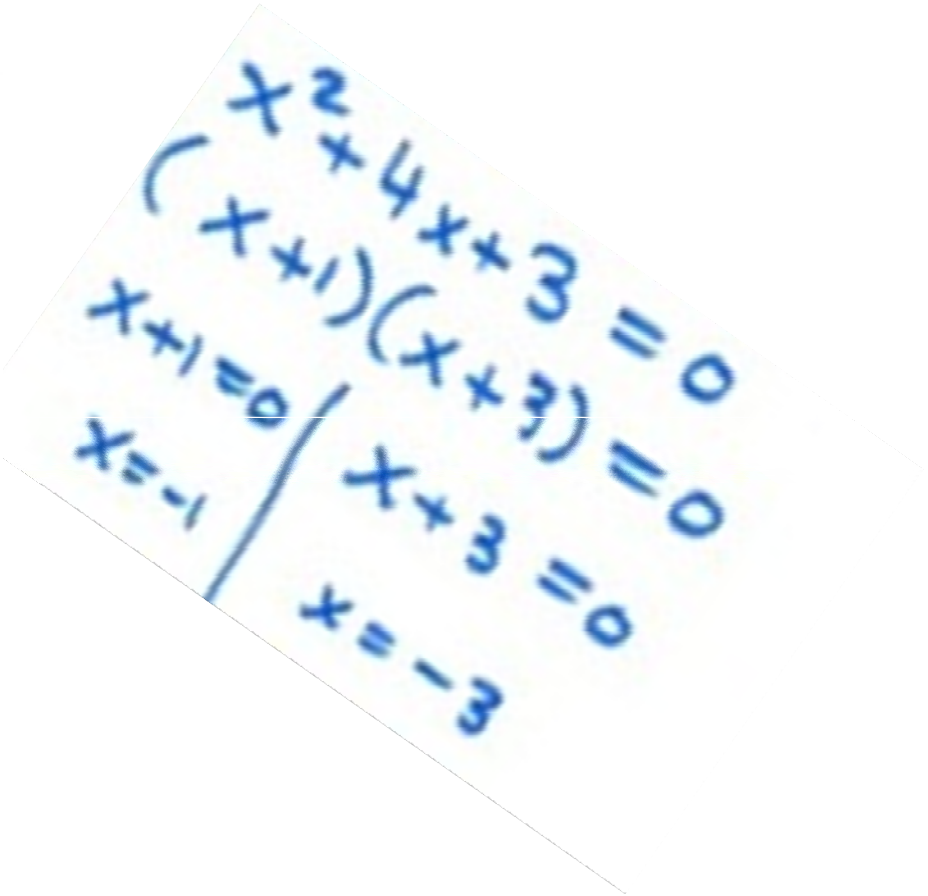
Factoring the Impact of Additive Manufacturing

A model for university, industry, & government collaboration



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One Industry Perspective

1. Development Pipeline

2. Product life cycle

3. Purchasing scale

Intellectual Property Perspective

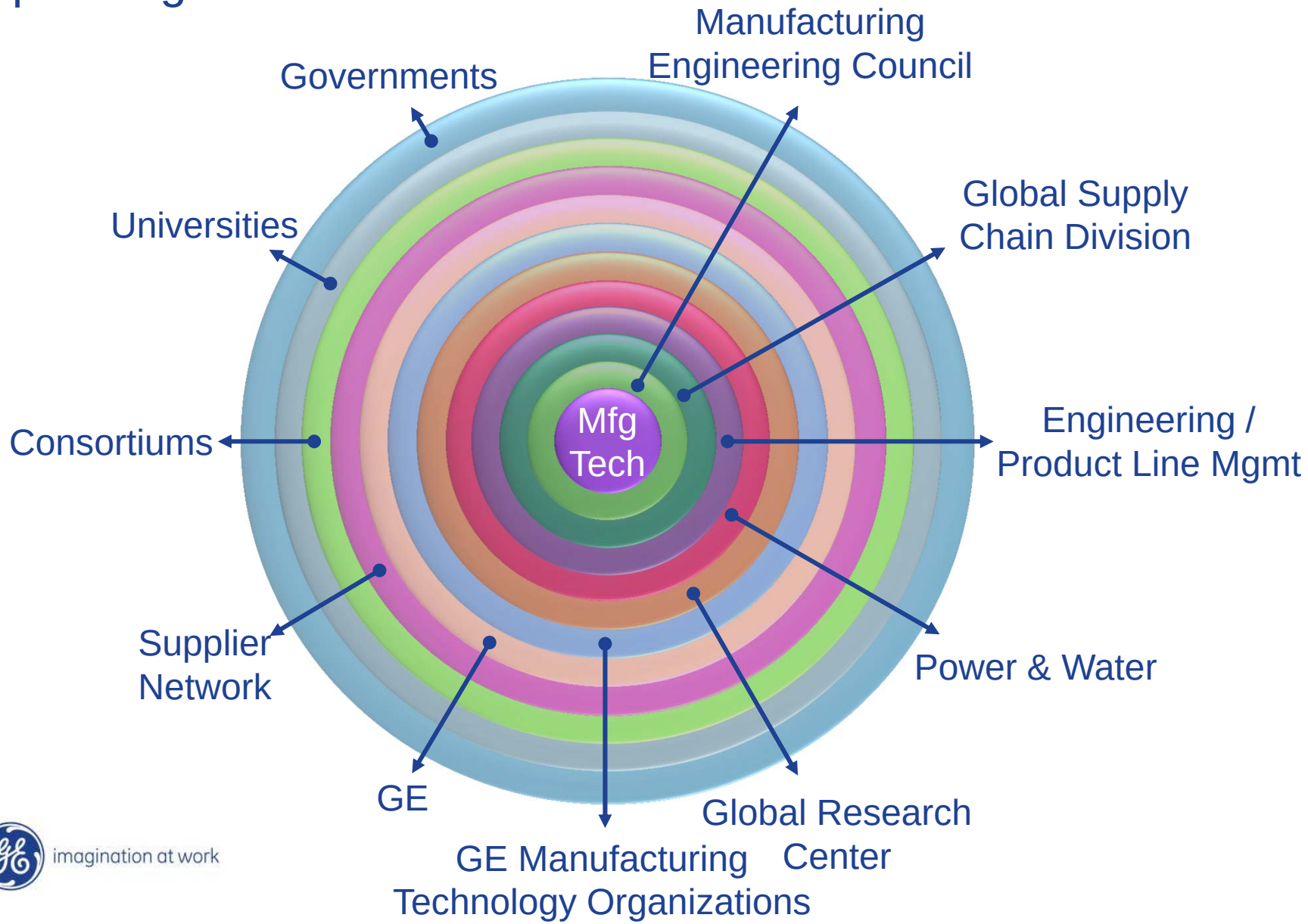
"That ideas should freely spread from one to another over the globe, for the moral and mutual instruction of man, and improvement of his condition, seems to have been peculiarly and benevolently designed by nature, when she made them, like fire, expansible over all space, without lessening their density in any point, and like the air in which we breathe, move, and have our physical being, incapable of confinement or exclusive appropriation. Inventions then cannot, in nature, be a subject of property."

Thomas Jefferson, 1813

Winners will be decided by Speed & Intellect
(i.e. the best collaborators)

Manufacturing Technology

Operating Model



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Technology Transition

Technology Transfer Criteria

Manufacturing Readiness Levels

Processes

- Variables and parameters established

Development Resources

- Production representative development/optimization assets available

Infrastructure

- Equipment specifications, product flow, plant design, and supply chains in place

People

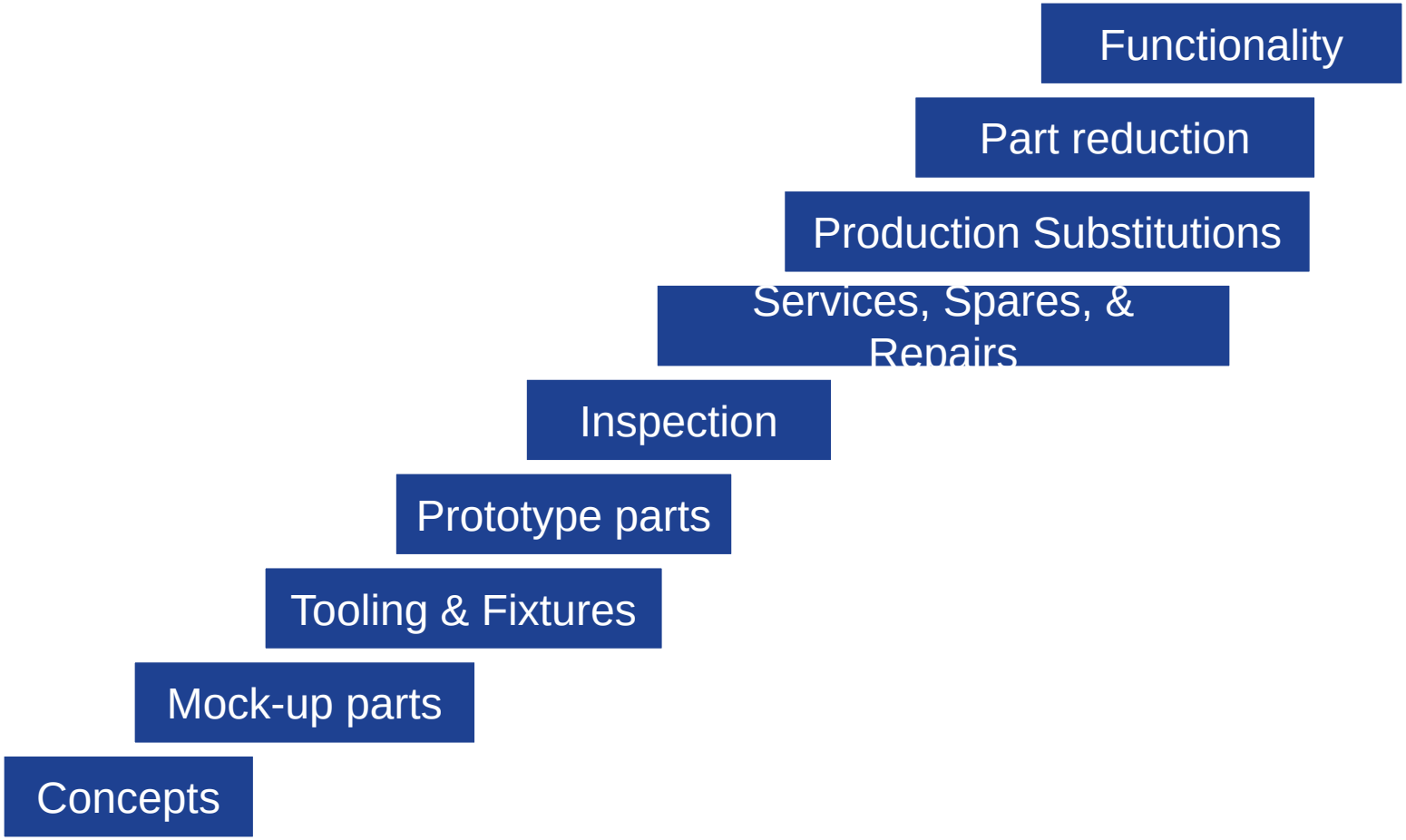
- Skill sets define, training available

Tools & Information

- Design practices, analysis methods, process specifications, quality requirements, cost models

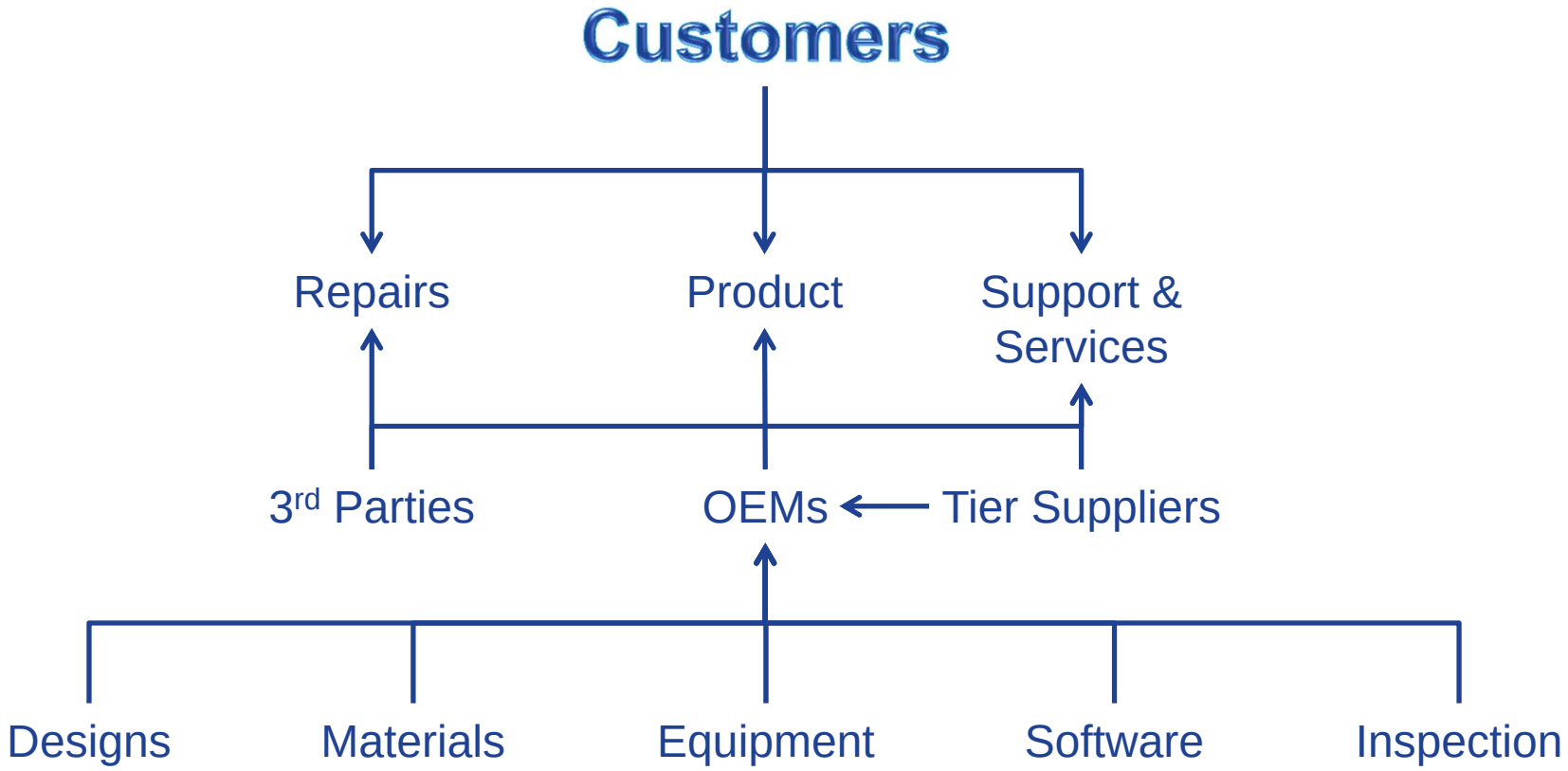
Progression of AM Applications

Change DFM paradigm… “make what we can design”



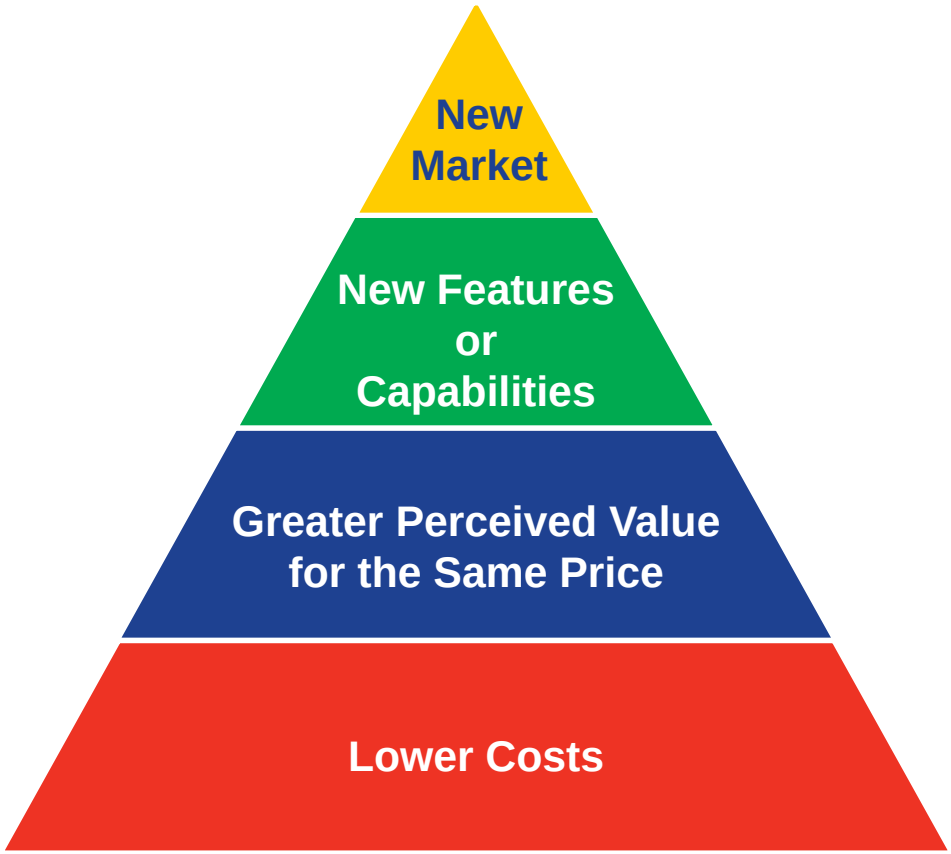
Additive Manufacturing Factors

Additive Manufacturing Breakdown



Level 0 - Customer Perspective

Why would a customer select an additive manufactured product



Level 1 - Industry Capacity

Scale

Rate

Standardization

Processes

- Consistency from run to run and machine to machine or process to process

Development Resources

- Limited configurability

Infrastructure

- Changing rapidly

People

- Small pool

Tools & Information

- Proprietary
- Generic

Level 2 - Design

Functionality

Design & Producibility Rules

Processes

- Repeatability

Resources

- Adapting traditional subtractive

Infrastructure

- N/A

People

- Creativity to think in additive dimensions

Tools & Information

- CAD/CAM

Level 2 - Materials

Metals

Polymers

Ceramics

Processes

- Microstructures
- Alloying
- Residual stresses
- Bi-material processing

Resources

- Adapting pre-existing materials

Infrastructure

- Limited material supply base
- Captive material supply

People

- Materials science, chemist

Tools & Information

- Properties testing & variation

Level 2 - Equipment

Cabinets

Beds

Laser

Electron beam

Heating source

Nozzles

Mechanical

Electrical

Controls

Processes

- Repeatability

Resources

- Larger and/or specialized
- Controls
- Software

Infrastructure

- Reliability
- Maintainability

People

- Multi-discipline skill set
- Tear down & rebuild

Tools & Information

- Sensors/feedback
- Process simulation

Level 2 - Software

CAD

STL file formats

Layering

3D Nesting

Integration

Processes

- Errors
- Orientation

Resources

- Captive

Infrastructure

- Not well integrated

People

- Specialization in 1 s/w

Tools & Information

- Need improved file transfer

Level 2 - Inspection

Destructive

Radiography

Computed tomography

Infrared thermography

In-situ

Processes

- Probability of detection undefined

Resources

- Basic inspection technologies are in place
- Selecting appropriate techniques

Infrastructure

- Utilizing commercial technologies

People

- Process knowledge

Tools & Information

- Stronger understanding of processing principles required

Summary

Model for evaluation of technology transfer readiness

1. Greater collaboration and inclusion of multiple disciplines
2. Progression of additive manufacturing applications

Additive Manufacturing Factors			Processes	Resources	Infrastructure	People	Tools & Information
Customers							
	OEMs						
	Tier Suppliers						
	3rd Parties						
		Designs					
		Materials					
		Equipment					
		Software					
		Inspection					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