Empowering the Industrial Internet of Things with 3D Printed Sensors and Antennas

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Agenda

- What is the Industrial Internet of Things (IIoT)
- Focus on Structural Health Monitoring
- Benefits of Structural Health Monitoring
- Optomec's Solution for the IIoT
- Antenna and Sensor Applications
- Summary

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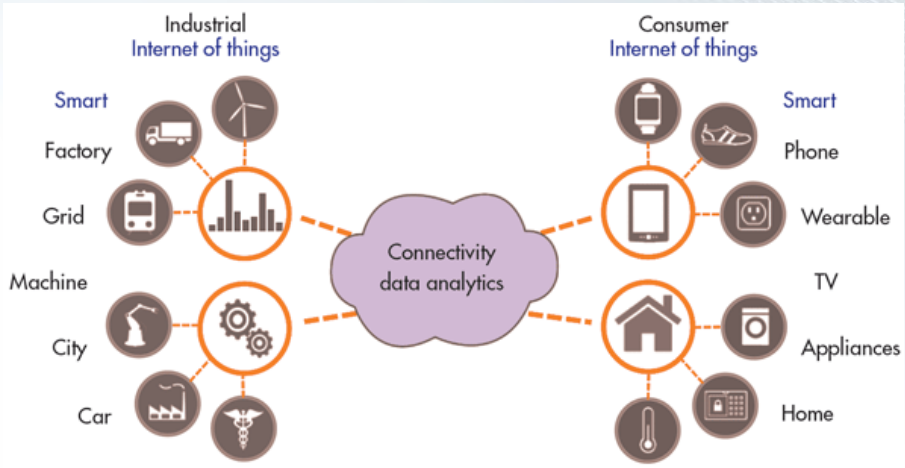
What is The IoT or IIoT?



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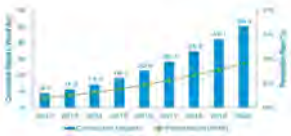
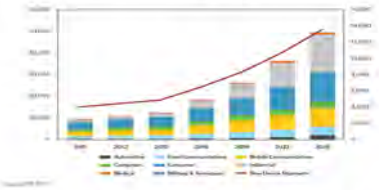
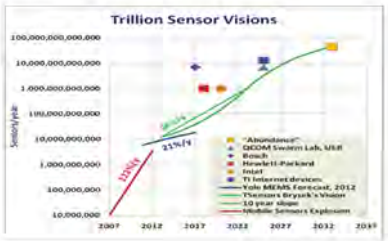
Internet of Things (IoT): 50 Billion …When? …Where?

- Cisco: 50B Connected Objects by 2020.
  - Breakdown shows ~30% M2M/Industrial
  - Growth: M2M Exponential; Human Linear
  - Penetration Rate at ~3%





- IHS (Source: AMAT): 50 Billion by 2025.
  - 13 Billion New Units per Year in 2025
  - 2025 New: 4B Mobile Device; 4B Industrial



- Multiple Sources estimating 1 Trillion to 10+ Trillion Sensors per Year.
  - Qualcomm, Bosch, TI, Intel, HP, etc.

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Structural Health Monitoring

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Impact of No or Limited Monitoring

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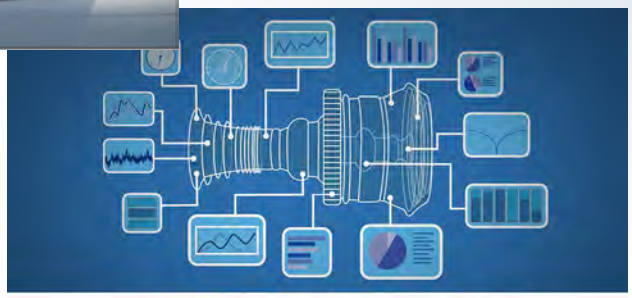
Communicating Data



200 sensors across the turbine generate 300 data points per second of performance and operation every hour.

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Projected Structural Health Monitoring Savings

Industry	Segment	Time to service (Man-hours per year)	Estimated Value (Billion US dollars)
Power	Steam & gas turbines	52 Million man-hours per year	$7 B
Aviation	Aircraft engines	205 Million man-hours per year	$10 B
Rail	Freight	52 Million man-hours per year	$3 B
Healthcare	CT+ MRI scanners	4 Million man-hours per year	$250 million

Source: GE estimates, 2013

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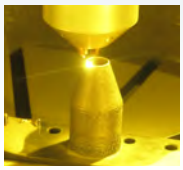
Optomec Enabling Technology for the IIoT



Fully Print 3D Parts or Print-on 3D™ Parts
- Print Structural metals, Electronic inks, ….
- Add material to existing components
- Micron to Meter scale

Provide Value Across Product Lifecycle
Functional prototypes to volume production
- Preventative maintenance to part repair
- Cost effective

Open Systems Approach
- Coexist with existing processes
- Integrate with existing machines
- Use commercially available materials

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Aerosol Jet Print Solution Overview

- Patented Material Deposition Process
- "Input" Fine Particle Inks and Standard Pastes
  - Conductors, Insulators, Semiconductors, Biomaterial…
- "Output" Fine Features to ~10µm to mm & Coatings from 100nm
  - Non-contact process
  - 2D / 3D Printing
- Cost and Functional Advantages
  - Lower Material and Process Costs
  - Improved End-Product Performance
- Standard System Products
  - Standard Development Platform
  - Medium Volume Production Systems
  - High Volume OEM Print Modules

Aerosol Jet Process

Standard Systems

Application Examples

EMI Sensor Array

3D Antenna

Staggered Die

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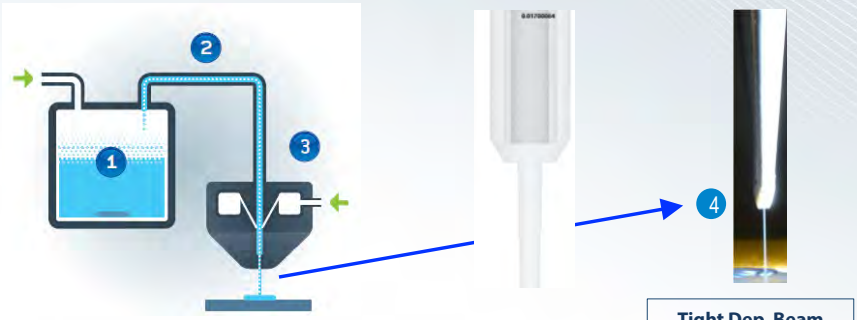
Aerosol Jet Technology Basics



Tight Dep. Beam
(~10µm to 2.5mm)

1. 1-1000cP fine particle inks
2. Mist of 2-5um Highly Dense, Highly Load Droplets
3. Non-contact deposition, 1-5mm standoff height from nozzle tip to substrate surface
4. Continuous Flow Exits at >50m/s remains collimated for up to 5mm
5. Process is highly scalable in terms of both feature size and multiplexing

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Aerosol Jet Process (Art to Part)

Design	Process	Part
		
▪ CAD Model ▪ Convert to DWG file ▪ Tool paths generated with Optomec software	▪ Liquid raw material ▪ Create fine (femto Litre) aerosol ▪ Focus to tight beam (~10µm >) ▪ Post-process (dry, cure, sinter...)	▪ Fine line traces ▪ 3D Conformal printing ▪ Interconnects ▪ Embedded passives ▪ Coatings

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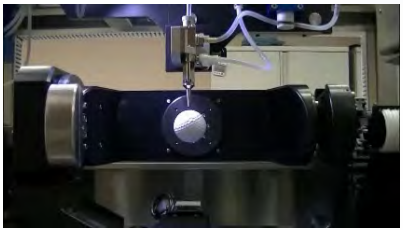
Aerosol Jet Process Key Advantages

- Print-On 3D™ structures enables:
- Conformal Antenna printed on industrial and consumer products
- Conformal Health Monitoring Sensors Printed on Structures where needed
- Condensed packaging reduces product size, weight, and cost
- Reduced time to service and focused on pending failures vs. needless replacement of expensive components.



Aerosol Jet Conformal Printing Process

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Material Availability

Metal Inks	Resistor Inks	Non-Metallic Conductors
An Cuig	Acheson	
Applied Nanotech	Asahi	Heraeus
Clariant	DuPont	NanoIntegris
DuPont	Lord (carbon)	SouthWest Nano
Henkel	Methode Development	**Semiconductors**
Intrinsiq	**Dielectrics and Adhesives**	Aldrich
Novacentrix	Aldrich	Alfa
Paru	BASF	Merck
PV NanoCell	DuPont	NanoIntegris
Sun Chemical	Henkel	**Reactive Chemistries**
UTDots	Loctite	Rohm & Hass
Xerox	Norland	Shipley

Partial Listing 0115

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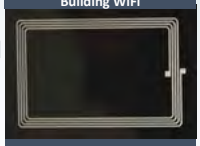
Printed Antenna Capability Overview

Market Driver	Lower Cost/COO than Existing Methods

- Printed Antenna for SmartPhones/Tablets, Notebooks, Automotive…
  - Main, Broadband, WiFi, Bluetooth, GPS, NFC, etc.
  - Printed Directly onto Standard Cases, Inserts, MIDs
- Benefits: Lower Total Cost of Ownership
  - Eliminates Environmental/Health Issues with Plating/Nickel
  - Greater Design Flexibility → Reduced Form Factors
  - Scalable Manufacturing envelop
- Current Status: In Production


Building WiFi


Near Field Antenna


Multiple Antenna on Case


Main SmartPhone Antennae


Main Tablet Antenna

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Printed Antenna Capability Overview

- One Shot Injection Molding
  - Standard Polymers – No Additives
- Print Antenna Pattern
  - Digital process - No hard tooling
  - Silver Nanoparticle ink
  - Patterns printed in 2D or 3D on polymer inserts
- Post Processing
  - Thermal cure – No plating, No Nickel
- Benefits
  - Fewer Process Steps (no plating)
  - Environment Friendly
  - Lower cost
  - High Throughput ~40,000 antennas / week / system

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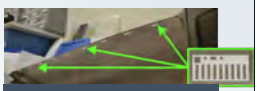
Printed Sensors Capability Overview

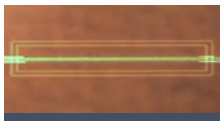
Market Driver	Predictive Maintenance

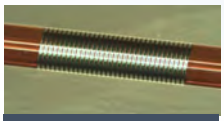
- AJ Supports Many Different Sensor Types.
- Print in 2D or 3D, directly onto target products.
- High Fidelity Printing Improves Data Resolution.
- Digital Input allows Mass Customization / Serialization.

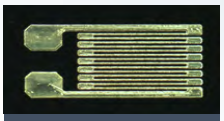

3D Strain Gauge


3D Creep Sensors


SAW Device 6um Features


Glucose Sensor


3D Temp Sensor on Catheter


1mm Strain Gauge


CNT-Based Gas Sensor


3D Current Sensor for EV


3D Interdigitated Ice Sensor


EMI Sensor Array

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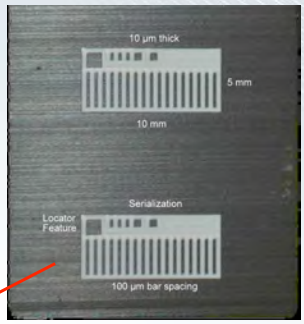
Aerosol Jet Example: Predictive Maintenance

- Health Monitoring for High-Value Components
- High Temp (>1800°F) In-Situ Creep Sensors
  - Optical sensors detects fatigue and creep
  - Unique serialization for each gage
- Enabled by Aerosol Jet Printing
  - 3D Conformal Printing directly onto parts.
  - Digital input enables Serialization
  - Supports High Temp YSZ Ceramic Ink



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Summary

- Optomec and the IIoT

Feature	Benefits
Aerosol Jet Process	Conformal printing with features from ~10µm to mm
Inks / Materials	Full Range of Conductive Materials, Dielectrics, Epoxies…
Platform Flexibility	2D and 3D Antenna and Sensors
Digital Process	No tooling – allows easy conversion to new antenna patterns
Complimentary	Fills gaps where current solutions are deficient
Environmentally Friendly	Direct Printing - no subtractive or plating processes – simplified logistics, reduces floor space, eliminates health hazardous materials
Cost Effective	Scalable Print Engine to Full solutions with lower overall operating cost than many current manufacturing solutions

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Thank You…Danke!

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