
Boeing Advanced
Research Center
(BARC)
Santosh Devasia
http://www.loydheath.com/UniversityofWashington/Rainier-Vista/i-pMDDrLh

Why the name BARC?

Boeing Advanced Research Center

Why the name BARC?

Boeing Advanced Research Center

- UW's symbol is a husky (dog)
- BARC is for the husky "BARK"
- So everyone is happy with the acronym BARC

Outline of talk

1. **What is BARC?**
2. Challenges/solutions in university-industry partnerships
3. Current Projects
4. Future directions (Advanced Composites Center)
5. Summary

U. of Washington at a Glance

- Founded in 1861
- #1 in federal funds for research among public universities (1.2-1.5B per year)
- Ranked #10 by *U.S. News & World R. Global University rankings*
- *Students:* ***45000***
- *Degrees: 7500 BS 800PhD & 4000 MS per/y*

UW College of Eng. Highlights

- About 269 faculty. 24% of faculty are women vs. around 16.9% national avg.
- Degree Awarded in 2018:
  BS: 1,117; MS: 734; PhD: 112
- Annual Research Funding
  ~ 153 M (about 15% from industry)
- 2017 (Reuters) UW is most innovative public university in the U.S.
- 85 Companies started in last 5 years (50% from College of Engineering)

CoE Strategic Planning effort (new COE Dean a few years back)

Key Idea:

Build on our unique strengths

(unfair advantages)

What is Seattle famous for?

What is Seattle famous for? Rain!

Picture by Szu-Chi Tien

UW campus is quite beautiful

Other famous WA things?

Strong High-tech Industrial Base

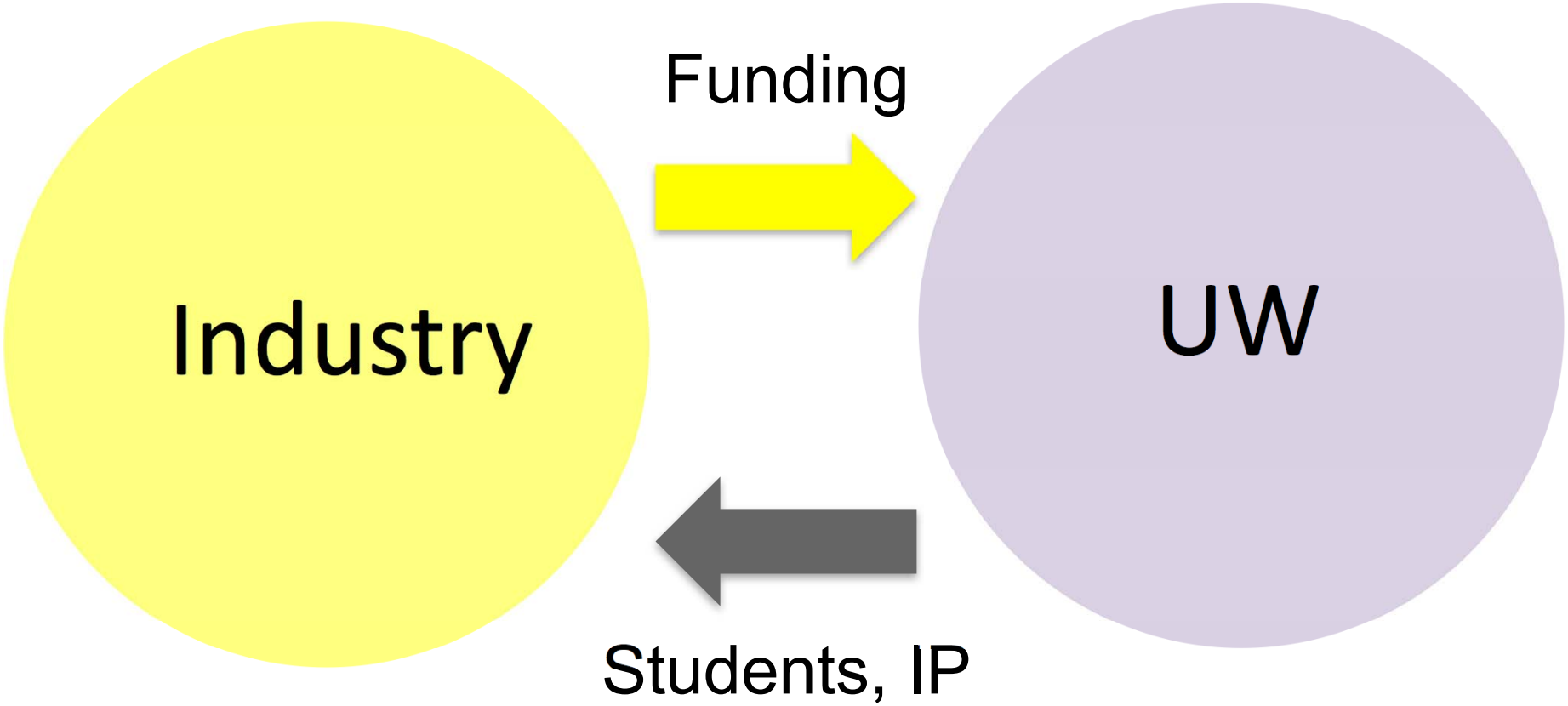
UPS (1907) UW (1861)

College-level Strategic Plan

Strengthen industry partnerships

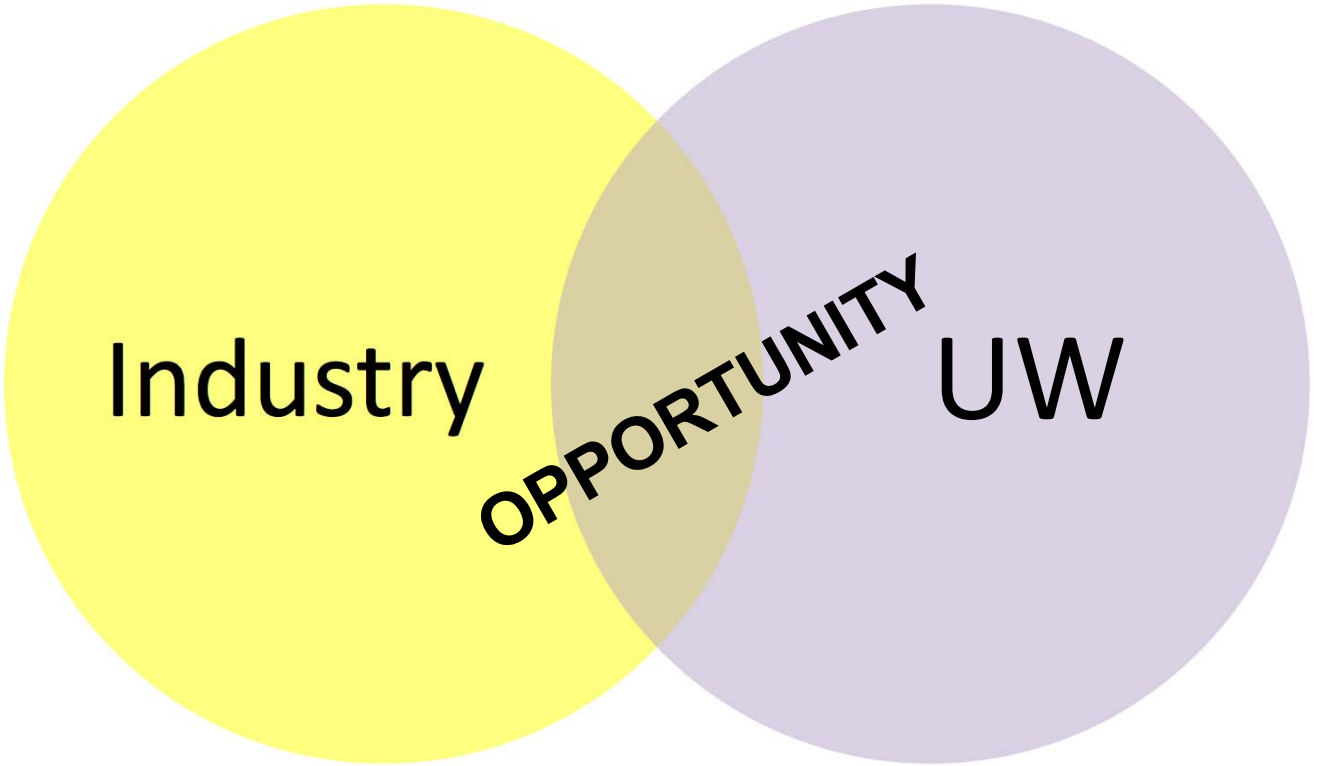
College-level Strategic Plan

Strengthen industry partnerships



TRADITIONAL MODEL

Goal: Co-location



Co-locate Industry and University

BARC is the first major co-location at UW

intel

amazon.com

PACCAR

BOEING

Boeing Advanced Research Center

Leadership (U & Industry) is critical

- UW is well poised to work with industry
- Leadership in U + Boeing helped to launch BARC
- Working on a Paccar co-located lab
- + Industry capstones projects for undergrads

PACCAR

BOEING

Boeing Advanced Research Center

BARC overview (big picture)

Boeing Advanced Research Center

- Founded in 2014 (fall)
- Goals:
  Transformation of manufacturing through development of advanced robotics, data analytics, and safety
- Co-location space : on campus at the University of Washington (UW).
  On each project, Boeing engineers work full-time in the lab with UW students and faculty
- Industry Perspective: Provides Boeing access to talented BS, MS, and Ph.D. students
- Across Boeing: Partners with several business including BR&T, BCA PD, and EHS

BARC Ribbon Cutting, January 2015
UW President Michael Young, BCA CEO Ray Conner, Gov. Jay Inslee, Dean Michael Bragg

Students work with Boeing Mechanics to make riveting safer

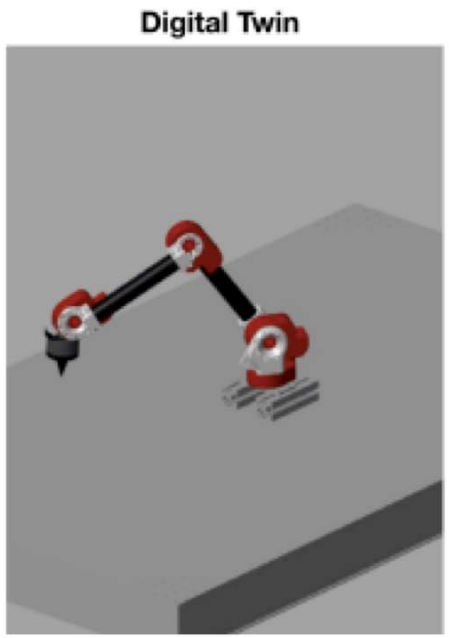
2018 by the numbers

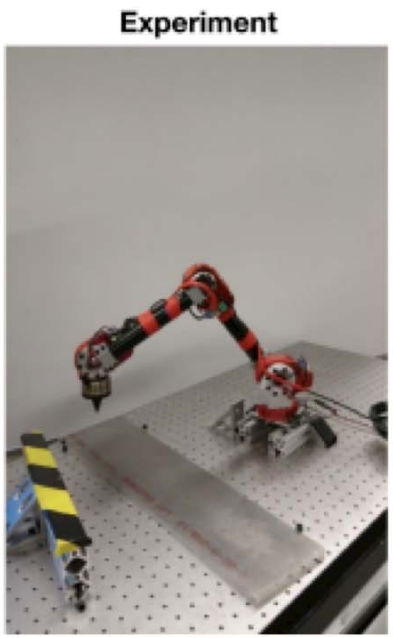
- 8 funded projects (1.6M, standard indirect costs)
- 9 faculty members
- 5 Ph.D. students
- 11 Master's students
- 7 Undergraduate students
- 8 sponsored capstone design projects supporting 32 senior undergraduate students
- **About 50 students**

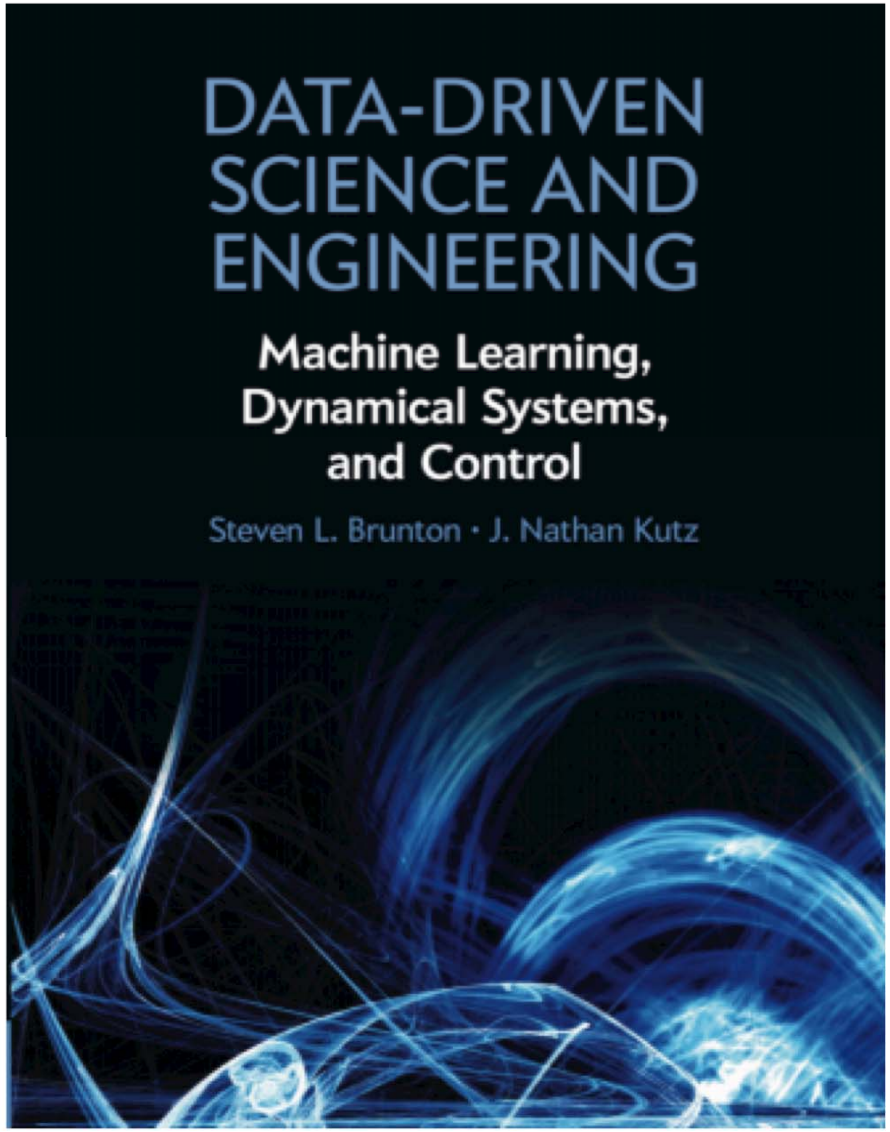
Students work with Boeing Mechanics to make riveting safer

2019 so far

- 3.4M this year from Boeing.
- Major change is efforts in big-data and machine learning efforts
- Leverages UW strengths in e-Science and big-data







Leveraging BARC

1. Unique partnership
   (Master agreement with Boeing, IP)
2. Augment with State and Federal funding
   (Start with company then state/fed)
   1. Potential State Funds,
   2. Federal Grants
3. Link with other UW and Boeing centers to strengthen BARC:
   1. Centers in UW (FAA funded AMTAS),
   2. State funding: New ARCAM machine
      (e-beam, 3D printing for Titanium)
   3. Boeing: Internal Tech Centers for research

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How to work together?

- This is a work in progress.
- Needed to learn to work together

How to work together?

- This is a work in progress.
- Needed to learn to work together
- Several Issues
  1. **IP:** Who owns IP. How can industry acquire it
  2. **Research needs:** Fast pace (industry needs) versus deeper dives (academic needs)
  3. **Funding cycle:** Yearly contract cycle (Jan to Dec) vs academic cycle (Fall to Summer). Affects hiring of students, project start & end

Some solutions

1. IP: Pre-packaged IP – fixed cost to industry

2. Research needs:
    1. Boeing ++ : Leverage state and federal funding (allows deeper study of rich problems)
    2. Mix of students on each project (BS, MS, PhD) to facilitate both academic and industry needs
3. Funding cycle
    1. Use of returned overhead (indirect costs) to provide stability across years for PhD students and buffer for contracting cycles
    2. Professional MS programs (in an urban environment) provides revenue stream to departments

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Why BARC (from U perspective)?

1. Why should a top research university have an applied research effort
2. Industries are better than universities at applied research for “engineering solutions”
3. Universities tend to focus on fundamental work, with very low technology readiness levels

What is BARC to UW?

1. Education impact is clear
    1. Students **learn by doing.**
       Never seen students more excited to work on projects
    2. Students at all levels, BS, MS, PhD
    3. Boeing-led aircraft structures course (AA/ME)
2. Research:
    1. High-impact Applied collaborative research.
    2. + A source for finding
       new research challenges for academic research,
       (federal grants & fundamental research)
    3. Illustrate this with some of the examples

Research topics

- **Big Data/Machine Learning**
  - Sparse-sensing
    (reduce number of measurements)
  - Standardization of multiple parts
  - Data-based Process Control?
  - ML models for Digital Twin?
- **Robotics / Ergonomics and Safety**
  - Human-Robot Collaboration
    for Manufacturing
  - Shoulder fatigue modeling
  - Riveting and reducing impact on humans
- **Composites (newer topic)**
  - Advanced Fiber Placement
  - Thermoplastics

BARC Ribbon Cutting, January 2015
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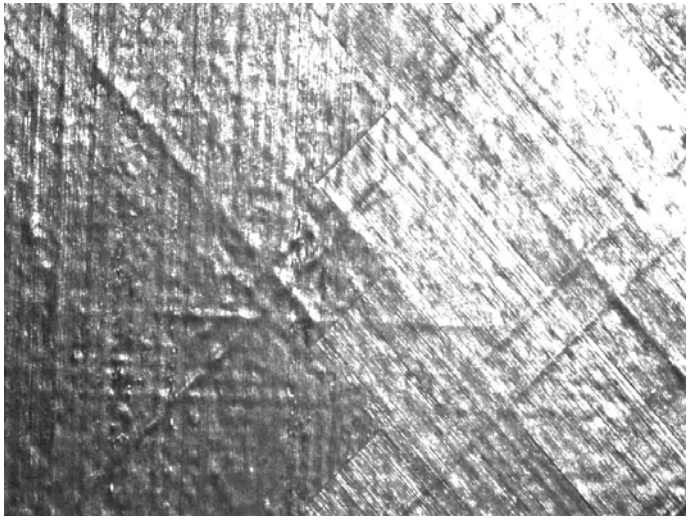
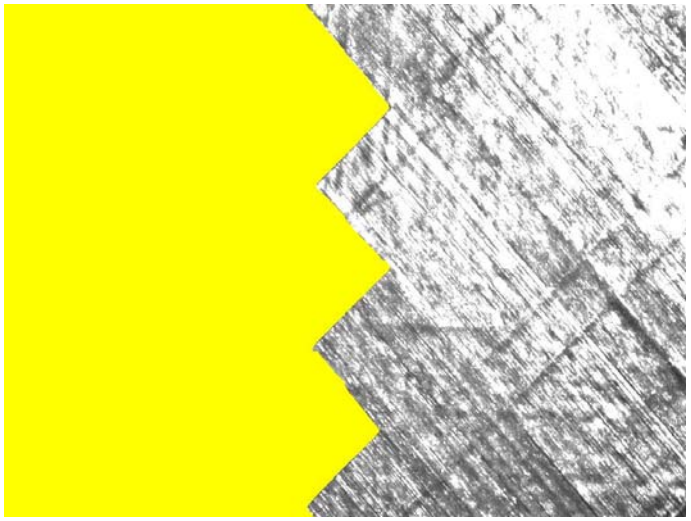
Example 1: machine learning & big data:

- **Typical:** Experimental data and process models for process development
- **New:** lots of data. Potential for machine learning for advanced manufacturing processes control.
- **Example:** automate feature recognition, such as tow wrinkles, laps and gaps in composites manufacturing
- Current camera-based systems are about 85% accurate
- **Challenges:** images with glares, artifacts/occlusions, and intensity variations
- **Efforts by** Wei Guo (Ph.D. student), Agnes Blom-Schieber (Boeing) and Prof. Ashis Banerjee





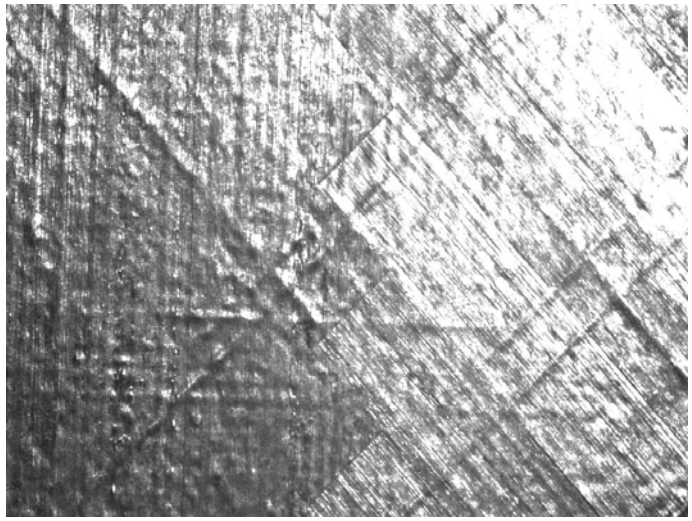
Pixels predicted to belong to bottom ply layer colored in yellow

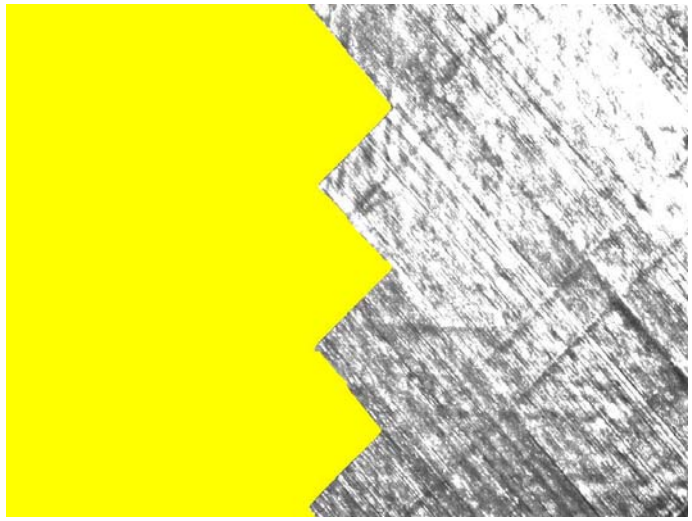
Example 1: machine learning & big data:

- Applied Research?
  Yes. Directly applicable now.

- Fundamental Research?
  Yes.
  1. Machine learning issues
  2. Process modeling and
  3. Perhaps Process control?

  Several PhD students working in this area





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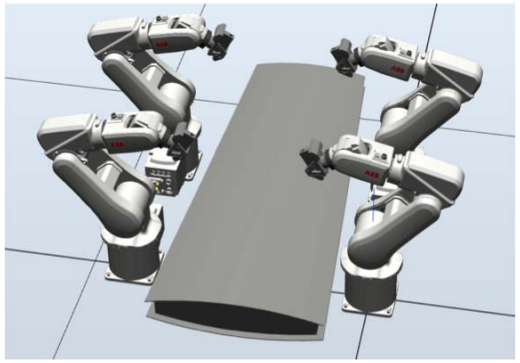
Example 2: Multi-Robot Coordinated Control

Drilling of a wing:

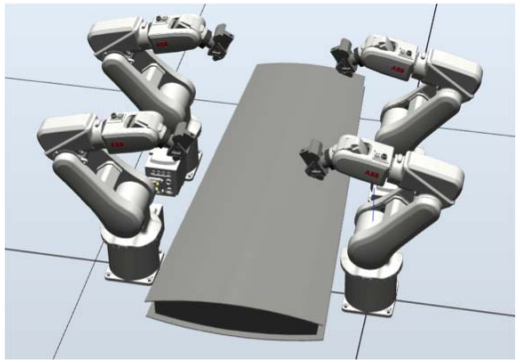
- **Goal**: Balanced, efficient, collision free scheduling of robots
- Minimize completion time of entire drilling operation
- Nothing should be idle at the end



Example 2: Multi-Robot Coordinated Control

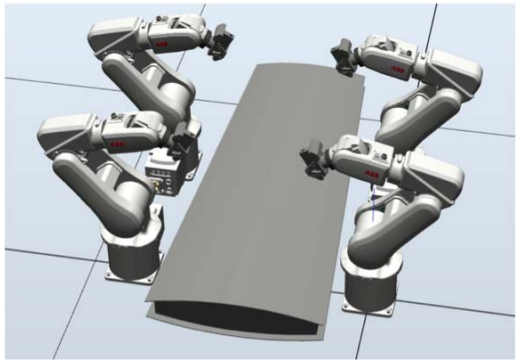
Drilling of a wing:

- **Goal**: Balanced, efficient, collision free scheduling of robots
- Minimize completion time of entire drilling operation
- Nothing should be idle at the end
- **Challenge**: Well known NP-hard traveling salesman problem
- Failures, such as a drill bit breaking, brings further complications
- Work with Ben Tereshchuk (PhD Student), 2 MS, 4 BS students, Sam Pedigo (Boeing Engineer), Prof. Banerjee & I



Example 2: Multi-Robot Coordinated Control

- Applied Research?
  Yes. Directly applicable
  Code developed for robots
  is directly applicable for larger robots
  in Boeing



- Fundamental Research?
  Yes. One PhD effort + papers
  1. New theory for Scheduling/Optimization
  for a class of manufacturing operations

- We (faculty, students and Boeing)
  are all happy with this research

Example 3. Shared Autonomy for Manufacturing

Parker Owan, PhD student (now working at Amazon Robotics)

Source unknown

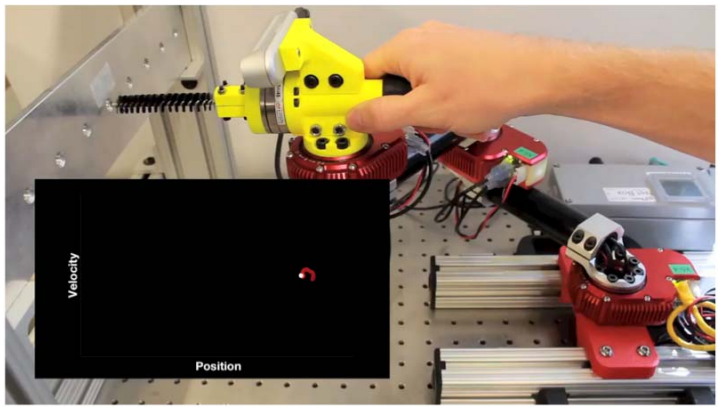
Problem characteristics:

- Workspace restrictions
- Repeated operations (e.g.: fastening, drilling, cleaning)
- Variable sequence work
- Skilled/adaptable mechanics

Research objective: reduce labor strenuosity and improve process efficiency.

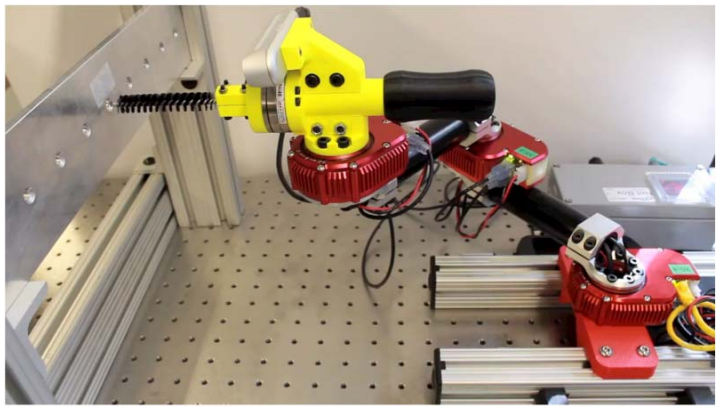
Research Thrusts: Learn from Human-Robot Interaction

1. Task teaching by demonstration

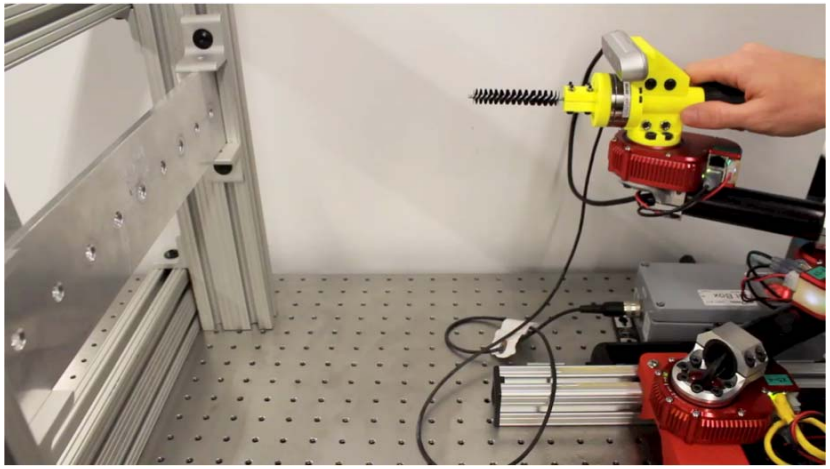


2. Machine learning (ML) dynamic systems

3. Task imitation and optimization



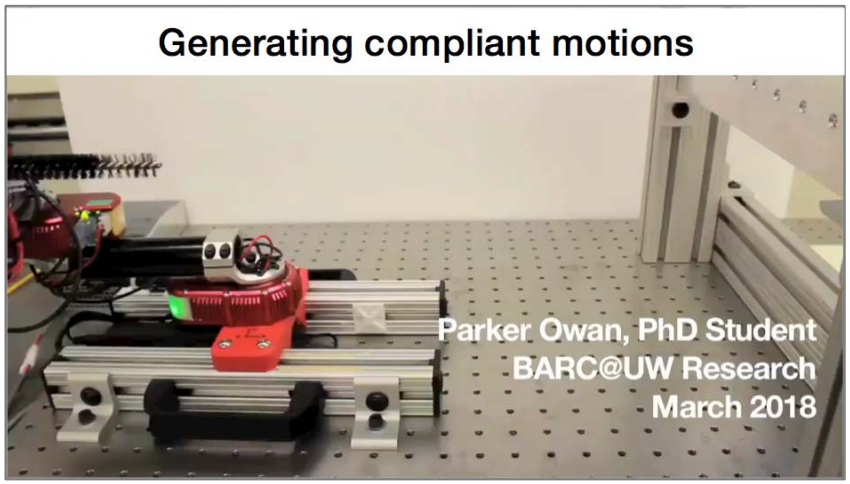
4. Collaboration with task kinetics

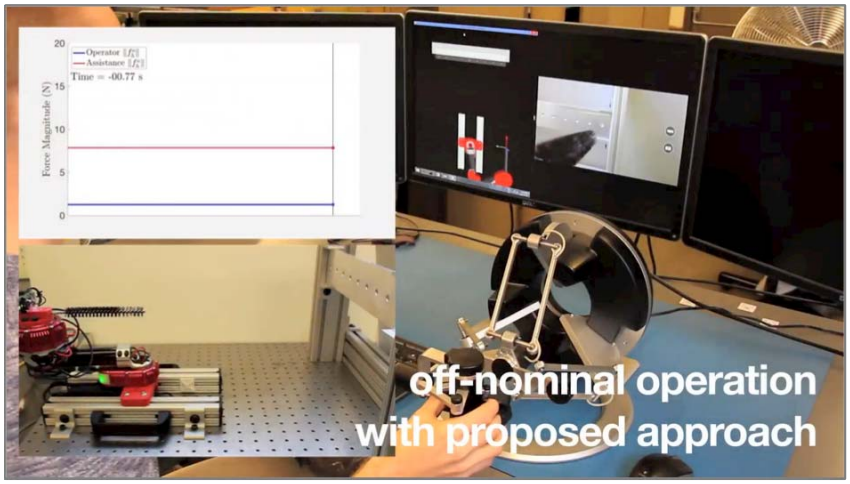


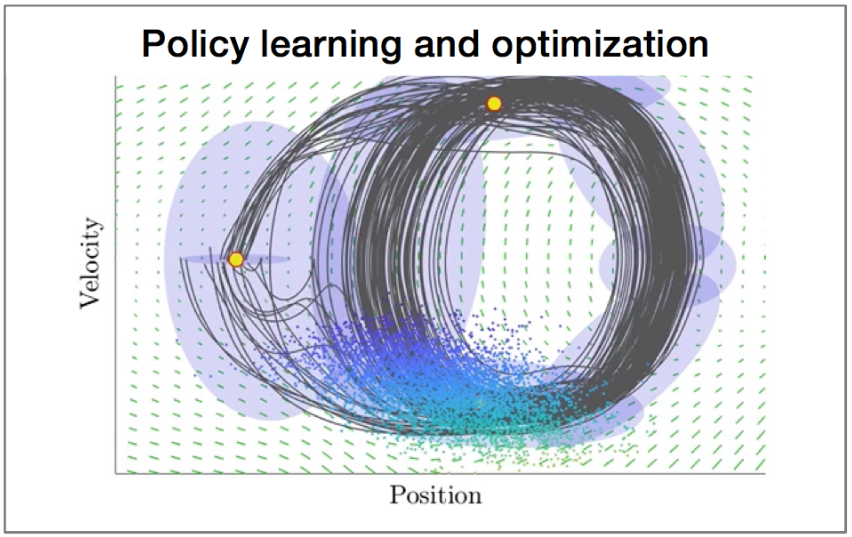
Humans for adaptation

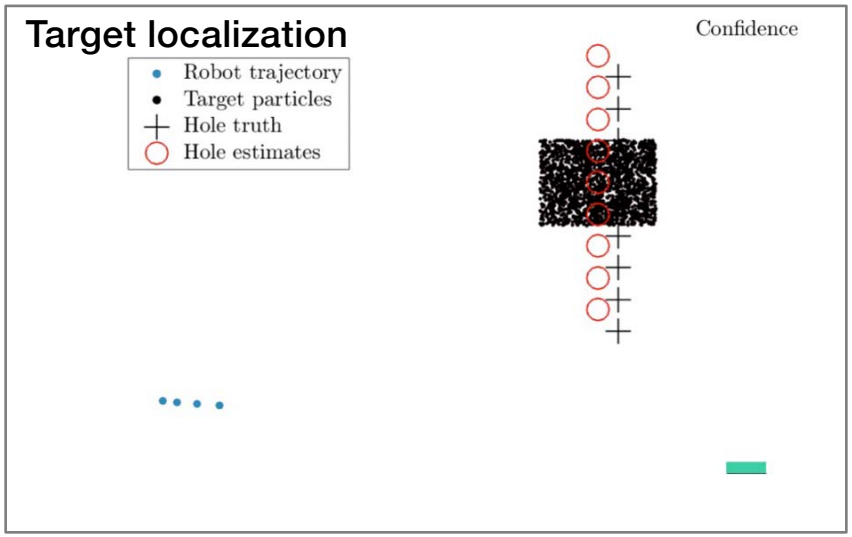
Robots for repetitions

Research issue: how to automate learning?









BARC@UW
BOEING ADVANCED RESEARCH CENTER

BOEING

UNIVERSITY of WASHINGTON

Engineering, Operations & Technology
Boeing Research & Technology

Example 4: Lift Assist Device (LAD)

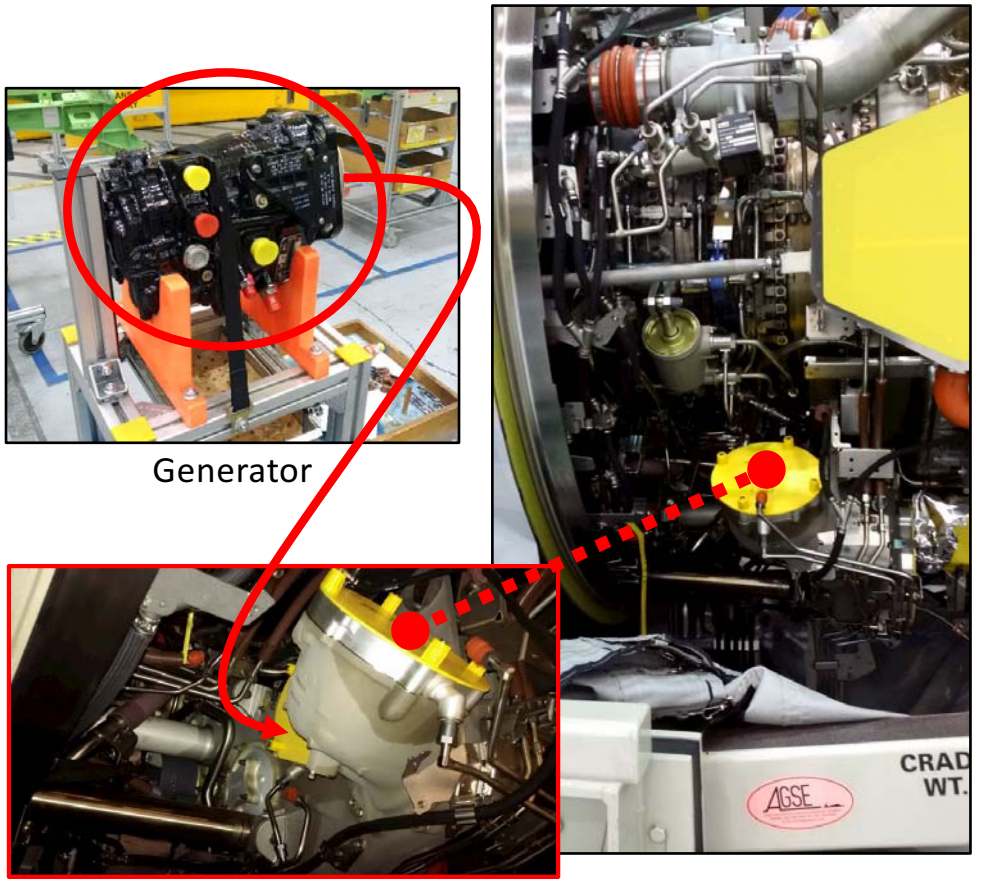
W. Tony Piaskowy	• UW, PhD Student
Cameron Fasola	• UW, MS Student
Alex de Marne	• The Boeing Company| UW, MS Student
Lance O. McCann	• The Boeing Company | UW, PhD Student
Don Coffland	• The Boeing Company
Kareem Shehab	• The Boeing Company
Terry Rowe	• Affiliate Professor, Mechanical Design Consultant

Motivating application

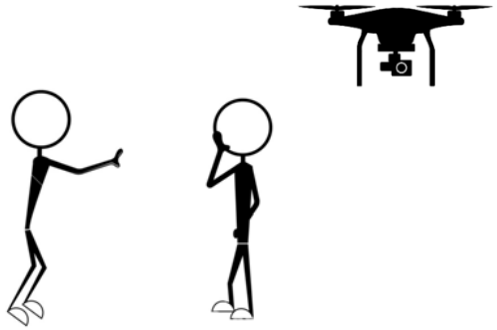
Problems:

1. Heavy components
   - 35-100 lb+
   - Require two-person lift

2. Awkward installation
   - Limited access
   - Delicate surroundings



Example 5: Gesture based robot control



- There exist a number of tasks today for which humans use gesture to collaborate with each other
- In order to embed robots into these environments or partially automate these tasks, robots must be able to understand these gestures
- **Phd Student Rose Hendrix** is working on what is a good gesture when communicating with a robot?

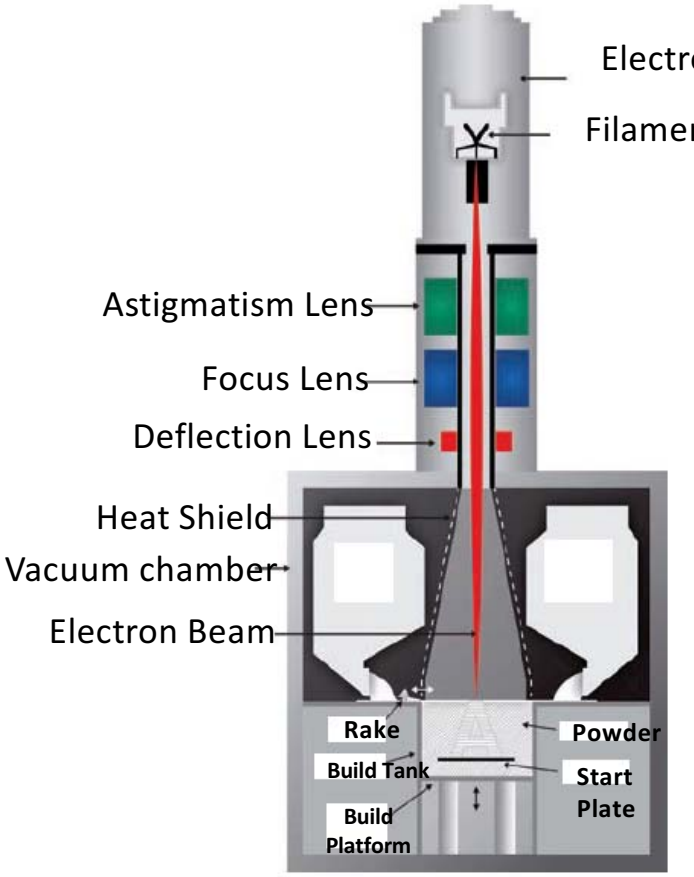
What is a good gesture?

- Problem: People do gestures differently? Can you choose gestures so it is more robust?

- Problem: how to distinguish between working and asking the robot to do something?

Example 6: Powder-Bed Electron Beam Melting (EBM) Additive Manufacturing Process

- 3D printing of Titanium parts
- Still challenging for structural parts
- Applied issue, but needs fundamental understanding to improve 3D printing
- Effort by 5 faculty members:
  M. Ramulu, D. Arola,
  A. Banerjee, C. Cobb,
  J. Wang
- Two Boeing Engineers:
  Stefanie Meier
  Andew Baker



Arcam EBM® systems, schematic architecture
Source: A2X Brochure

ARCAM® A2X EBM Additive Manufacturing Machine

BARC inspires fundamental research

- **In addition to TRL 5-8 projects**
- BARC applied projects reveal challenging & interesting problems
- Leads to fundamental research lower TRL
- With potential for substantial impact

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NEXT GEN THERMOPLASTICS RESEARCH IS CRITICAL

(i) Reduce fuel consumption in transportation systems;

(ii) Promote energy efficient manufacturing
can avoid large energy-intensive autoclaves and component refrigeration

(iii) Reduce waste and energy use by facilitating repair of damaged structures

+ (like Gifu)

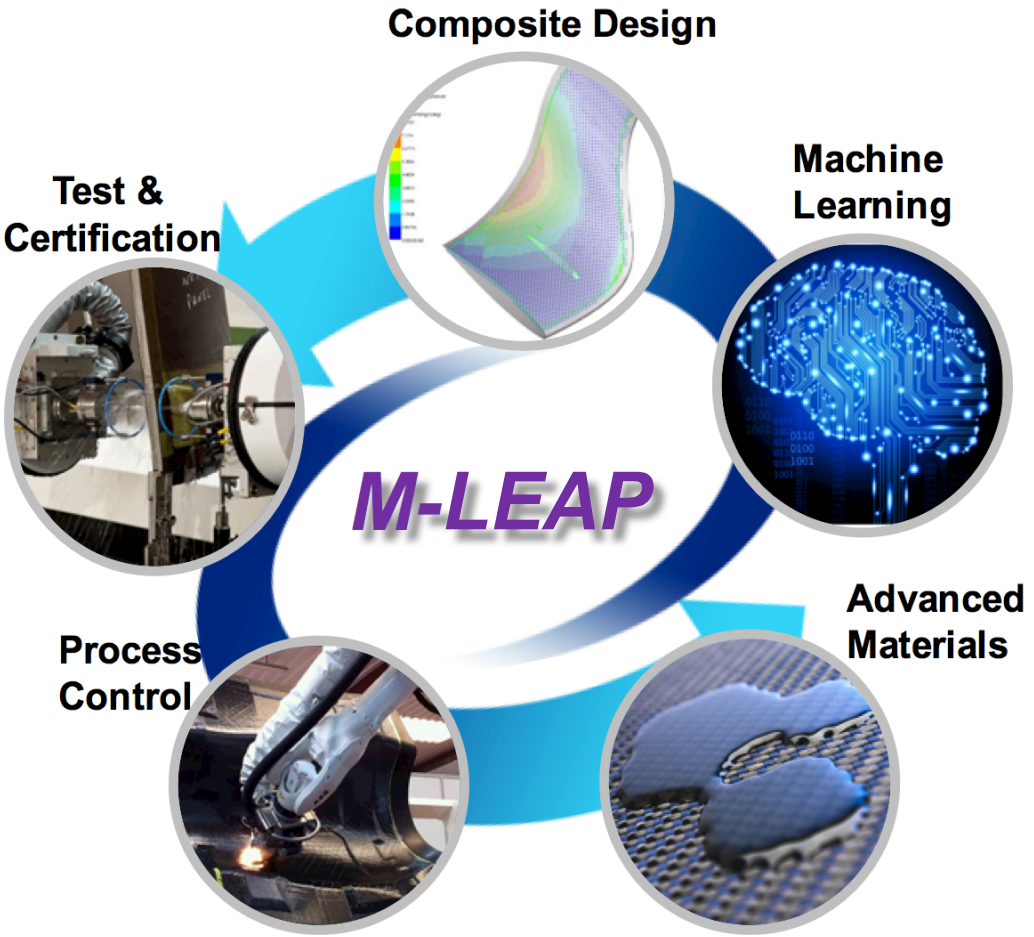
(iv) Maintain our states leadership in Aerospace

(v) We have 130,000 highly-skilled jobs and
WA manufactures most of all commercial aircraft in the United States

(vi) We want to remain a leader.

GOAL: UW ADVANCED COMPOSITES CENTER

- National magnet for design, manufacturing, evaluation and certification of novel energy-efficient lightweight composite systems.
- + Federal Aviation Administration (FAA) funded Center of Excellence for Advanced Materials in Transport Aircraft Structures (AMTAS).
- + Boeing efforts in BARC
- Work with WA companies in Aerospace, Space, Automotive & Clean Energy sectors



The Future of Design for Manufacturability

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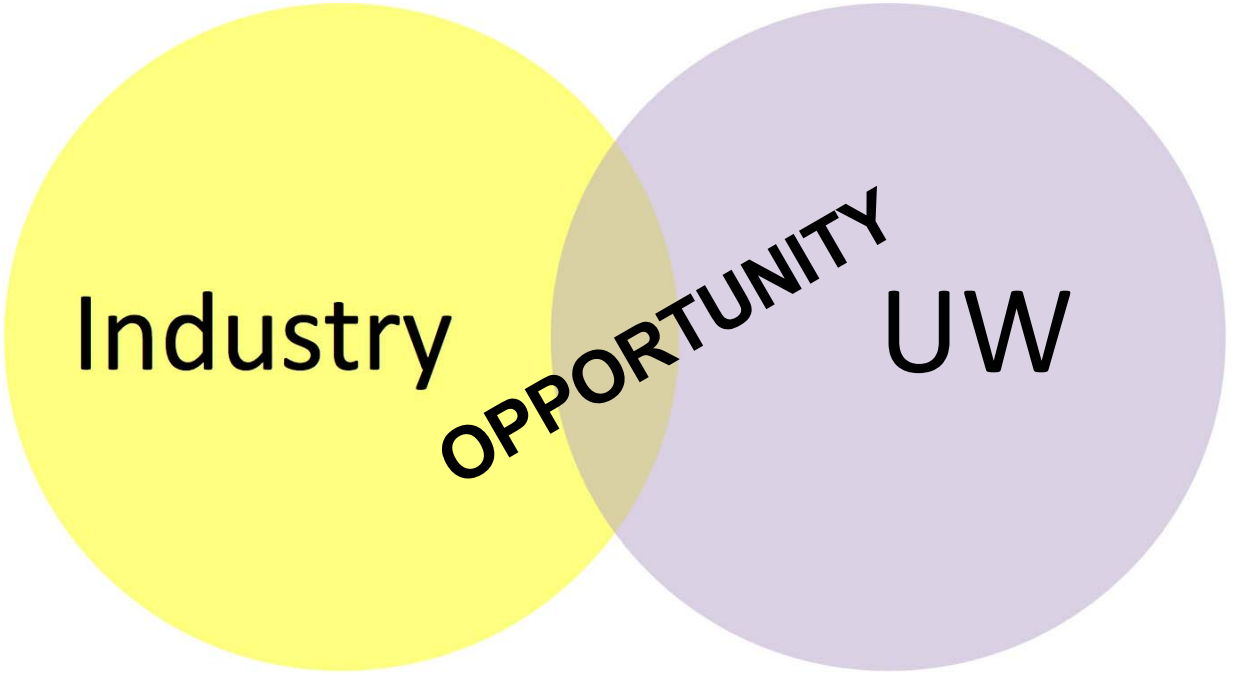
Summary



1. BARC represents a new paradigm for University-Industry collaboration
2. High impact research & Education
3. Helps maintain WA leadership in Aerospace

Thank you

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Dennis Muilenburg Visits the BARC

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Mike Bragg and Per Reinhall for making it happen!