

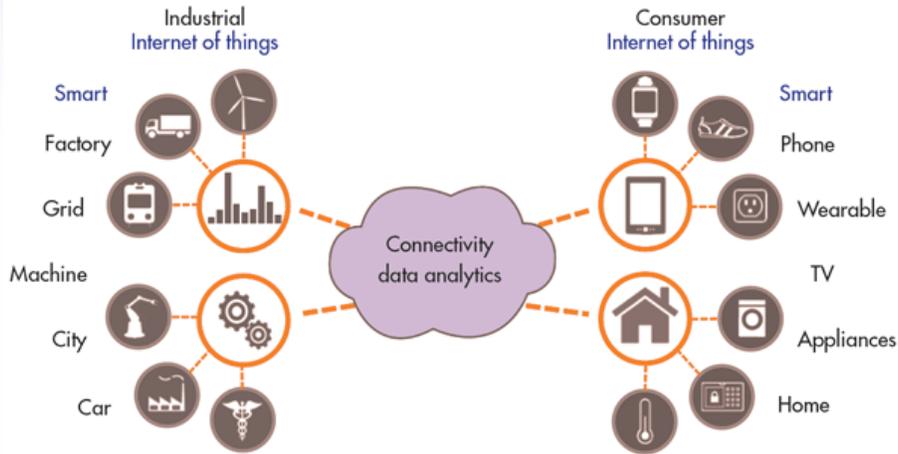
Empowering the Industrial Internet of Things with 3D Printed Sensors and Antennas

OPTOMECC[®]
Production Grade 3D Printers... with a Material Difference

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

What is The IoT or IIoT?

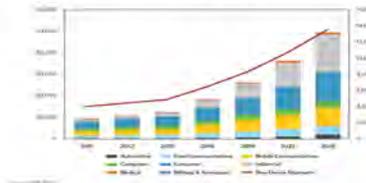
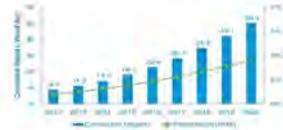


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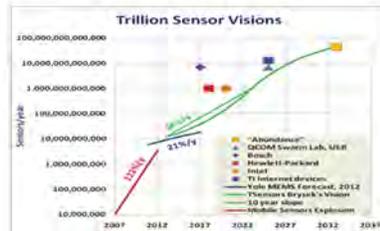
Internet of Things (IoT): 50 Billion ...When? ...Where?

- 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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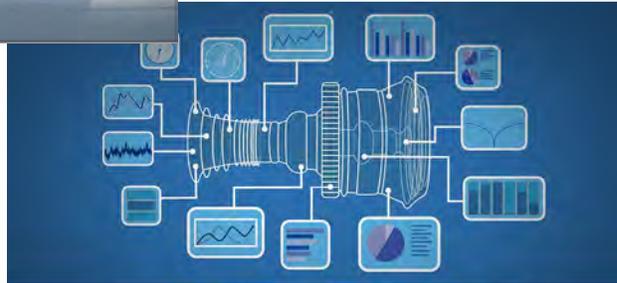
Impact of No or Limited Monitoring



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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

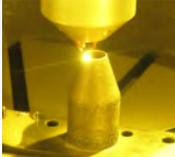
Industry	Segment	Time to service (Man-hours per year)	Estimated Value (Billion US dollars)
 Power	Steam & gas turbines	52 Million man-hours per year	\$7 B
 Aviation	Aircraft engines	205 Million man-hours per year	\$10 B
 Rail	Freight	52 Million man-hours per year	\$3 B
 Healthcare	CT+ MRI scanners	4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



Application Examples



EMI Sensor Array



3D Antenna



Standard Systems

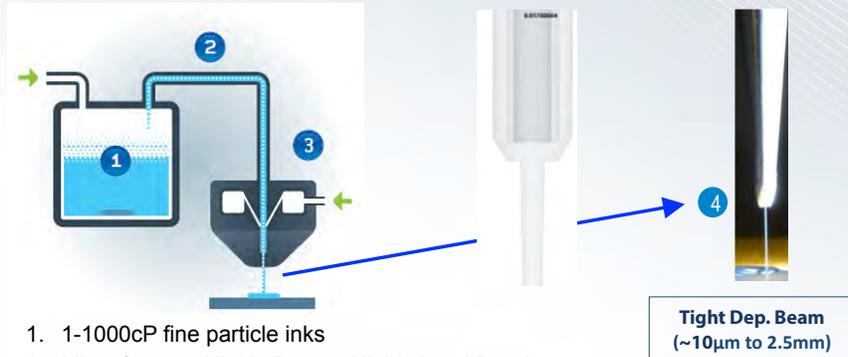


Staggered Die



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Aerosol Jet Technology Basics



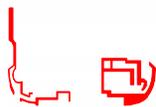
1. 1-1000cP fine particle inks
2. Mist of 2-5µm Highly Dense, Highly Load Droplets
3. Non-contact deposition, 1-5mm standoff height from nozzle tip to substrate surface
4. Continuous Flow Exits at >50m/s remains collimated for up to 5mm
5. Process is highly scalable in terms of both feature size and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



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Aerosol Jet Process (Art to Part)

Design



- CAD Model
- Convert to DWG file
- Tool paths generated with Optomech software

Process



- Liquid raw material
- Create fine (femto Litre) aerosol
- Focus to tight beam (~10µm >)
- Post-process (dry, cure, sinter...)

Part



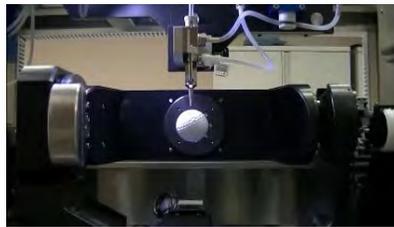
- Fine line traces
- 3D Conformal printing
- Interconnects
- Embedded passives
- Coatings



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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	Method 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



Main Smartphone Antennae



Main Tablet Antenna



Building WiFi



Near Field Antenna



Multiple Antenna on Case

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Printed Antenna Capability Overview

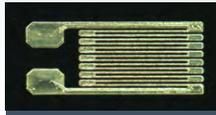
- ▶ One Shot Injection Molding
 - Standard Polymers – No Additives
- ▶ Print Antenna Pattern
 - Digital process - No hard tooling
 - Silver Nanoparticle ink
 - Patterns printed in 2D or 3D on polymer inserts
- ▶ Post Processing
 - Thermal cure – No plating, No Nickel
- ▶ Benefits
 - Fewer Process Steps (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
<ul style="list-style-type: none"> ▶ 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. 	 <p style="text-align: center; font-size: 8px;">3D Strain Gauge</p>  <p style="text-align: center; font-size: 8px;">3D Creep Sensors</p>  <p style="text-align: center; font-size: 8px;">SAW Device Gum Features</p>  <p style="text-align: center; font-size: 8px;">Glucose Sensor</p>  <p style="text-align: center; font-size: 8px;">3D Temp Sensor on Catheter</p>  <p style="text-align: center; font-size: 8px;">1mm Strain Gauge</p>  <p style="text-align: center; font-size: 8px;">CNT-Based Gas Sensor</p>  <p style="text-align: center; font-size: 8px;">3D Current Sensor for EV</p>  <p style="text-align: center; font-size: 8px;">3D Interdigitated Ice Sensor</p>  <p style="text-align: center; font-size: 8px;">EMI Sensor Array</p>

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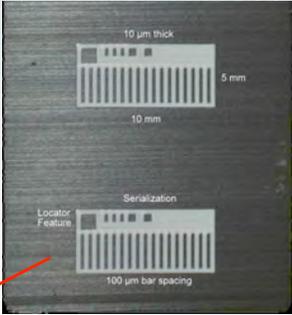


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Aerosol Jet Example: Predictive Maintenance

- ▶ 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





10 μm thick
 5 mm
 10 mm
 Serialization
 Locator Feature
 100 μm bar spacing

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 Production Grade 3D Printers... with a Material Difference

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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