Hybrid Autonomous Manufacturing: Moving from Evolution to Revolution

A National Science Foundation Engineering Research Center,
Began Sept 1, 2022, $52M NSF support over 10 years*,
favorable collaboration and partnership terms.

Foundational Components:

- Convergent Research
- Engineering Workforce Development
- Culture of Diversity and Inclusion
- Innovation Ecosystem

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http://hammer.osu.edu

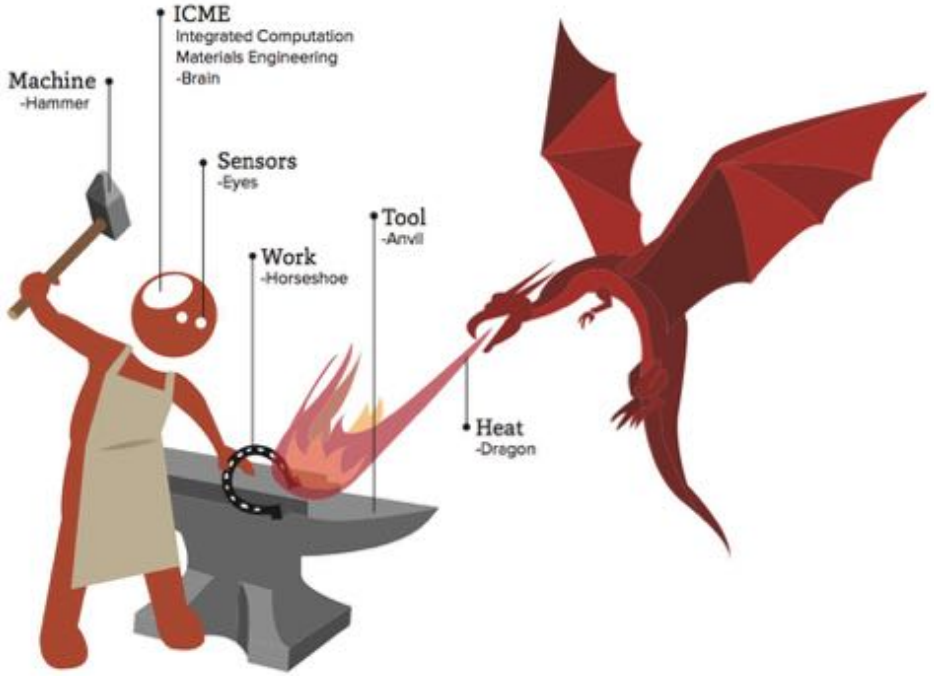
Join the mailing list at:
hammer@osu.edu

* pending renewal at year 5

Summary – Automate the blacksmith!

Evolution:

-- Sensors
-- Robots
-- Computation
-- Control
-- Data
-- Logistics



Revolution:

-- Hybrid
-- Autonomous
-- Learning
-- High Performance
-- Certified Quality

Robot Artisan

New capabilities for $300B precision manufacturing industry

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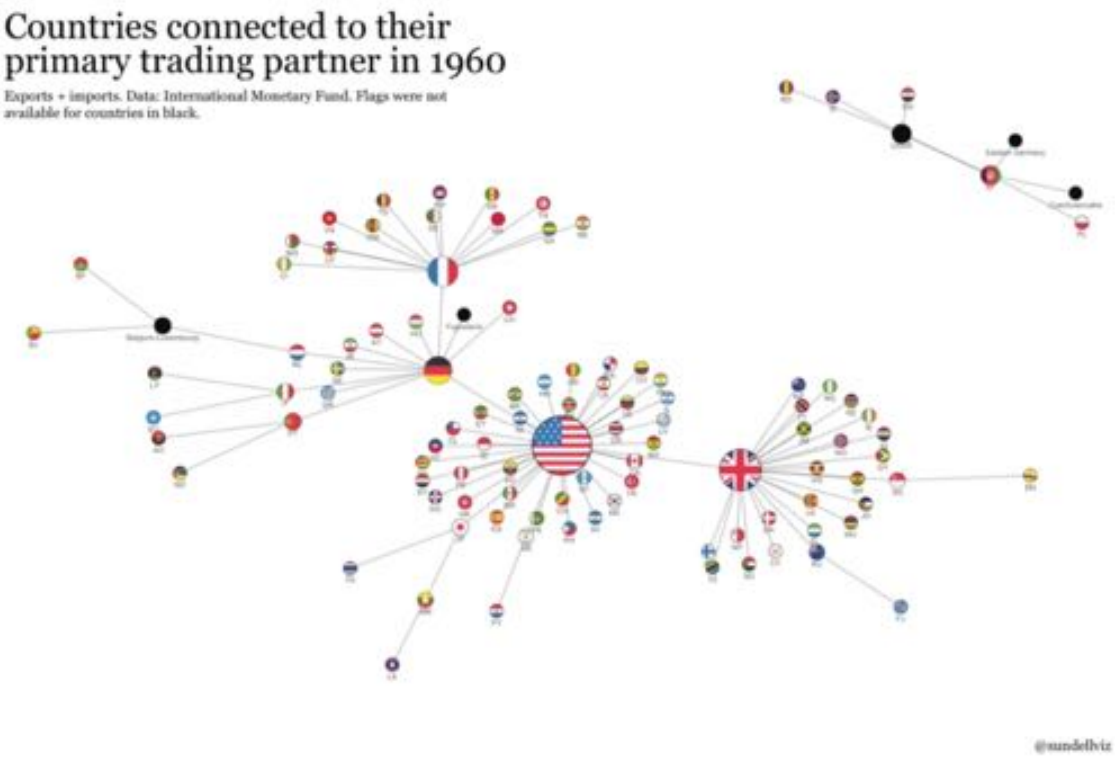
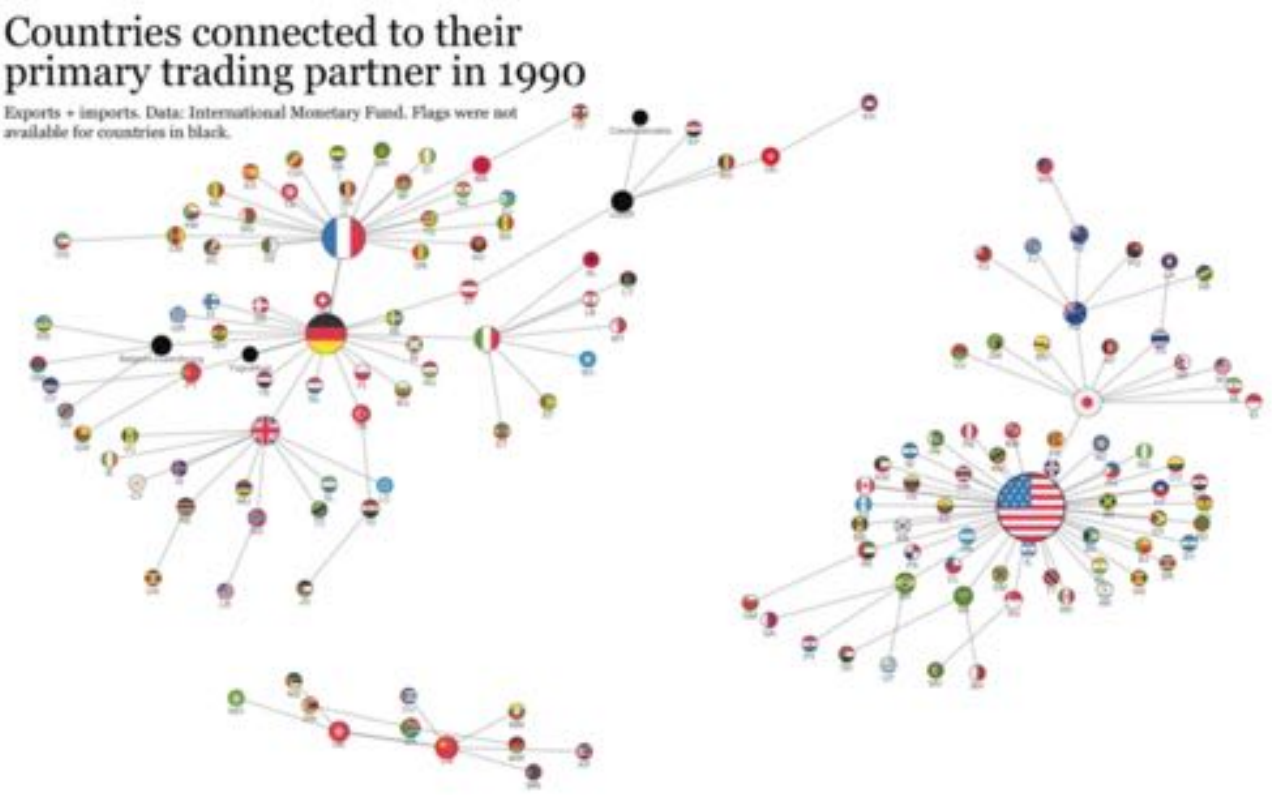
A very quick history lesson



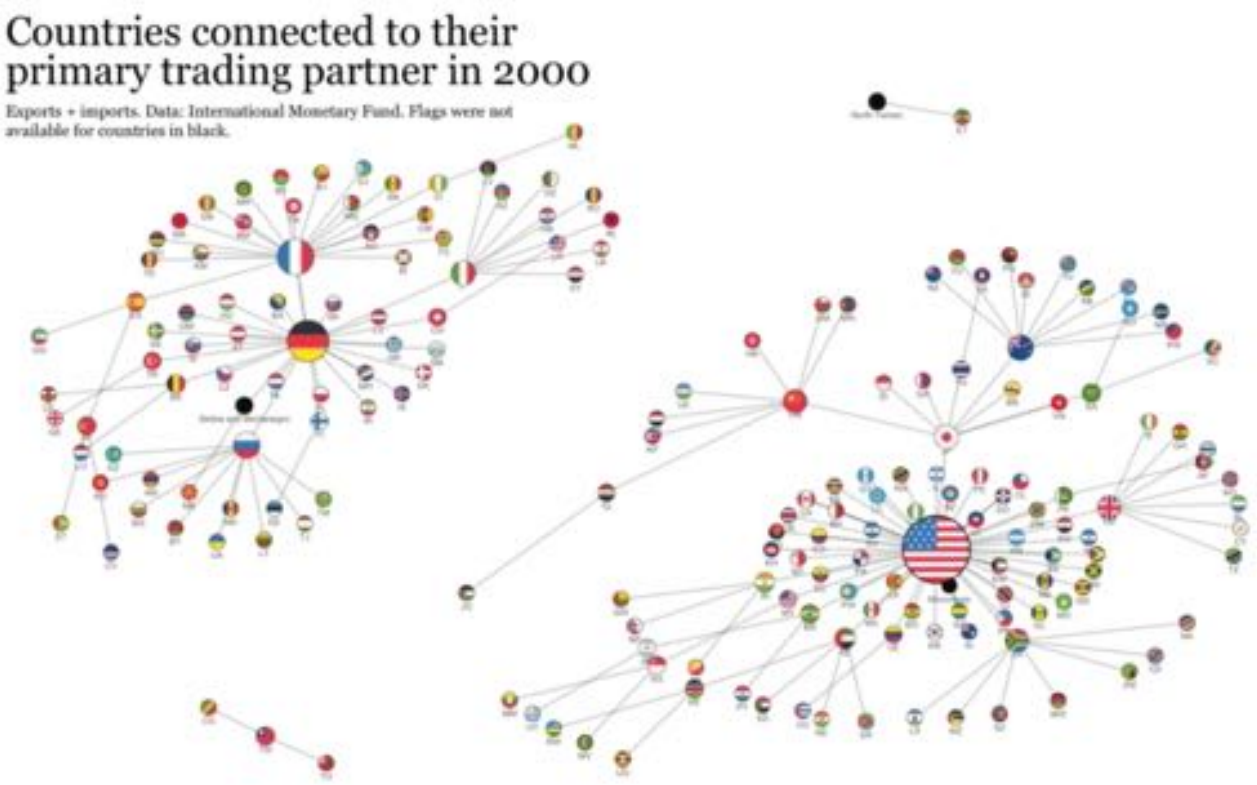
Original: Anders Sundell, Twitter

A very quick history lesson II



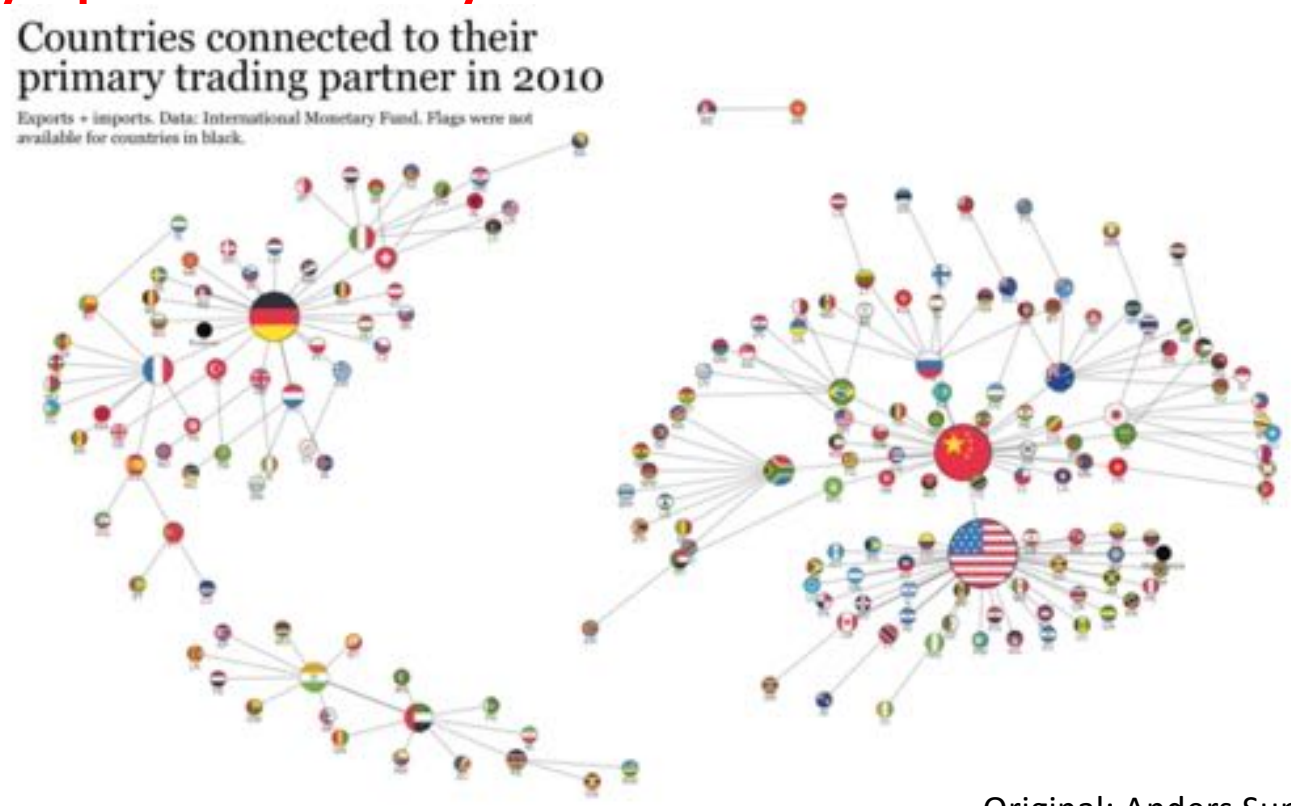
Original: Anders Sundell, Twitter

A very quick history lesson - III



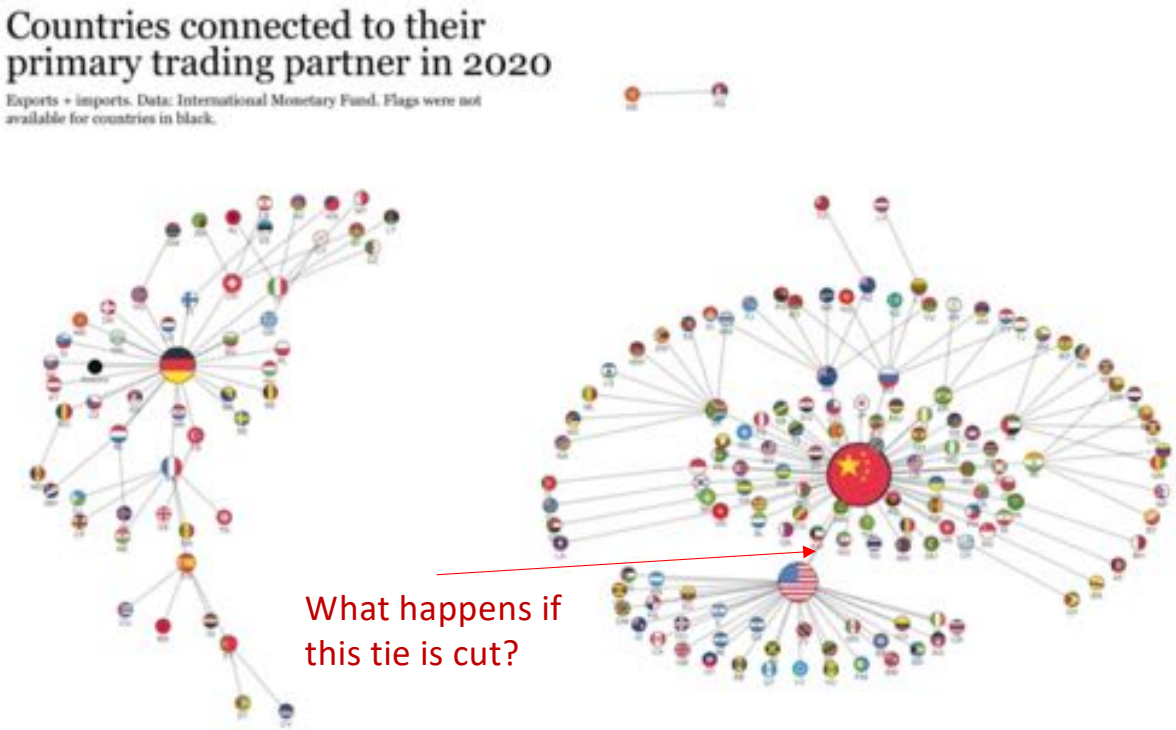
Original: Anders Sundell, Twitter

A very quick history lesson - IV

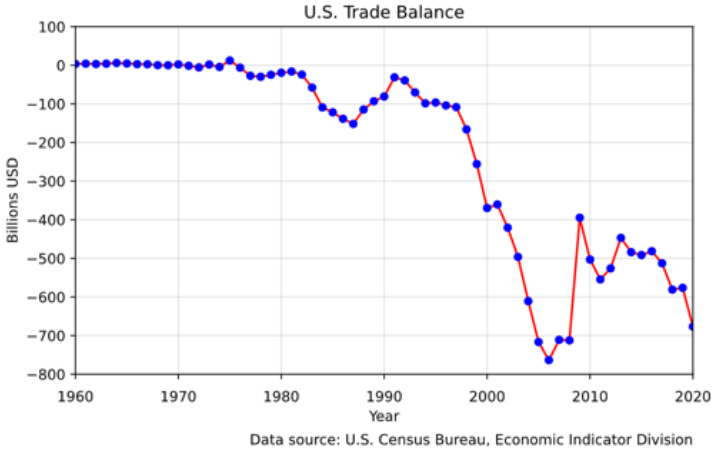


Original: Anders Sundell, Twitter

A very quick history lesson - V



What happens if this tie is cut?



Latest Estimates Trade Deficit >$800B in 2020. (BEA)

Original: Anders Sundell, Twitter

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$800 B annual trade deficit – Compare to $ flows

20 largest **GDP** countries

1	United States	$20.94 trillion per year
2	China	$14.72 trillion per year
3	Japan	$4.975 trillion per year
4	Germany	$3.846 trillion per year
5	United Kingdom	$2.708 trillion per year
6	France	$2.63 trillion per year
7	India	$2.623 trillion per year
8	Italy	$1.886 trillion per year
9	Canada	$1.644 trillion per year
10	South Korea	$1.631 trillion per year
11	Russia	$1.483 trillion per year
12	Brazil	$1.445 trillion per year
13	Australia	$1.331 trillion per year
14	Spain	$1.281 trillion per year
15	Mexico	$1.076 trillion per year
16	Indonesia	$1.058 trillion per year
17	Netherlands	$913.9 billion per year
18	Switzerland	$748 billion per year
19	Turkey	$720.1 billion per year
20	Saudi Arabia	$700.1 billion per year

(2020 estimates)

Annual **Earnings**

		EBITDA
1	Apple	$128.2 billion
2	Microsoft	$91.62 billion
3	Alphabet Class C Shares	$91.16 billion
4	Tesla Motors	$9.407 billion
5	Meta	$54.72 billion
6	NVIDIA	$11.37 billion
7	Johnson & Johnson	$33.69 billion
8	UnitedHealth	$27.07 billion
9	Visa	$17.69 billion
10	Exxon Mobil	$43.84 billion

Greater than EBITDA 10 largest companies, <u>combined</u> ($~550B)

Annual Gross **Revenue**

Revenue rankings:

1	Wal–Mart Stores	$572.8 billion per year
2	Apple	$378.3 billion per year
3	UnitedHealth	$287.6 billion per year
4	Exxon Mobil	$276.7 billion per year
5	Alphabet Class C Shares	$257.6 billion per year
6	Microsoft	$184.9 billion per year
7	Chevron	$155.9 billion per year
8	Home Depot	$151.2 billion per year
9	Meta	$117.9 billion per year
10	Johnson & Johnson	$93.78 billion per year

$800B ~About gross revenue of Wal-Mart and Apple combined.

NSF annual budget ~$8.8B

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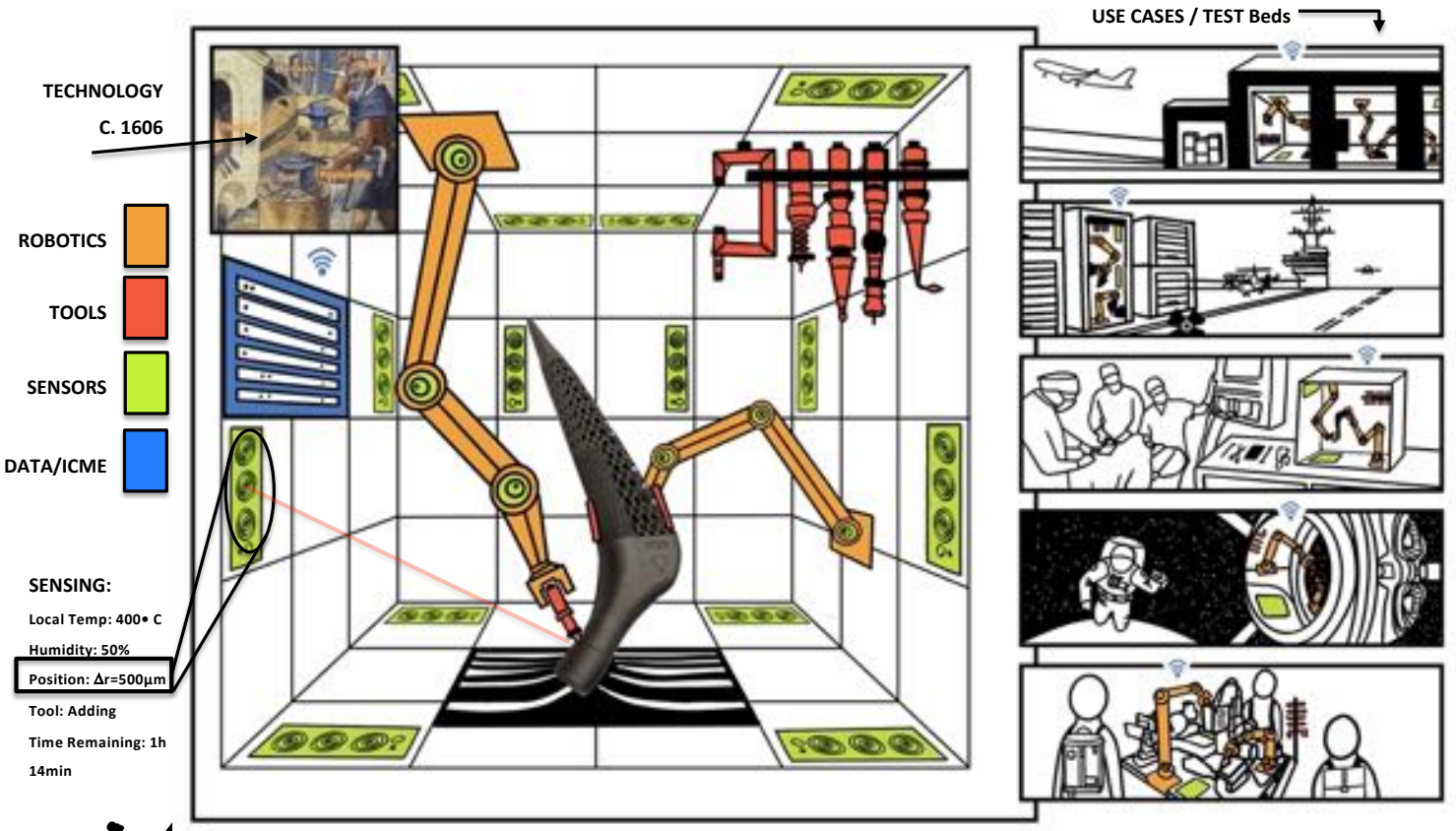
Vision: Autonomous-Factory/Artisan Box (Auto-FAB)



Research Thrusts

Design: product and process.

Tools and Process Convergence: new tools and processes.

Materials State Awareness: Enabling process- and model-based quality certification.

Control, Intelligence, and Autonomy: Leveraging AI to control processes learn.

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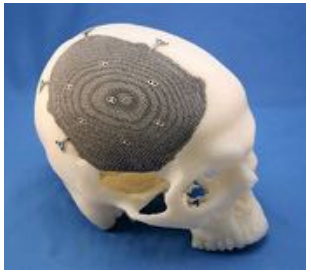
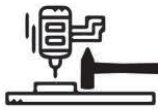
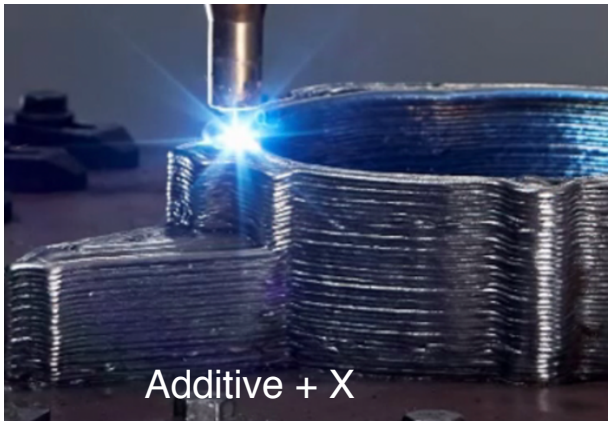
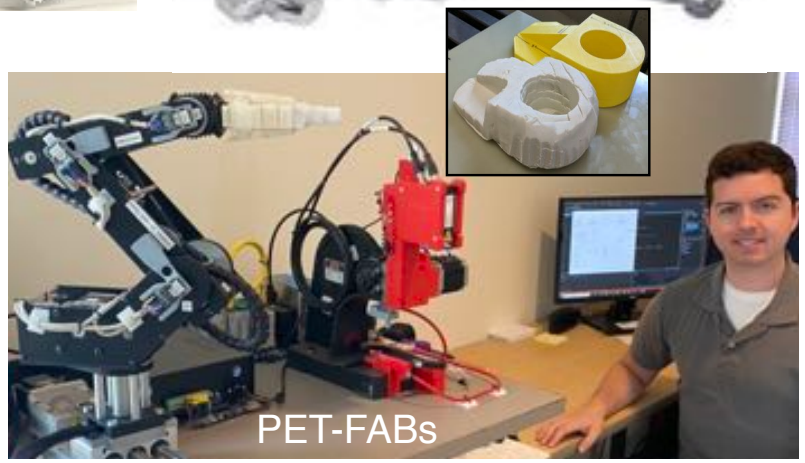
HAMMER Testbeds









Physical Exploration & Training – Factory/Artisan Boxes

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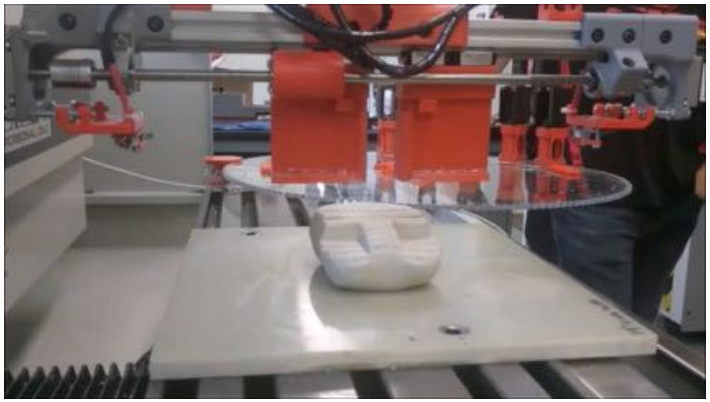
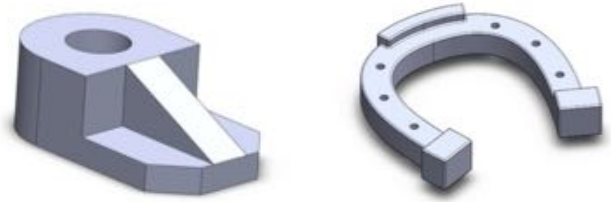
Incremental Deformation / Metamorphic Manufacturing

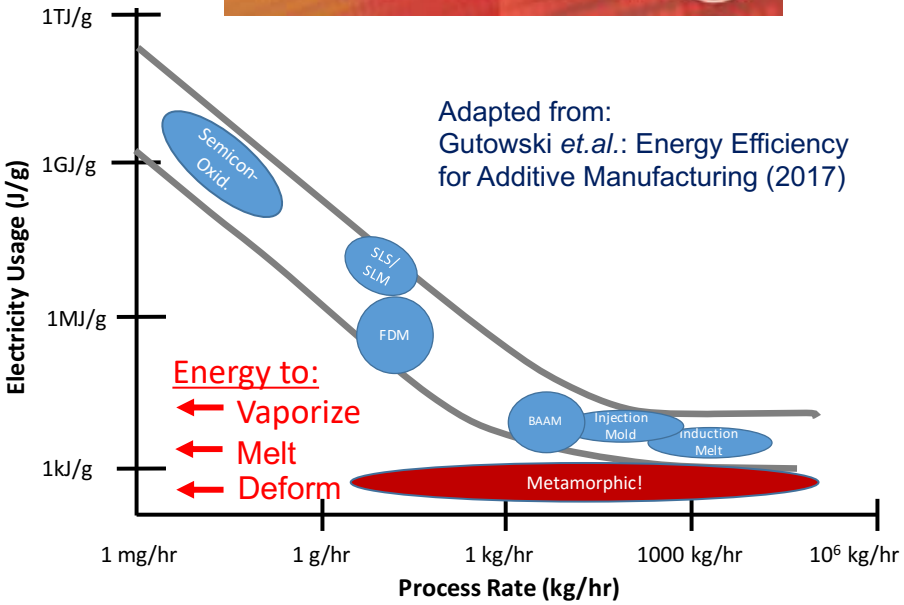




LIFT Prize – $25k programmable for shaping 2 of 3 target parts.

Team Honey Badger, of Ohio State University.
Alex Koenig, Bhuvi Nirudhoddi and Brian Thurston

2019
Daehn,
Cao,
Lewandowski,
Schmitz, *et al.*



www.tms.org/MetamorphicManufacturing

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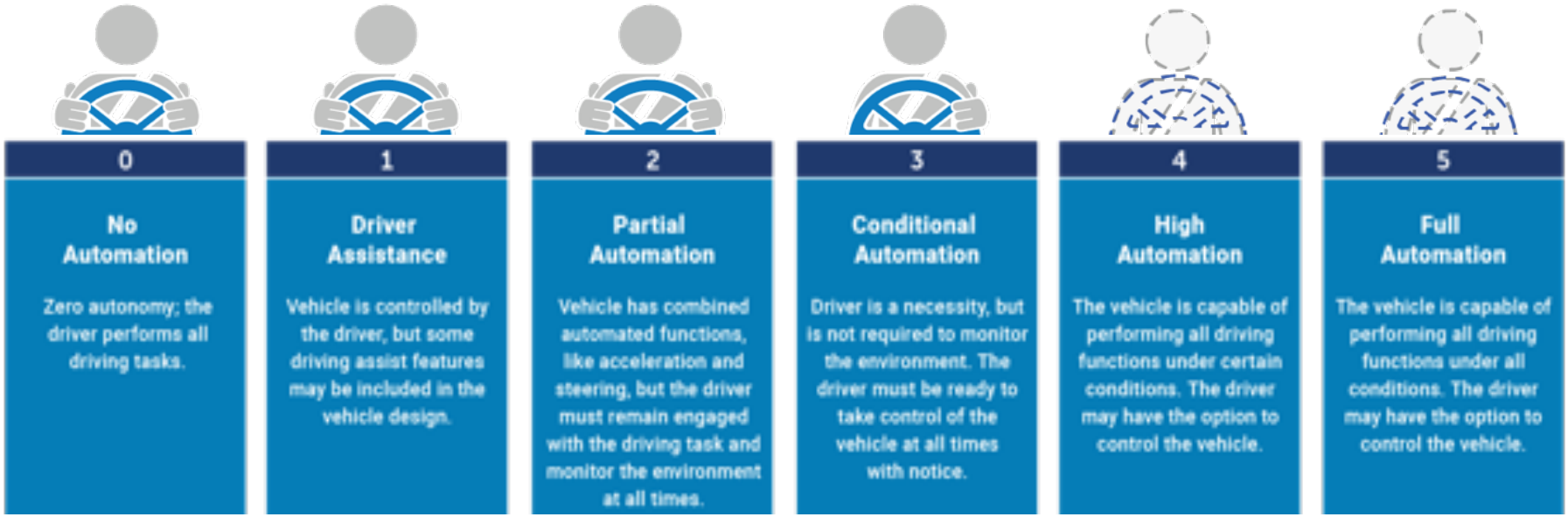
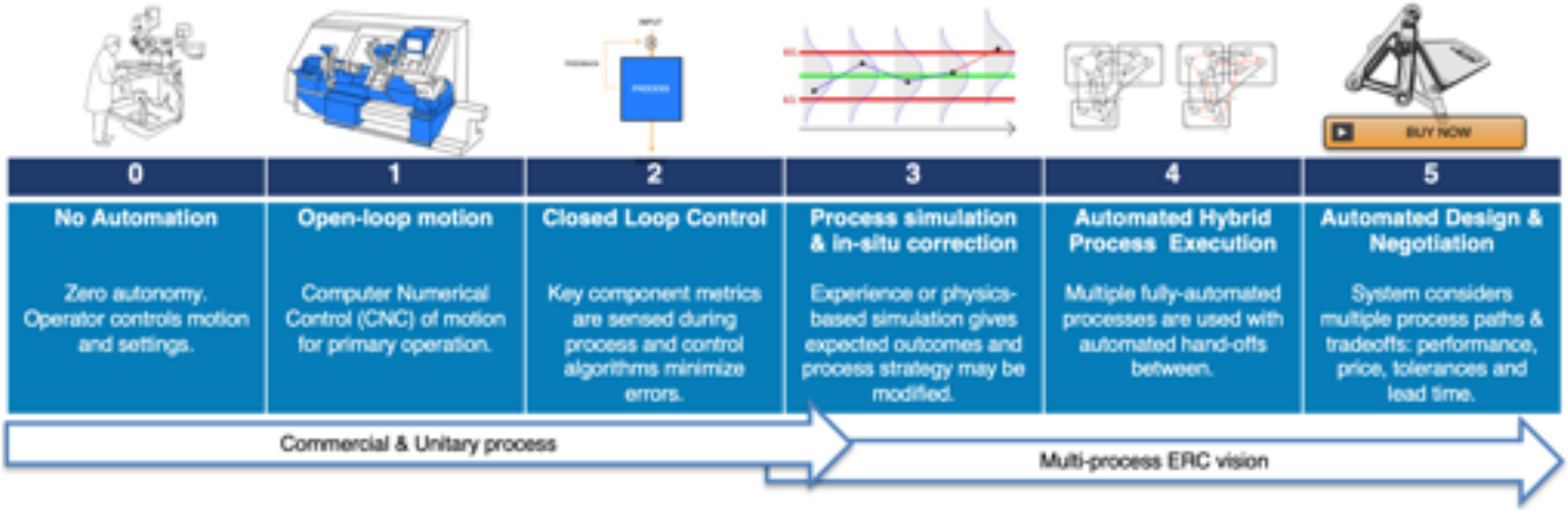
Levels of Vehicle Autonomy



Summary of SAE J3016

Levels of Manufacturing Autonomy



Additive +	GE, Markforged, others…
Machining +	FormLogic
Welding +	Path Robotics
Deformation +	Machina Labs

Requires concurrent hardware and computational development

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Concluding Remarks

- Key outcome goals
  - Hybrid process framework
  - Digital forming
  - Model-based certification
  - Manufacturing for design
- Get involved, please
  - Mailing list, ask: Hammer@osu.edu
  - Base Membership: $200 - $5000
  - Tech Leader: $75k/yr
  - Projects & Investment

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Team

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