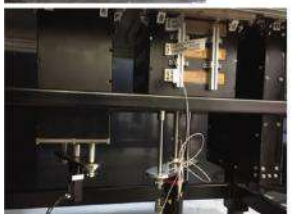
Selected UConn Research Facilities (X. Chen)

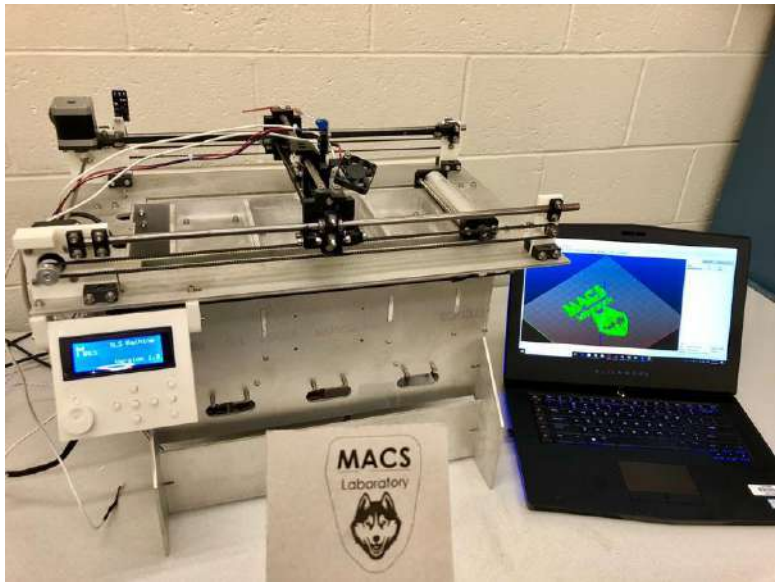


- 100W laser
- 270x270x270mm^3 build volume
- Multi-zone heated chamber and bed
- High-precision laser galvoscanner
- Coaxial sensing and multi-sensory control





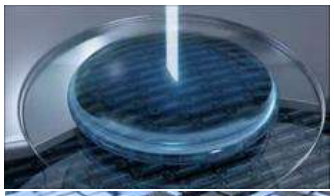


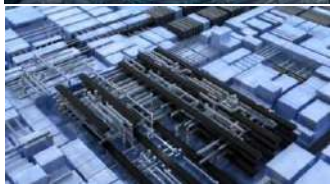


Principle Investigator: Xu Chen, Mechanical Engineering, University of Connecticut

Machine, Automation, and Control Systems Laboratory

Semiconductor manufacturing





Adaptive Vibration Rejection

Best results: Xu et al. and Airimitoaie and al.

Nikon

WD

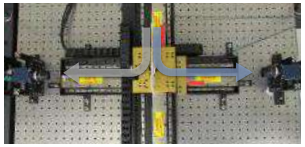
Information storage

- 2.5 inch (nm error tolerance)
- >800 ft.

Quality and fast control in a changing environment, subject to disturbances and sensing limitations.

Laser-material interaction

Additive manufacturing



Robotics