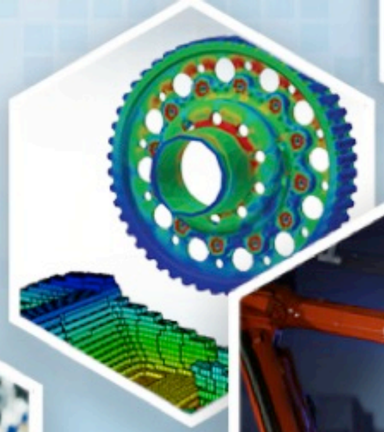
The Internet of Things (IoT) and How It's Impacting Next Generation Manufacturing

Doug Adams, IACMI NDE Tech Fellow



THE COMPOSITES iacmi INSTITUTE

Photo credit
Dale Brosius

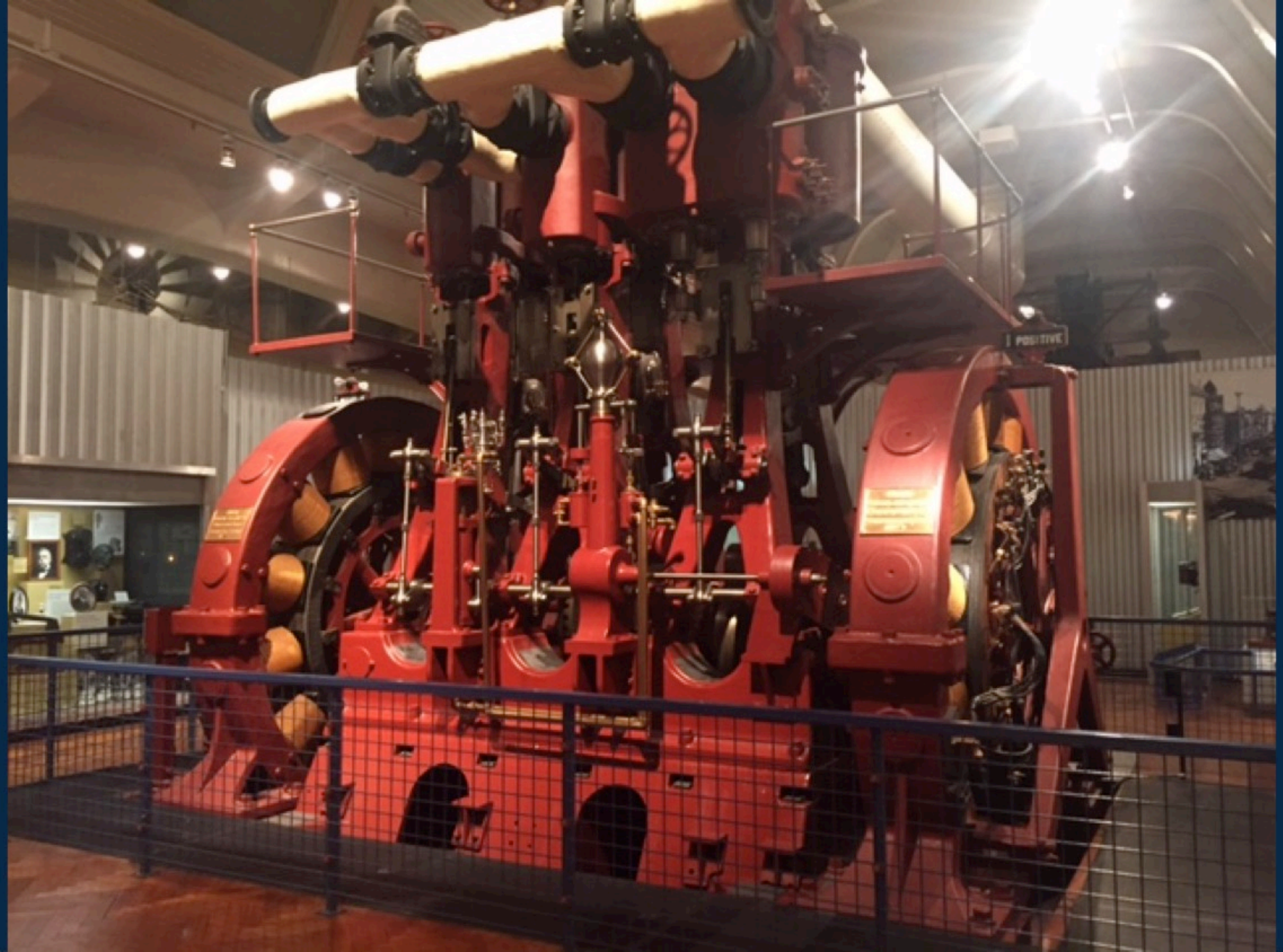
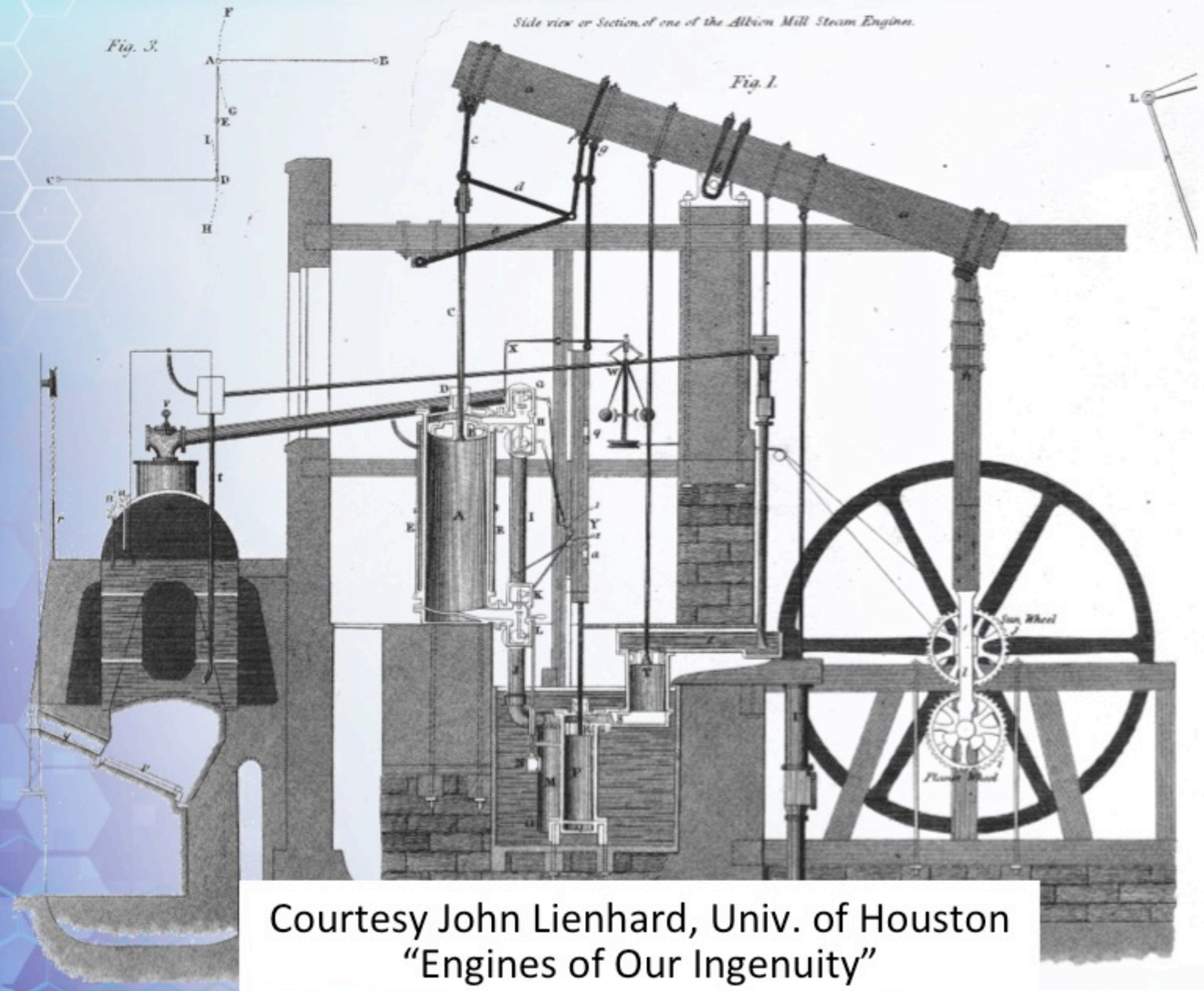


Photo credit
Dale Brosius

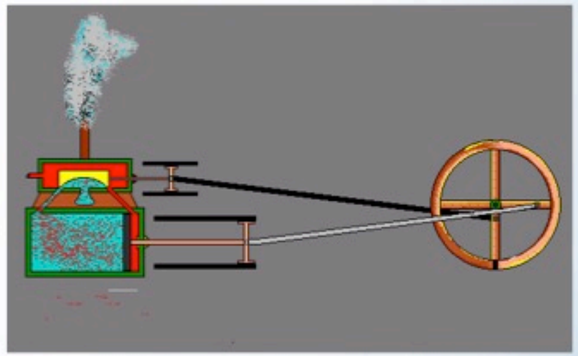
Photo credit
Dale Brosius

Powering the first industrial revolution



Courtesy John Lienhard, Univ. of Houston
"Engines of Our Ingenuity"

- Steam power
  - transformed nearly every industry
  - transportation and energy
  - connected businesses



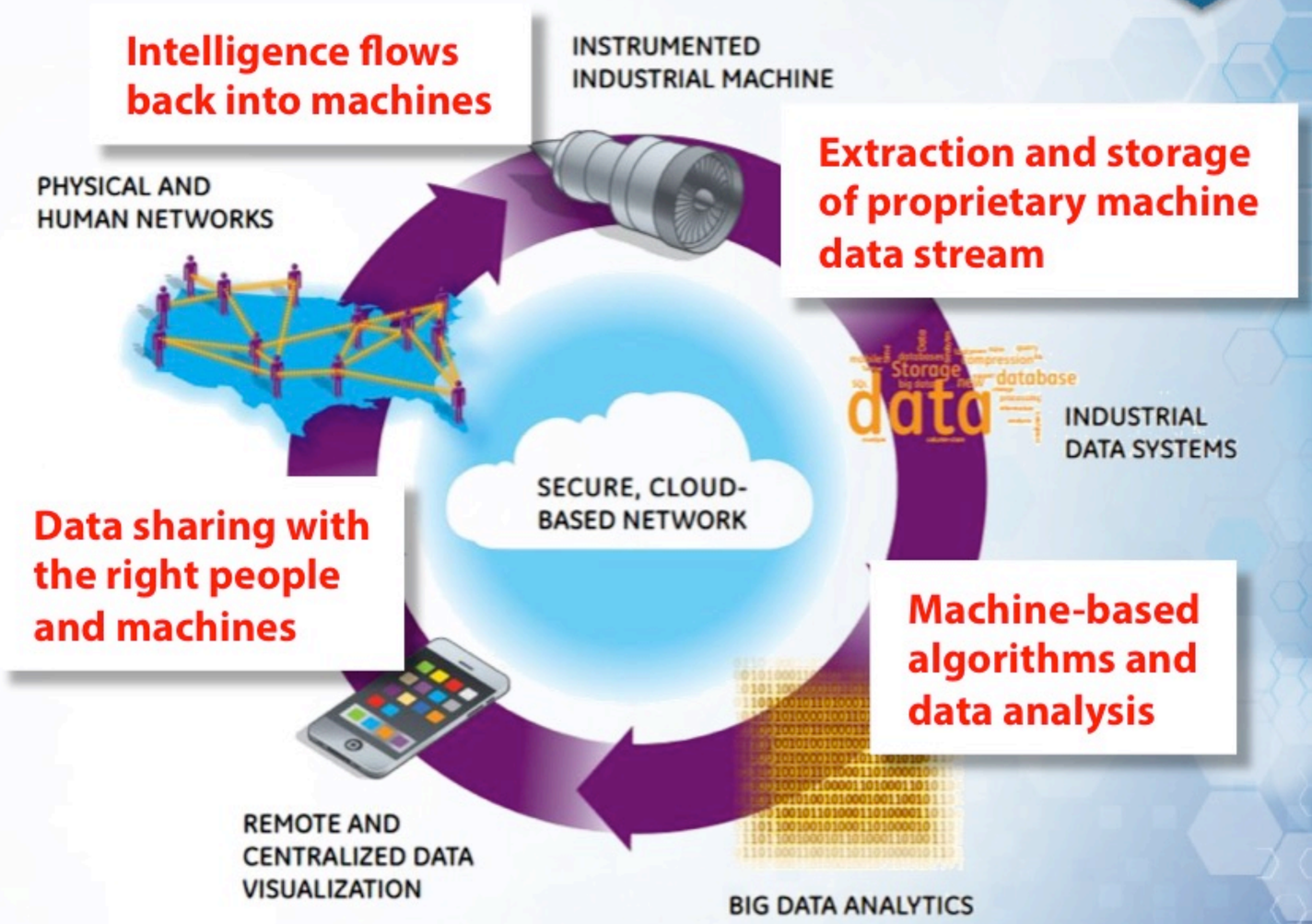
Courtesy giphy.com

Powering the next industrial revolution

- The IoT enables us to,
  - **Acquire** data
  - **Analyze** data
  - **Understand** data
  - **Act upon** data

across the supply chain

- Is this useful for the composites supply chain?



Source: General Electric

Moving fast with IoT

- High volume manufacturing relies on moving fast with cost targets while achieving uniform flow, cure, etc. in spite of variations.

Mapping of Recent Strategic Alliances in the Automotive Industry Related to Carbon Composites

Auto OEMs	Targeted Technology	Targeted Cycle Time	CF Stakeholders
DAIMLER	HP-RTM	Cycle Time: <10 Minutes	TORAY
BMW	HP-RTM	Cycle Time: <10 Minutes	SGL GROUP
Lamborghini	Forged Composites, RTM	Cycle Time: 6 to 10 Minutes	Callaway
LEXUS	Prepreg Layup, RTM, SMC	Cycle Time: Unknown	TORAY
Ford	CFRTP	Cycle Time: Unknown	DOW
GM	CFRTP	Cycle Time: 1 Minute	TohoTenax
McLaren	HP-RTM	Cycle Time: <3 Minutes	Carbo Tech
Chrysler	Press Molding	Cycle Time: 6 to 10 Minutes	Gurit

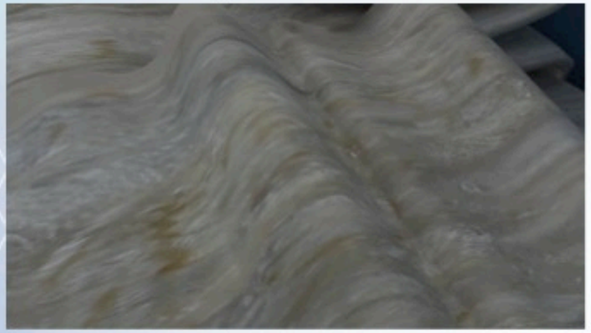
Source: Luncintel

10 minutes

1 minute !

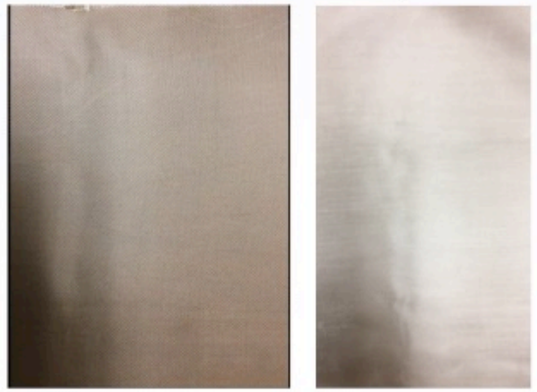
Connectivity across the composites industry

Fiber production

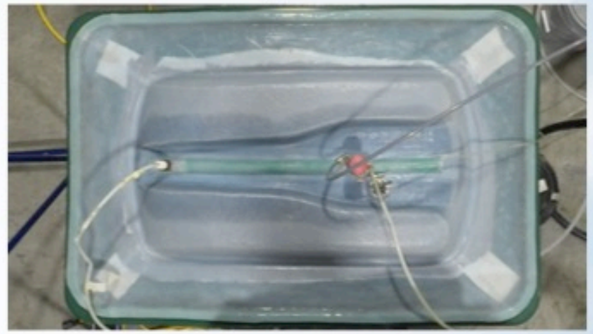


Courtesy ORNL CFTF (Cliff Eberle)

Preforming

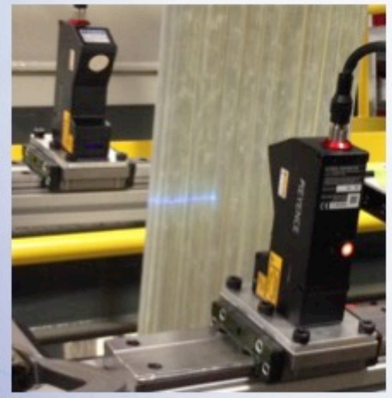


Infusion

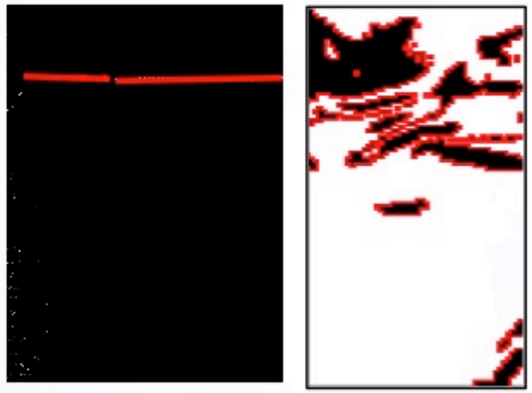


Collaborate with Uday Vaidya, UTK

Composites supply chain



In-line diagnostics of tow form



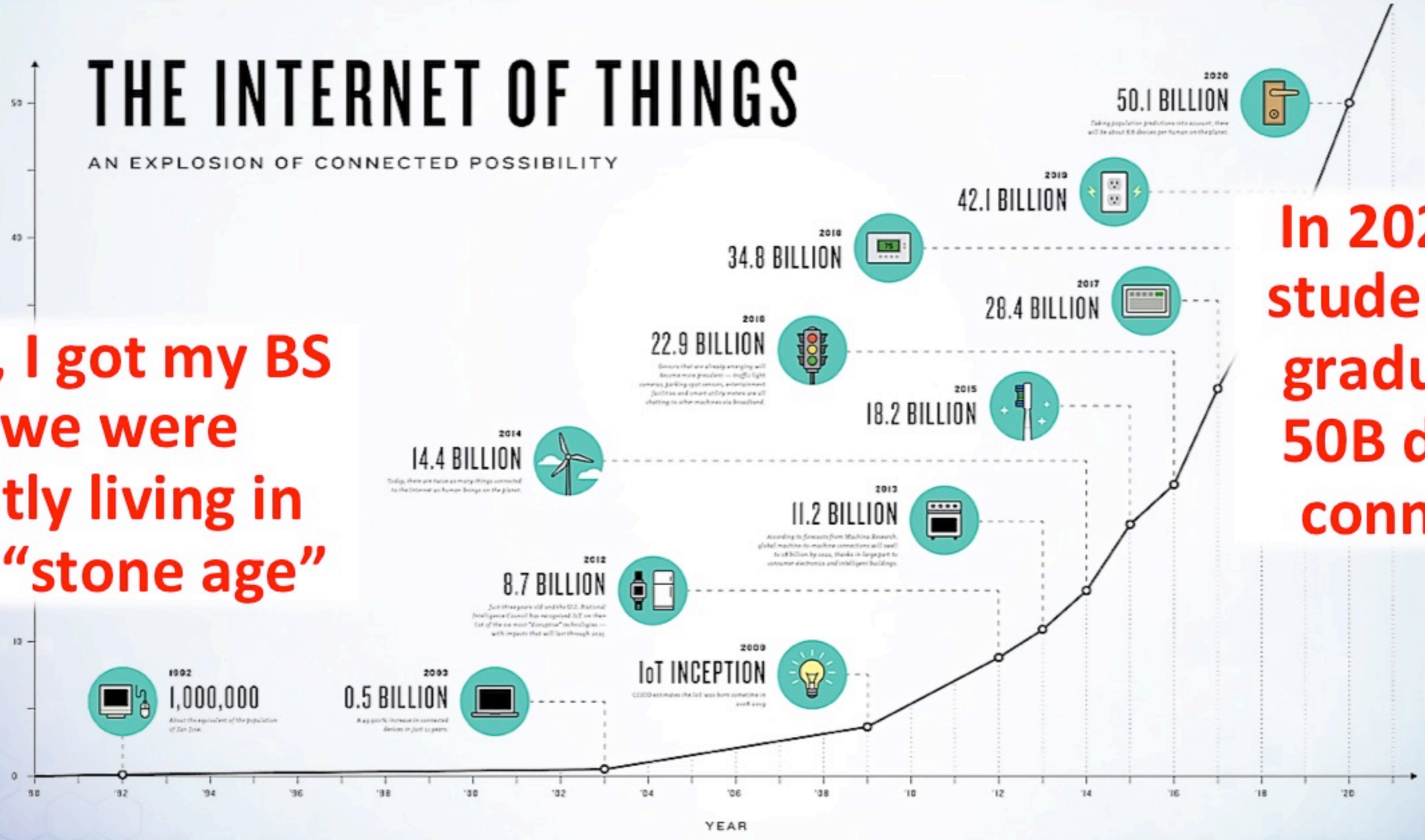
Data analytics for preforming

RTM flow and cure state monitoring

How do we enable IoT
to enable high volume manufacturing
when sensors/models/data are high volume?


FLIR
~68.4 °F
IRON
TIME-LAPSE
PANO
PHOTO
VIDEO
Build on
connected
and secure
platforms…

The pervasiveness of connectedness



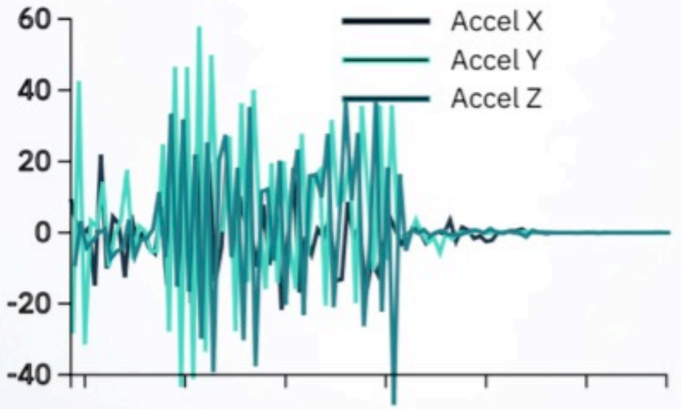
In 1994, I got my BS and we were evidently living in the IoT "stone age"

In 2020, our students will graduate to 50B devices connected

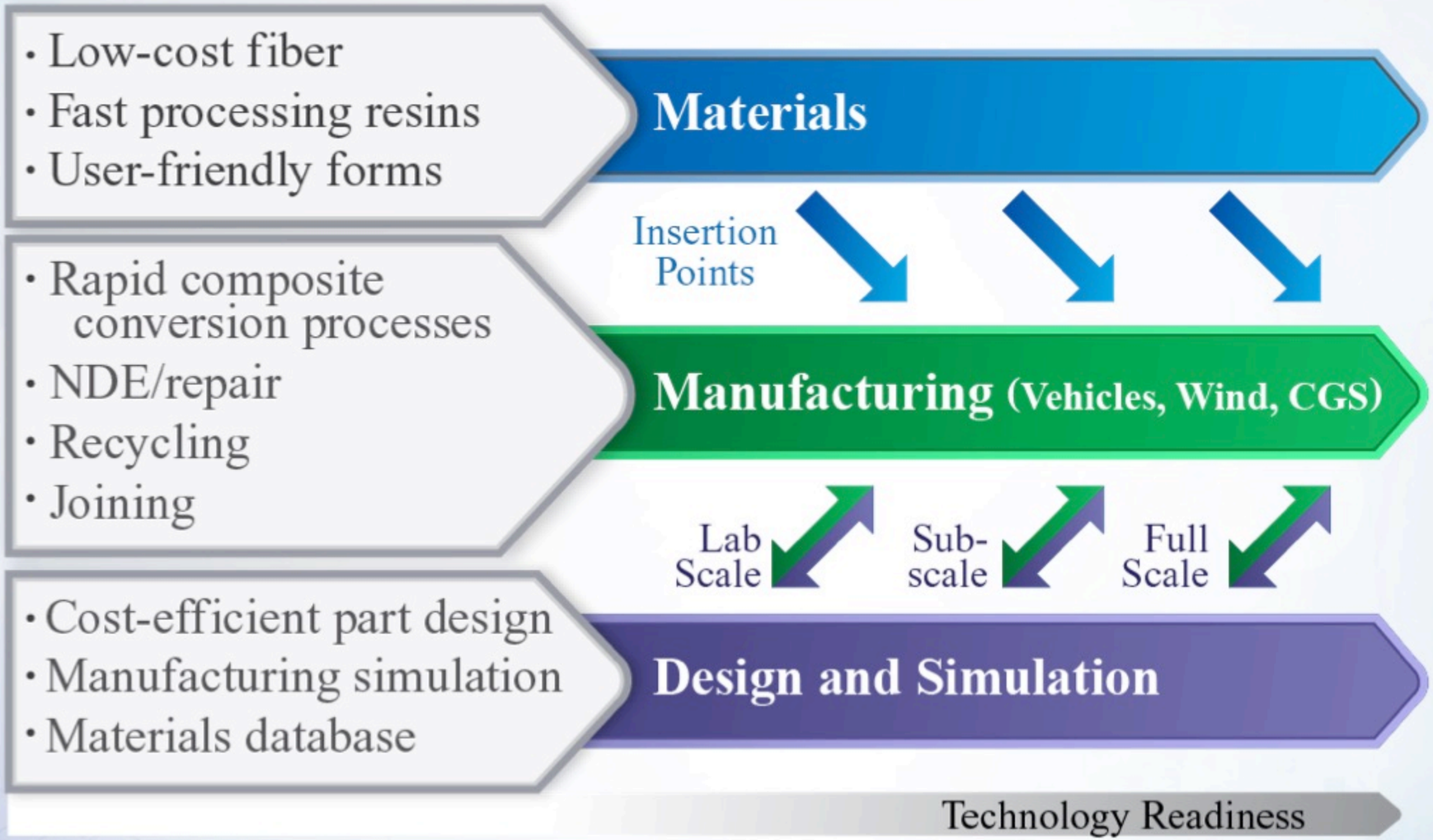
IoT – Accessible and pervasive

IBM Watson IoT Platform

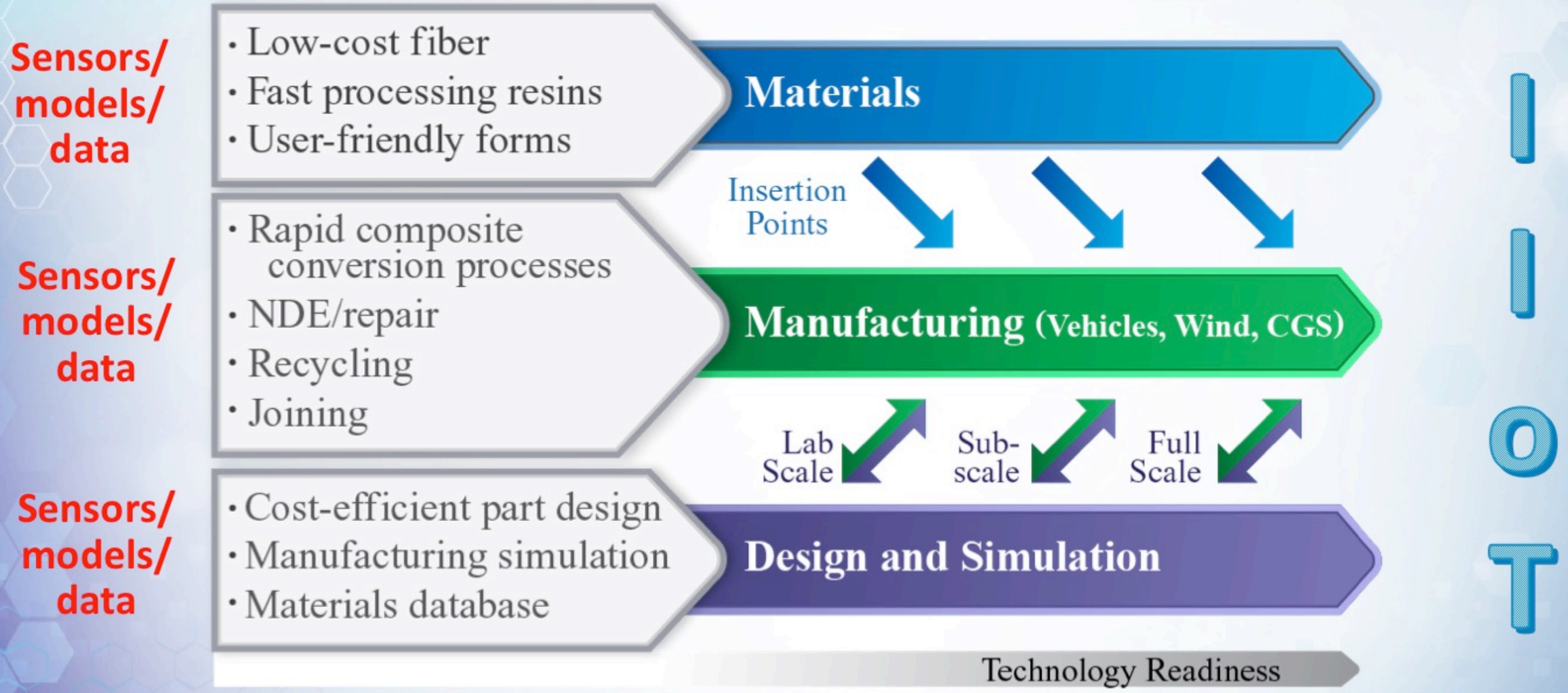
- Connectivity
  - is transforming society, industry and our behavior
  - $14T to global economy 2030
  - http://iotworm.com



IACMI's model of connectivity and integration

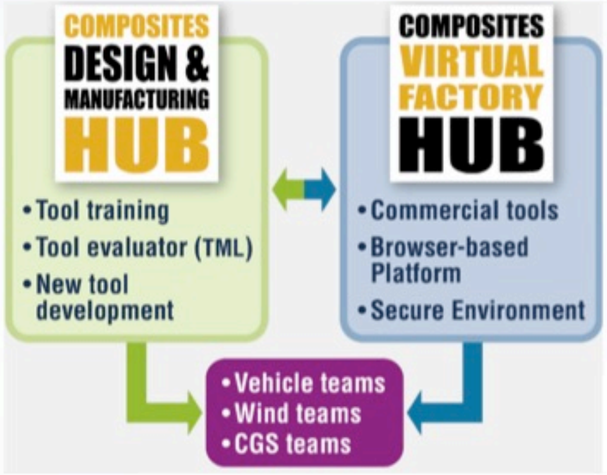


IACMI's model of connectivity and integration



Example of connectivity – integrated, validated simulation tools

- Simulation provides a foundation for revolution in composites design, manufacturing and qualification



- Finger tip access to composites simulation tools anywhere anytime on any devices including smart phones (HPC resources in the cloud)

The image part with relationship ID rId5 was not found in the file.

PURDUE UNIVERSITY

The image part with relationship ID rId5 was not found in the file.

Purdue's Composites HUB Tools for enabling IIoT

- Purdue's cdmHUB and cvfHUB will put integrated and validated simulation tools in the hands of subject matter experts and Tier I–II suppliers
  - cvfHUB: Deliver a comprehensive suite of commercial simulation tools for center of excellence project teams

Integration of many major commercial simulation tools

CONVERGENT MANUFACTURING TECHNOLOGIES

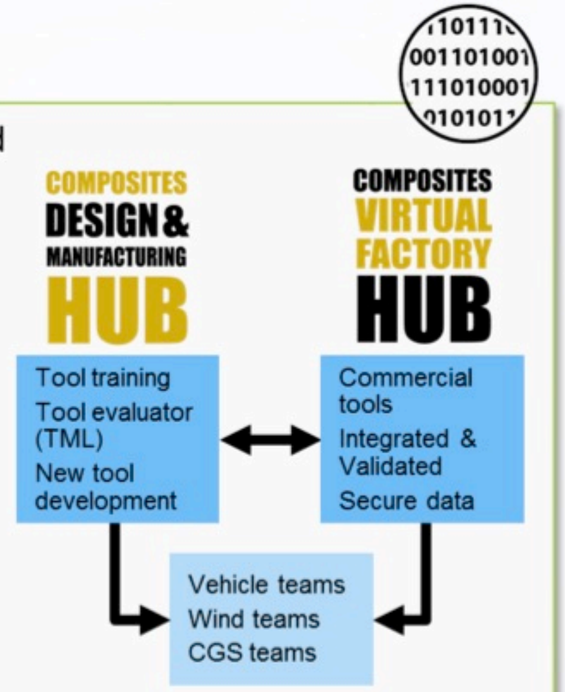
SwiftComp™ MICROMECHANICS

DASSAULT SYSTEMES

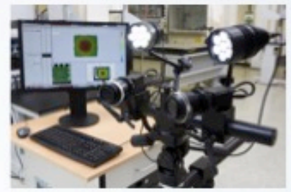
esi get it right®

Moldex3D MOLDING INNOVATION

digimat



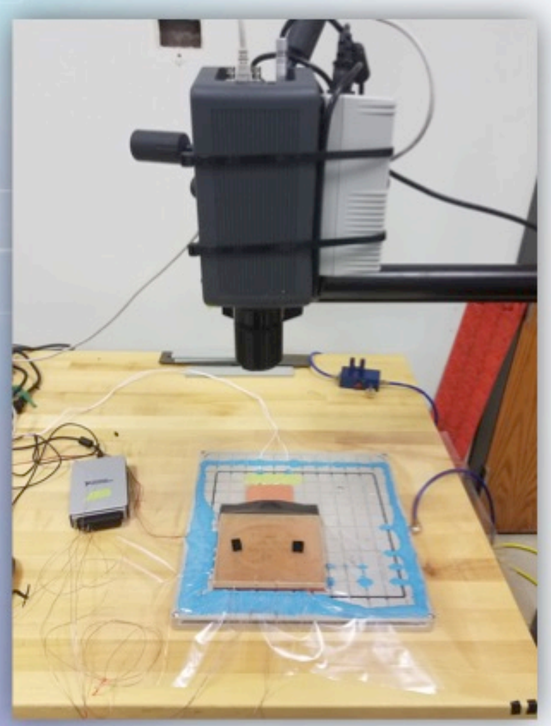
Composites Design & Manufacturing HUB and Composites Virtual Factory HUB



Validation & Verification Capability Installed

IIOT

Example of connectivity – manufacturing equipment



Vanderbilt LASIR facility

Courtesy IACMI – NREL COMET facility

IACMI's scale-up facilities to enable IIoT

Solution spinning line

Carbon Fiber Technology Facility

Pre-preg production pilot/full scale

Pilot-scale PCM 1,000 ton press

Full Scale PCM 4,000 ton press

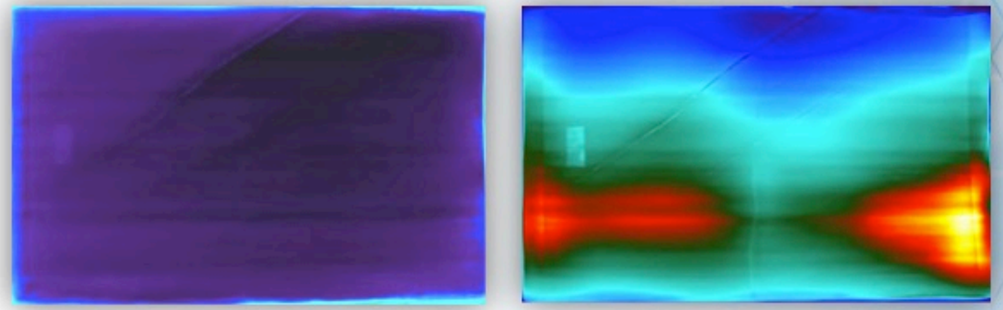
IIoT

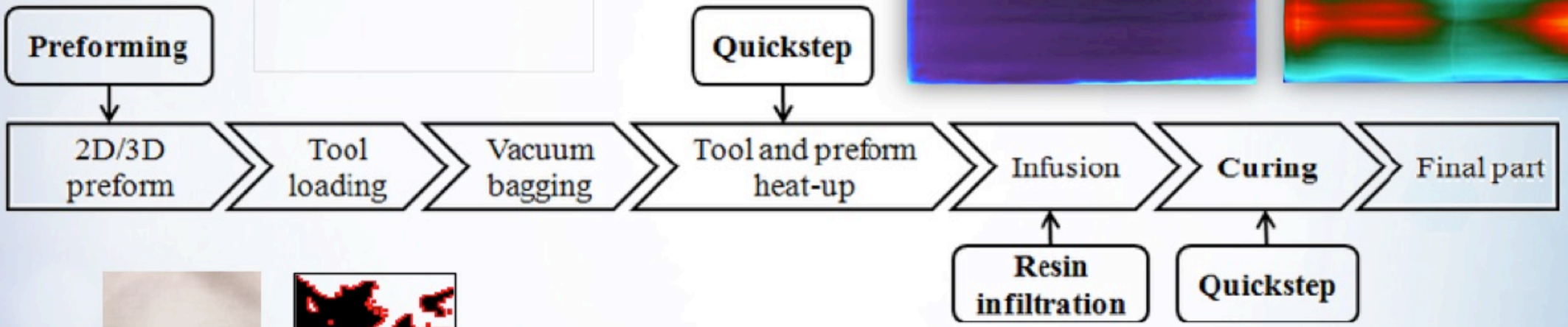
Bringing capabilities together – IoT for VARTM

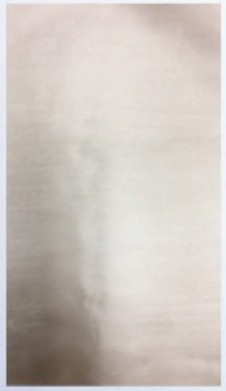
PURDUE UNIVERSITY

The image part with relationship ID rId15 was not found in the file.

Collaborate with NREL, COMET facility







Credit: Ogale, Amol & Schlimbach, Jens. (2011). Quickstep: Beyond Out of autoclave curing. International SAMPE Technical Conference

Thermoplastic Composite Development for Wind Turbine Blades

Collaboration of 11 Industry Partners – Partnership = Opportunity for IIoT

DOWAKSA

CHOMARAT

COMPOSITES ONE®

Johns Manville

CREATIVE FOAM CORPORATION

OAK RIDGE National Laboratory

STRONGWELL

Chem Trend

tpi COMPOSITES

ARKEMA INNOVATIVE CHEMISTRY

Axson

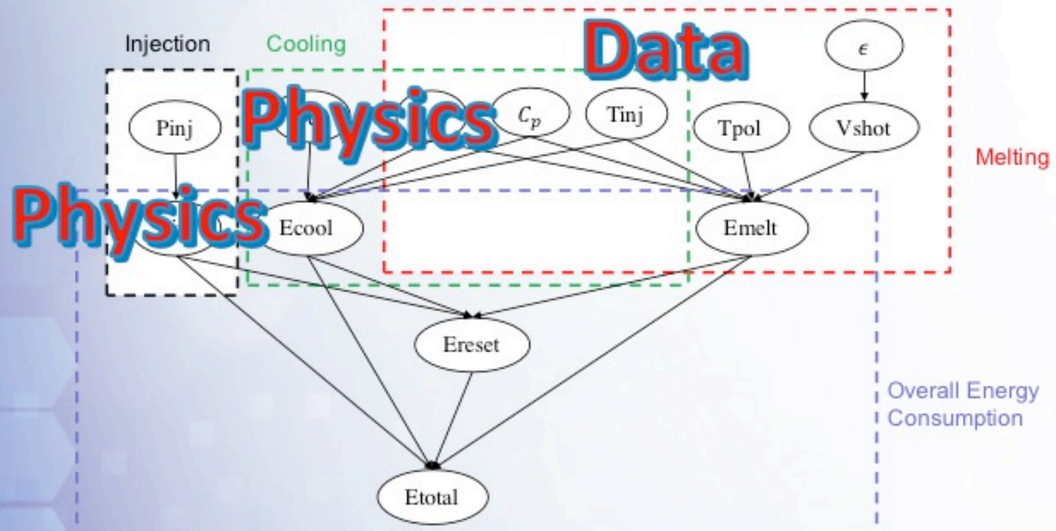
BUILDING TRUST

Sika®

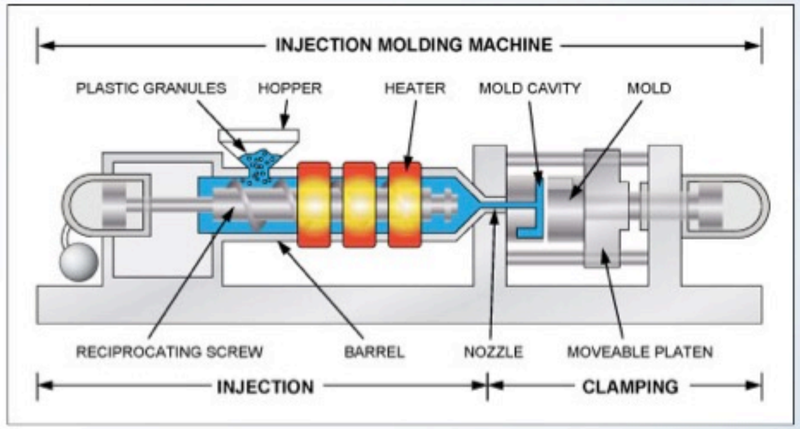
HUNTSMAN

Uncertainty quantification analytics for energy consumption in injection molding (VU/Mahadevan)

- IoT enables powerful analytics such as Bayesian networks to quantify process uncertainties.

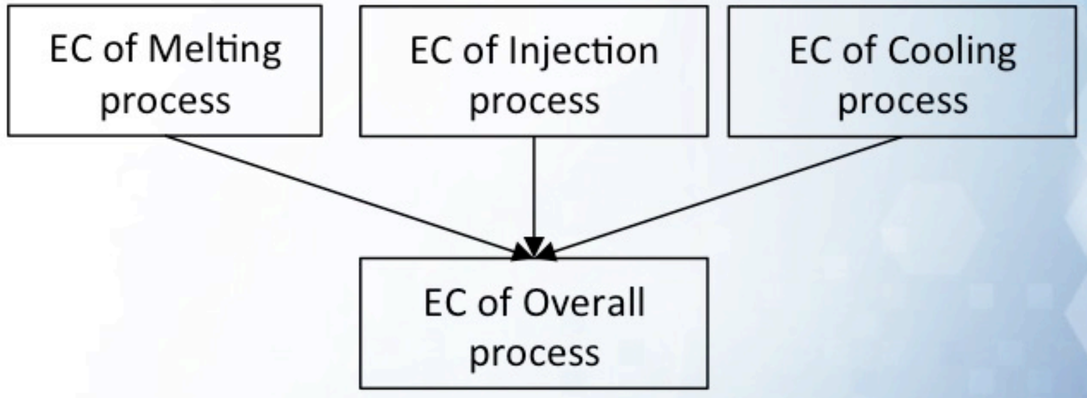


Bayesian Network



Source: http://www.maximintegrated.com/en/app-notes/index.mvp/id/4717

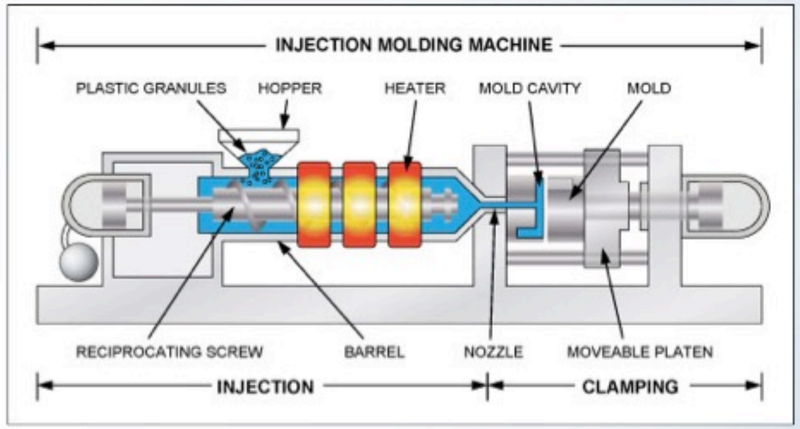
Energy consumption



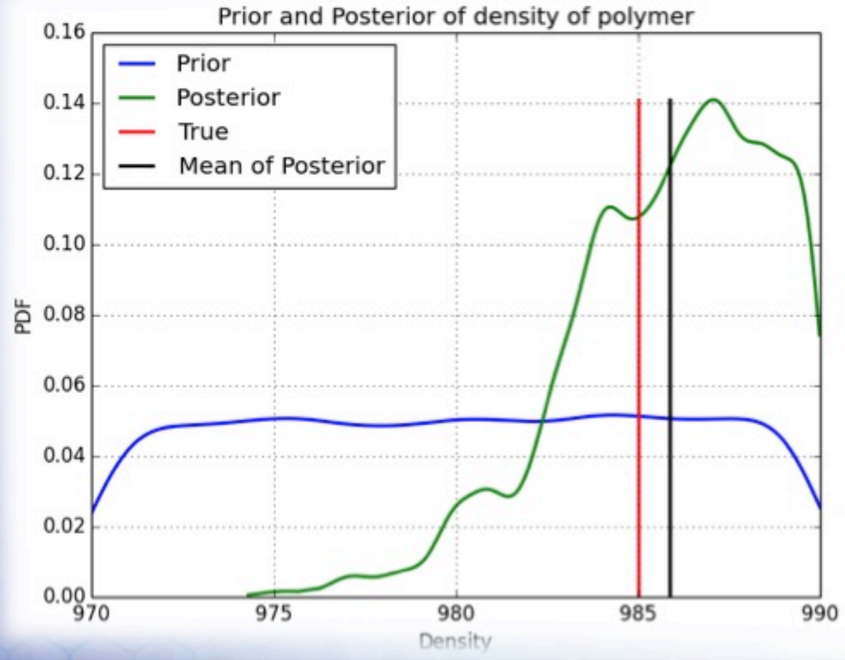
Nannapaneni et al, ASTM SSMS, 2017

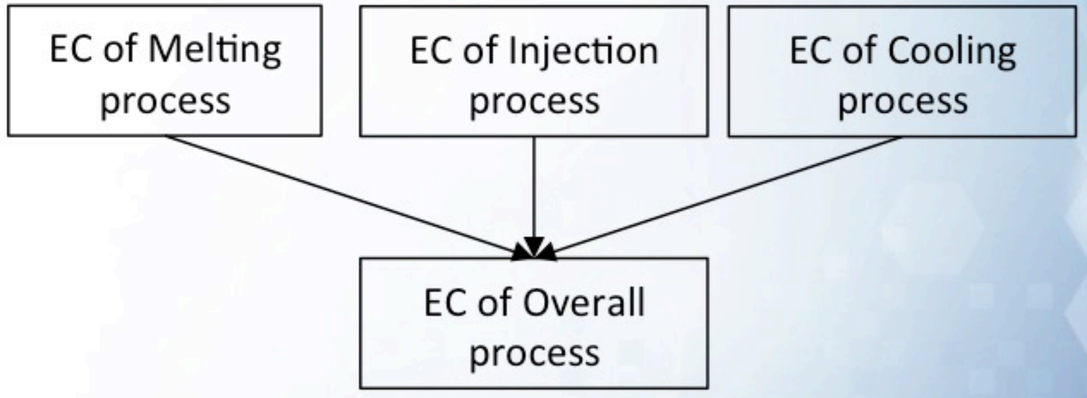
Uncertainty quantification analytics for energy consumption in injection molding (VU/Mahadevan)

- IoT enables powerful analytics such as Bayesian networks to quantify process uncertainties.



Source: http://www.maximintegrated.com/en/app-notes/index.mvp/id/4717





Nannapaneni et al, ASTM SSMS, 2017

THE FOUR INDUSTRIAL REVOLUTIONS

Acquire
↓↑
Analyze
↓↑
Understand
↓↑
Act

Credit World Economic Forum

IIoT


MAX 70
70
mph
300
150
75
kW
-50
Avg. 360 Wh/mi
Past 5 mi
Holiday Deep Dive
Caroling, Caroling
Natalie Cole — Holly & Ivy
2:30
-0:34
252 mi
61°F
3:56 PM
P R N D

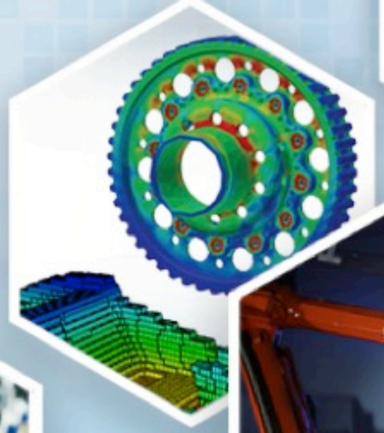
Credit EV Museum

Imagining the future!

IoT in Manufacturing & Mobility

The Internet of Things (IoT) and How It's Impacting Next Generation Manufacturing

Doug Adams, IACMI NDE Tech Fellow



THE COMPOSITES iacmi INSTITUTE