Increasing the Pace of Adoption and Commercialization:

Capturing Expert Judgment at the Technical Frontier

Patrick Funk, Alex Davis, Parth Vaishnav, Barry Dewitt, and Erica Fuchs

Manufacturing Futures Initiative

The Digital Transformation of Manufacturing

Carnegie Mellon University

Engineering & Public Policy

Climbing Out of the Valley of Death

"… the introduction and acceptance of new technology often depend more on social, cultural, and historical factors than on technological merit"

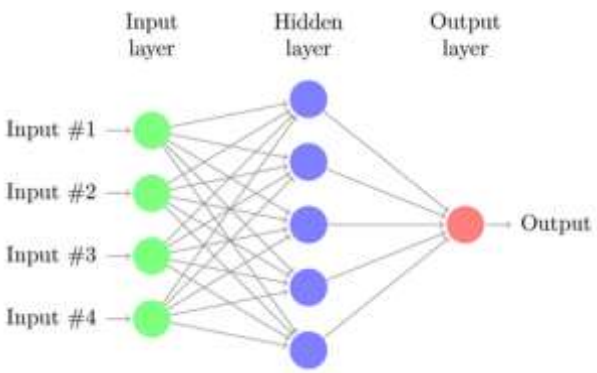
"…typical development times range between ***2 and 20*** years"

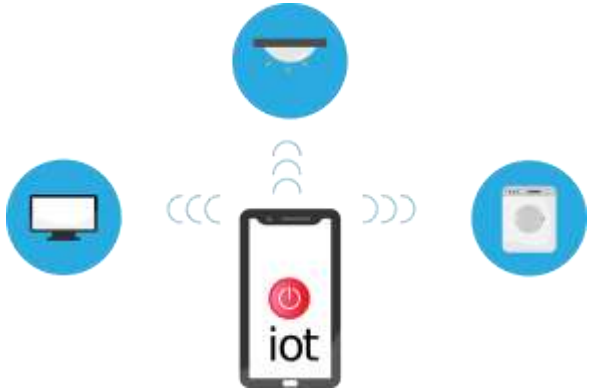
National Resource Council of the National Academies (2004) Accelerating Technology Transition: Bridging the Valley of Death for Materials and Processes in Defense Systems. (The National Academies Press, Washington, DC).

When to Adopt a New Technology?

- In-house expertise
- Consultants
- Outside vendors

How can these decisions and advice be evaluated?





Source: Wikimedia Foundation, NavAir, TeXample

What Do Experts Know?

- Experts are poor at certain types of judgments including
  - Additive
  - Systemic
- There is randomness in expert judgment, leading to inconsistency in small groups
- Decision rules are not always consistent
- Expert vary in degree of randomness *and* decision rules!

What Do Experts Know?

- Experts are poor at certain types of judgments including
  - Additive
  - Systemic
- There is randomness in expert judgment, leading to inconsistency in small groups
- Decision rules are not always consistent
- Expert vary in degree of randomness *and* decision rules!

Expertise or luck in business and engineering choices?

Can we capture and scale *expert knowledge* for new manufacturing technologies where:

1. Judgement is an **art**,
2. Experts are **few**, and
3. Potentially no one expert has all information?

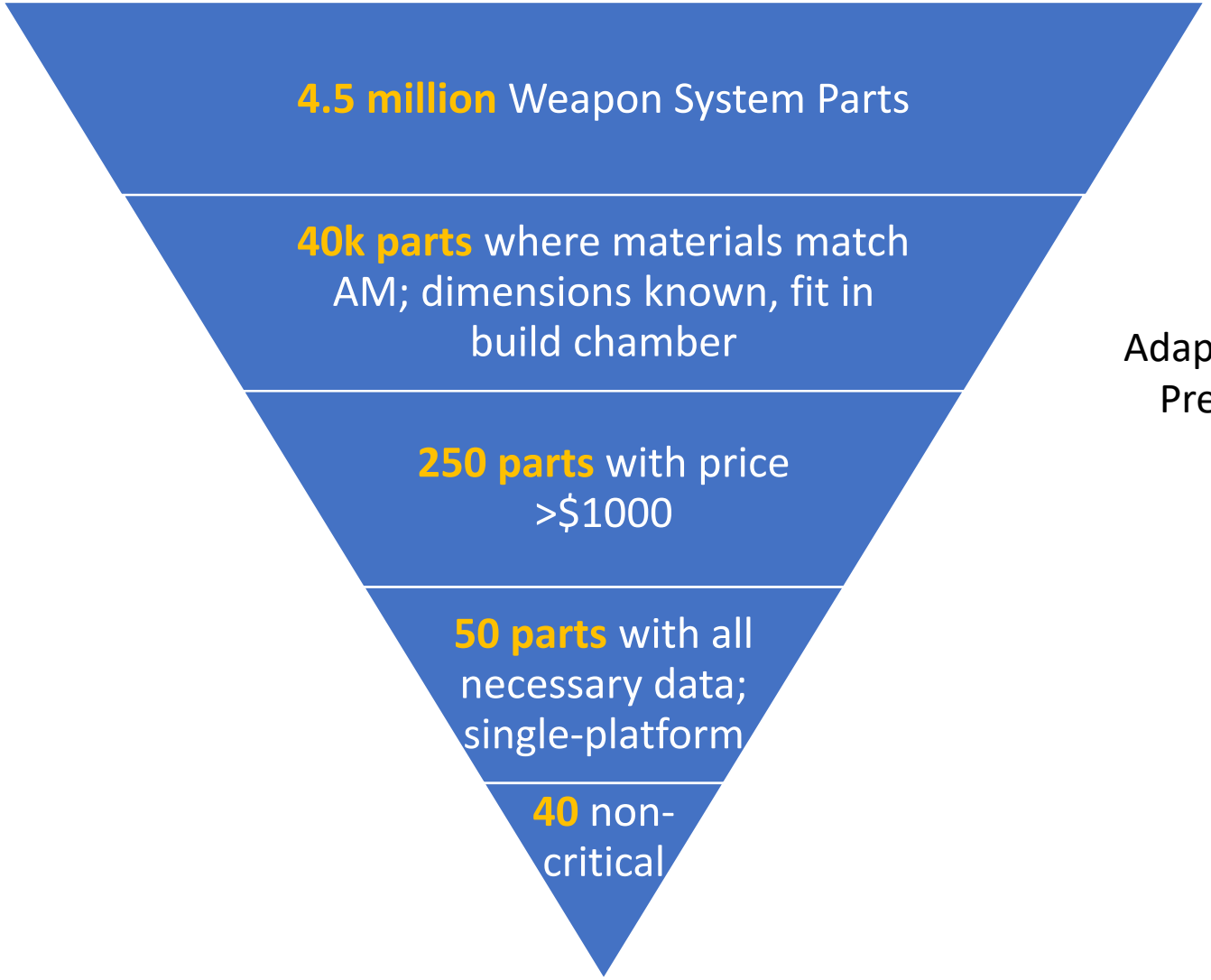
Example Case:
Metal Additive Manufacturing (MAM) for Aerospace

- Economic impact
  - Largest export value of U.S. manufactured goods (civilian engines and airframes)

  (US Census Bureau 2017)
- High barriers to new technology adoption
  - High risk industry with low tolerance for production uncertainty

  (Bonnin Roca et al 2017)
- State of maturity
  - MAM immature and tacit, aerospace inherently tacit (Bonnin Roca et al 2017; McNichols 2008)
- High level of expertise
  - Professionals with high level of expertise likely working with tacit cues (Abbott 1988)

Identifying MAM candidates: Many parts, few experts, arbitrary rules



Adapted from Tom Parks (LMI) Presentation at DMC 2015

Implicit Knowledge: Which do you prefer?

Which part has the greater likelihood of being feasible for metal additive manufacturing within the next 5 years?

Compressor Blisk (25cm diameter)

Monocrystalline Turbine Blade (5cm x 15cm)

Source: GE Aviation, Wikimedia Foundation

Explicit Knowledge: What do you care about?

How does this part rate on the following attributes?

Monocrystalline Turbine Blade (5cm x 15cm)

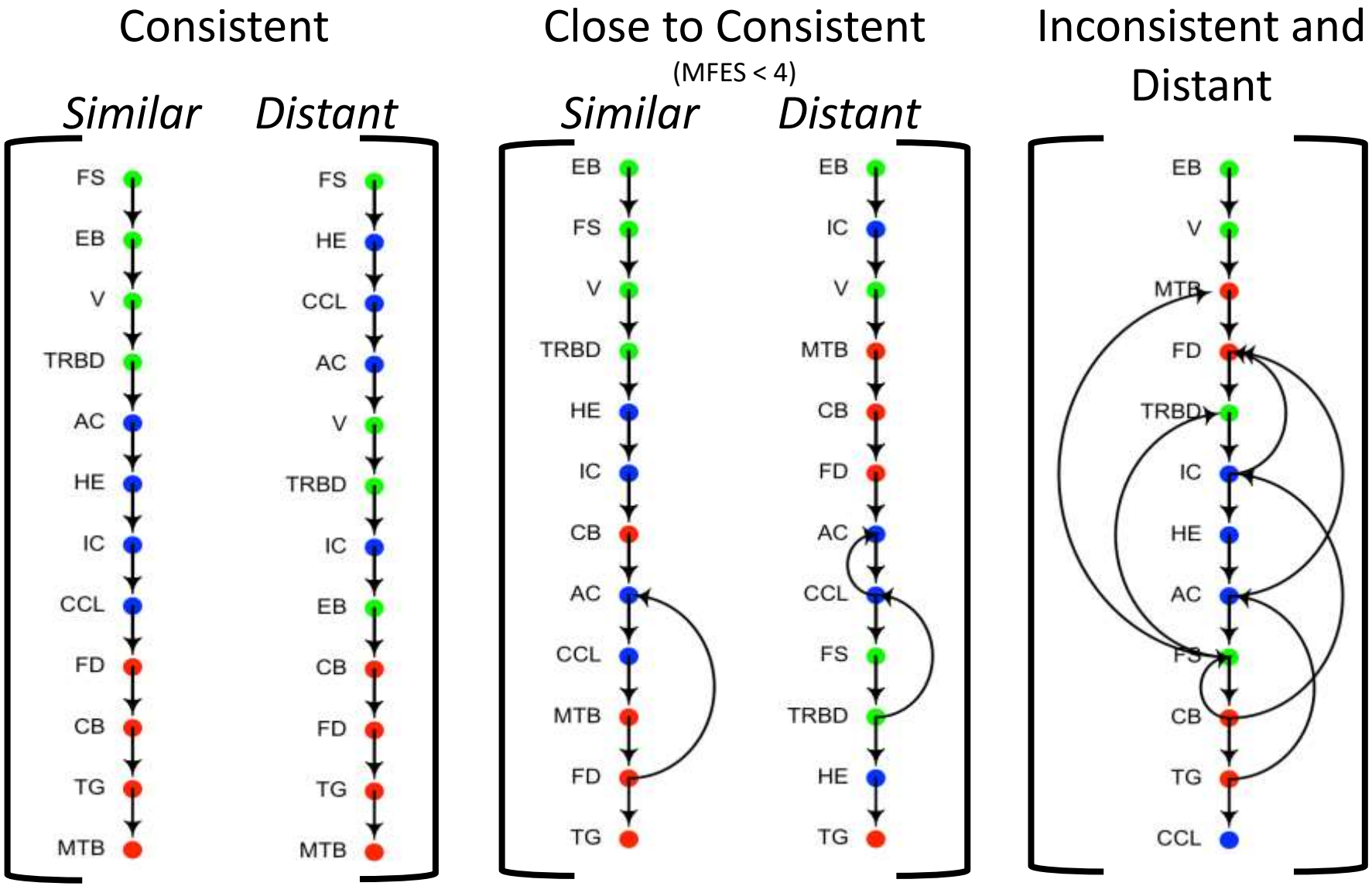
Source: Wikimedia Foundation

Economics:

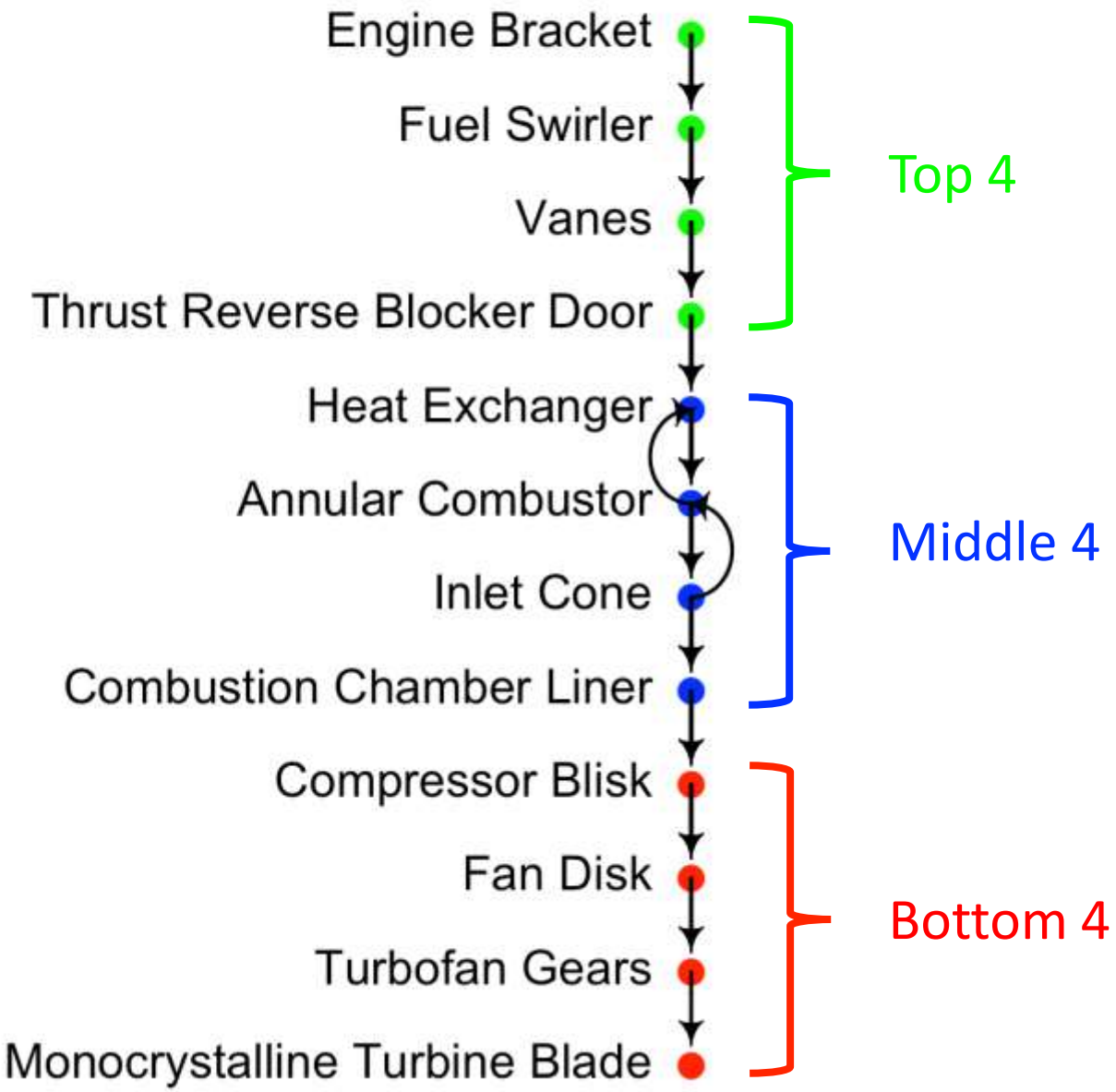
To what extent can a business case be made to produce this part using additive manufacturing?

Not at all	Slightly	Moderately	Very	Extremely
○	○	○	○	○

Experts disagree (even with themselves!)

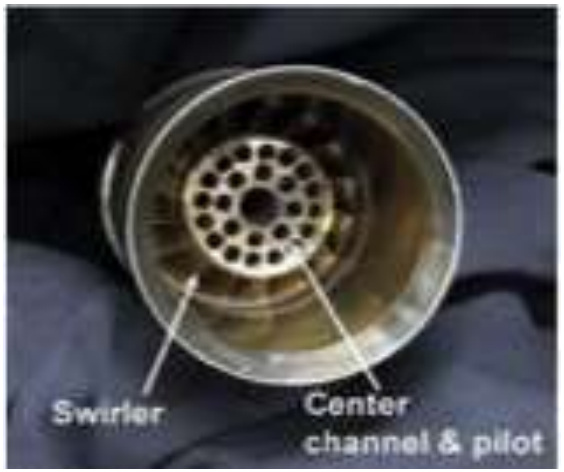


Aggregate experts are more consistent



Comparison to Filter Method (LMI)

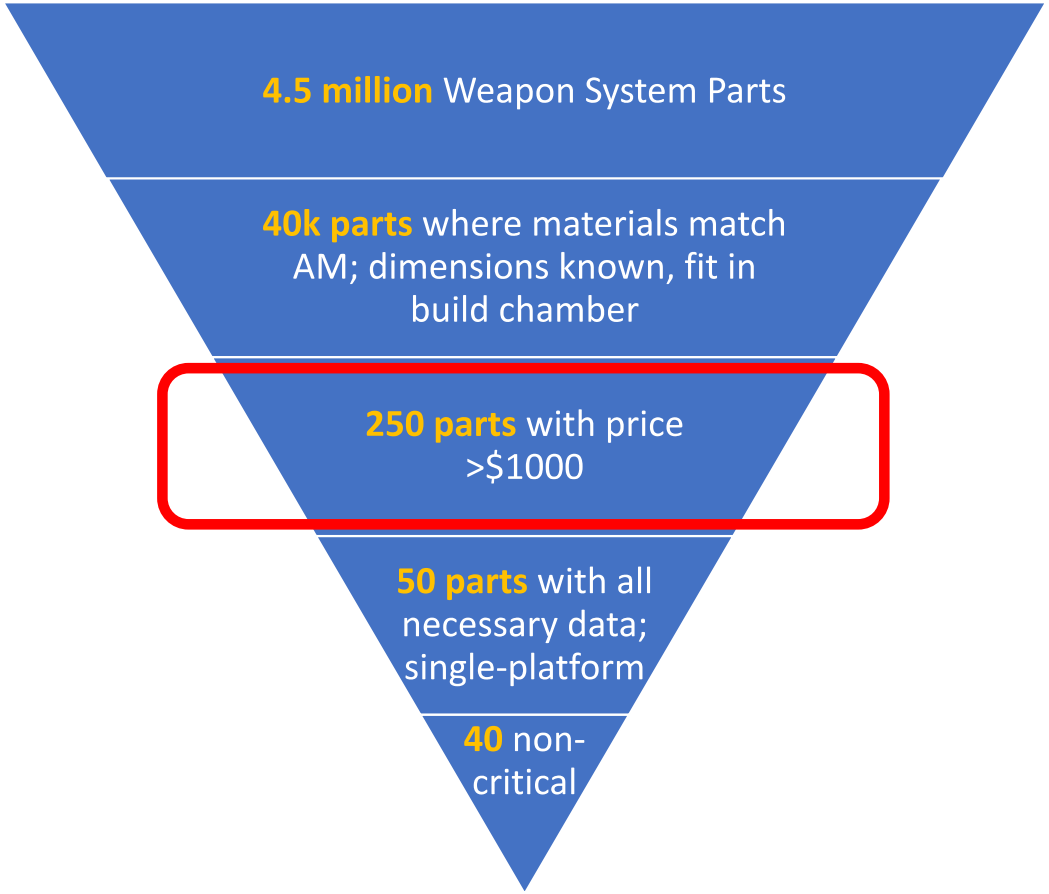
Fuel Swirler



Source: Lawrence Berkeley National Lab

LMI: Excluded (price)

Our Method: High economic value (likely undervalued)
Low criticality
= 2nd part in average preference order and DCM



Adapted from Tom Parks (LMI) Presentation at DMC 2015

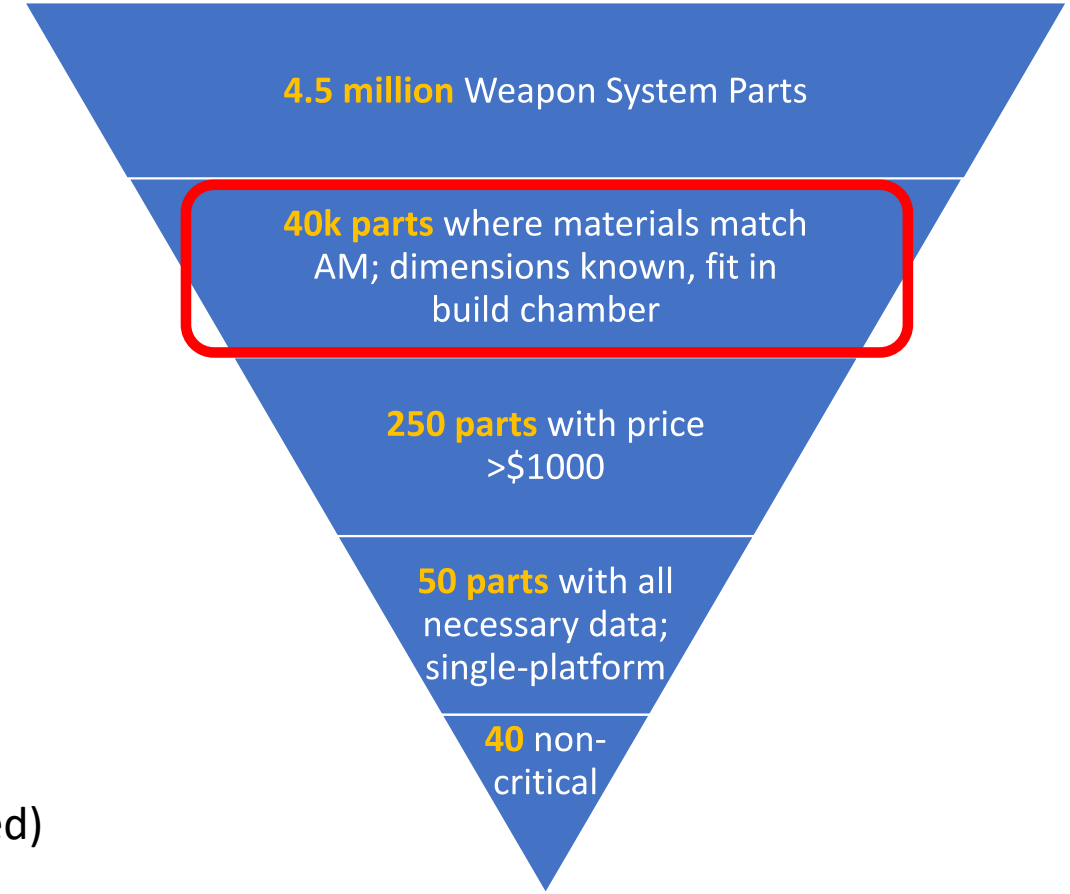
Comparison to Filter Method (LMI)

Vanes

Source: Ebay

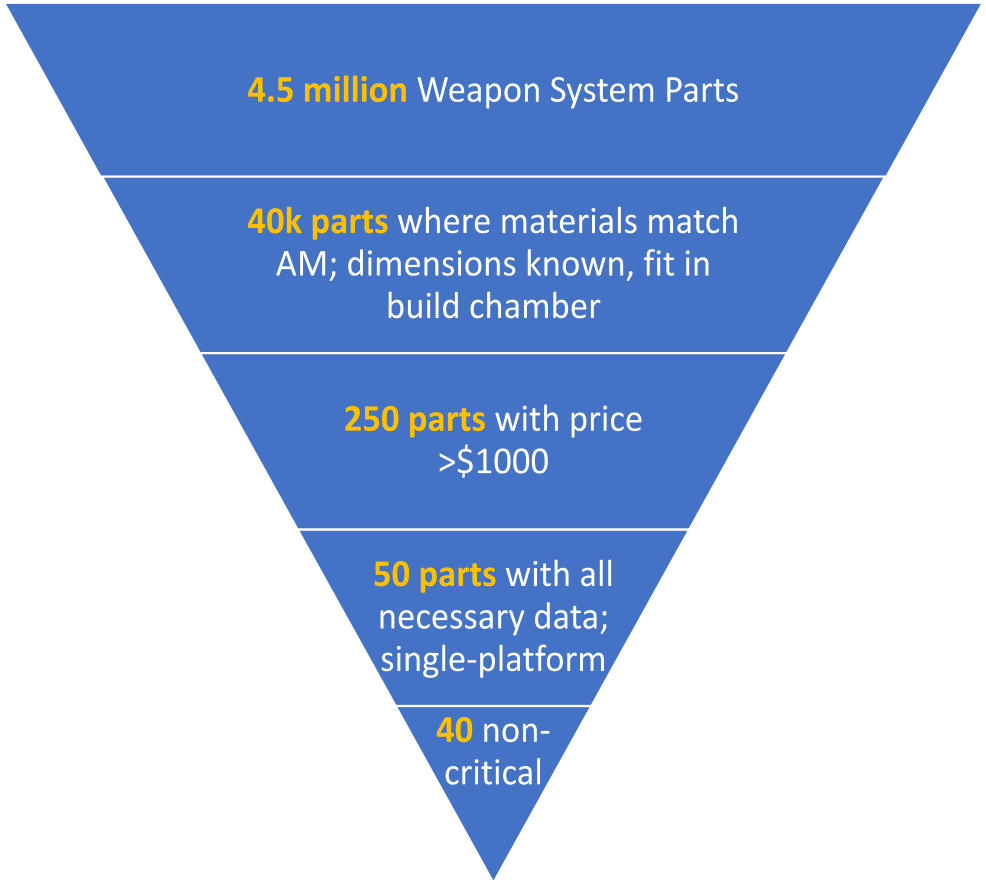
LMI: Excluded (size)

Our Method: High economic value (likely undervalued)
Average criticality
= 3rd part in average preference order, middle in DCM



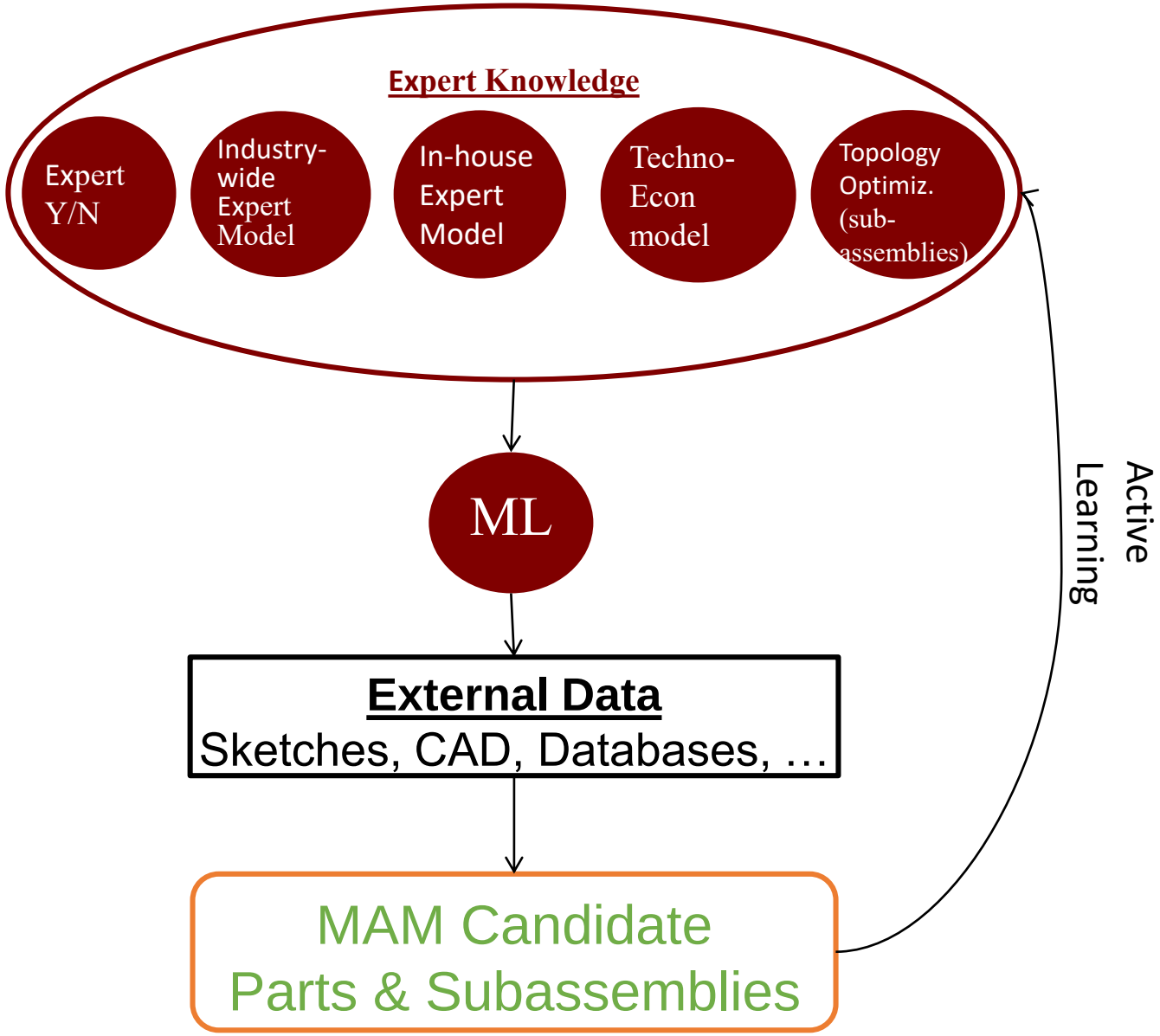
Adapted from Tom Parks (LMI) Presentation at DMC 2015

Better Methods Move the Industry Forward



Adapted from Tom Parks (LMI) Presentation at DMC 2015

(Current Best Practice)



Better Methods for Individual Businesses

We can aid experts in technology commercialization questions like:

- Do we adopt the tech?
- Where in our business do we apply it?
- Who has the expertise? Where do we get it?

Our process measures and systematizes decision making practices within a business or consortium, providing

consistency, repeatability, and interpretability

Thank you

Patrick Funk

PFunk@cmu.edu

Engineering and Public Policy

Carnegie Mellon University

digitalbridge 2018

PITTSBURGH'S INDUSTRY 4.0 CONFERENCE

Bank of America Merrill Lynch

COMCAST BUSINESS

ARM ADVANCED ROBOTICS FOR MANUFACTURING

ectobox

America Makes

RiverPoint TECHNOLOGY

INTERSTACKS

datanomix

PA MEP PENNSYLVANIA MANUFACTURING EXTENSION PARTNERSHIP

CATALYST CONNECTION Your Strategic Partner for Manufacturing Growth