AUTODESK UNIVERSITY

# Autodesk Is to Additive Manufacturing as Stratocaster Is to "Stairway to Heaven"

Dave Gleason - Optomec Software Manager

## *Learning Objectives*

- Visualize opportunities for Autodesk product use for additive manufacturing
- Understand some key differences between additive and subtractive manufacturing

## *Class Description*

Optomec uses Autodesk products to translate CAD designs into printed features on existing parts or surfaces. We will cover specific additive manufacturing challenges that relate to Aerosol Jet printing and how we have used Autodesk technologies to address our needs. We will further explore the subtle differences between additive and subtractive manufacturing and how Autodesk has worked to address the philosophical differences in an easy-to-understand way. Attendees will develop a deeper knowledge of the use of Autodesk products for additive manufacturing and how they can be adapted to suit their specific additive requirements. This session features AutoCAD, FeatureCAM.

## *Your AU Expert*

Dave Gleason is the Software Manager / Senior software engineer for Optomec a work leader in 3d printing equipment manufacture. He has worked at Optomec for 14 years in a variety of capacities, from developer through manager. His academic education is in Mechanical Engineering; however he has been developing code commercially for ~ 17 years. During his career, he has worked for Boeing, GE Engines, Lockheed, TRW and Optomec. He is fiercely passionate about his work, and is known for his desire to innovate, collaborate and support others in any way he can.

At Optomec we produce Additive Manufacturing solutions ranging from products targeted at high value part repair to printed electronics.

## *Introduction*

This course is intended for industry professional interested in exploring additive manufacturing and how Autodesk products provide the necessary technology, customization and flexibility to get the job done right. Thought it may seem that additive manufacturing or 3d printing is an exact science with point and click ease it actually requires a deep understanding of the process to achieve excellent results. With this knowledge and some key enabling technologies, the sky is the limit.

In this discussion we will focus on Optomec's additive manufacturing technologies (Aerosol jet and LENS) and two Autodesk products (AutoCAD and FeatureCAM) that make 3d printing an exact art.

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## *Production Grade 3D Printing*

Optomec is evolving the world of additive manufacturing by taking 3D printing in new directions. Our production-grade 3D printers support the broadest set of functional materials, from structural metals to conductive electronics and biologic matter. Our flexible systems are used for building prototypes to volume manufacturing to repairing high-value metal components to remanufacturing obsolete parts.

Our capabilities are used in high reliability applications in aerospace and military markets, and meet the demanding performance and cost requirements of consumer electronics. And, we are breaking new ground with our unique ability to print conformal electronics such as antennas and sensors onto a variety of devices, making Optomec a key partner for enabling the Internet of Things (IoT).

With Optomec, functional electronics can be readily integrated onto 3D structures in ways not previously possible or even imagined. The breadths of our technology along with the range of feature sizes we support allow us to help drive innovation and add value.

Our open-systems based technology can be implemented in a modular format to easily integrate into existing production processes and automation platforms. This flexibility provides a cost-effective and scalable method to adopt additive manufacturing across the product lifecycle.

While 3D printing has been the subject of much industry hype, Optomec is delivering on the promise of high-volume additive manufacturing today.

## *Aerosol jet*

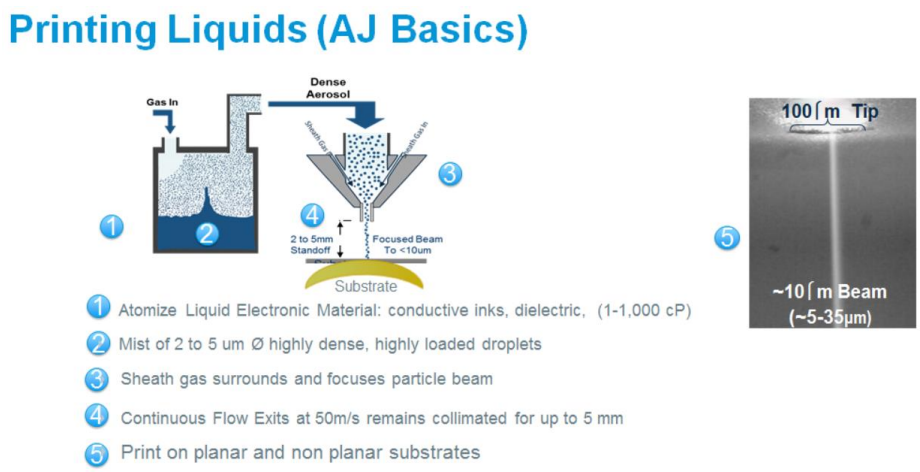
The Aerosol Jet system prints fine-feature electronic, structural and biological patterns on to almost any substrate such as 3D conformal sensors and antennas for aerospace, defense, consumer electronics, wearable's and the Internet of Things (IoT). It can effectively produce 3D printed electronics. It uses commercially-available conductive, dielectric, semiconductor and biologic inks onto a variety of 2D or 3D plastic, ceramic, and metallic substrates. The result is 3D printed electronics that eliminate the need for hard tooling photomasks or stencils and enable engineering changes to be quickly implemented by simply modifying the design file.

The technology behind Aerosol Jet enables printing of interconnects on both 2D and 3D substrates. For 2D applications, multi-level interconnects can be created by printing a dielectric material at circuit cross over points – in essence emulating a multi-layer circuit board but on a single layer. This can be accomplished because the Aerosol Jet process supports multiple ink input devices allowing materials to be switched or even blended during printing.

Also, Aerosol Jet can print conformal interconnects on 3D surfaces eliminating the need for wire bonding – for example printing electrical connections on 3D stacked die or for LED chip fabrication.

Aerosol Jet technology enables 3D printed electronics. Electronic components such as resistors, capacitors, antennas, sensors, and thin film transistors have all been printed with Aerosol Jet technology. The performance parameters of printed components, for example the ohm value of a resistor, can be controlled through printing parameters. Components can also be printed onto 3 dimensional surfaces eliminating the need for a separate substrate thereby reducing the size, thickness and weight of the end product. For example, Aerosol Jet is used to print antennas and sensors that conform to the shape of the underlying substrate such as a cell phone case.

The Aerosol Jet process supports printing on a wide variety of substrates including plastics, ceramics and metallic structures. Commercially available materials, such as nano-particle inks, have been optimized for the Aerosol Jet process to allow printing (and subsequent ink sintering) onto plastic substrates with low heat deflection temperatures.



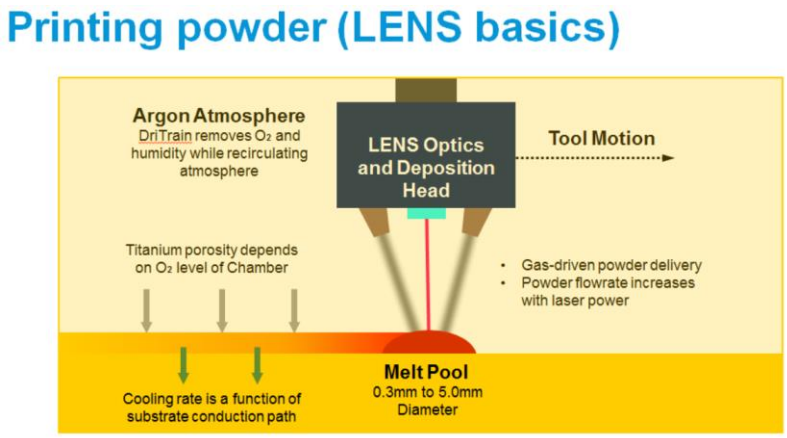
## *LENS*

The LENS family of 3D metal printers can be used throughout the product life cycle to cost-effectively repair, rework and manufacture high-performance metal components in materials such as titanium, stainless steel, and super alloys

LENS systems use a high-power laser (500W to 4kW) to fuse powdered metals into fully dense three-dimensional structures. The LENS 3D printer uses the geometric information contained in a Computer-Aided Design (CAD) solid model to automatically drive the LENS process as it builds up a component layer by layer. Additional software and closed-loop process controls ensure the geometric and mechanical integrity of the completed part.

The LENS process is housed in a hermetically-sealed chamber which is purged with argon so that the oxygen and moisture levels stay below 10 parts per million. This keeps the part clean, preventing oxidation. The metal powder feedstock is delivered to the material deposition head by Optomec's proprietary powder-feed system, which is able to precisely regulate mass flow. Once a single layer has been deposited, the material deposition head moves on to the next layer. By building up successive layers, the whole part is constructed. When complete, the component is removed and can be heat-treated, Hot-Isostatic-Pressed, machined, or finished in any customary manner.

LENS technology is available either in turnkey system configuration or as a modular print engine that can be integrated into existing or new CNC machine tools. With the LENS Print Engine metal deposition and machining can be performed in the same system allowing you to leverage capital assets and accelerate implementation of additive technology through an HMI already familiar to your machinists.



## *Additive vs Subtractive manufacturing*

It's pretty easy to visualize subtractive manufacturing or machining. Start with a block of material and slowly sculpt that block into the desired widget. Just like a sculptor you can use different tools to trim, surface and mill a masterpiece. Considerations like approach angle, clearance planes, tool spindle speed and cutter allowances become key.

Once the piece takes a near final shape you than then slow things down so tool chatter is minimized and the appropriate surface finish is revealed. For each part of a given material you can complete the same tasks and eventually you have an assembly.

Below are several key points that compare subtractive and additive manufacturing.

### Subtractive (Machining)

- One material at a time with lots of drop.
  - Drop is the cut material lost in a machining operation.
- Assembly tolerances add up
  - Parts are assembled together (the mechanical link between two pieces is often a pin, screw or adhesive.
  - For every connection there is a tolerance (So for all of them a summation of errors).
- Multi-pass, multi-cut approach takes care of speed
  - In typical machining a part is produced by a series of rough then finish cuts. Because the cuts are typically separated into many operations we can visualize the cutting tool contacting the part many times in many ways to produce the result. Tool feed speed (rate in the direction of the cut) and spindle speed (rate at which the cutter spins).
  - Therefore, constant build velocity isn't very important. Another pass at a slower speed with a more shallow depth can "clean things up".

### Additive

- Make parts that can't be manufactured any other way!
- Structures are built out of thin air!
  - Not exactly, a more accurate way to say this is that material is directed to a point and then stacked and bonded at the particle level.
- Add features to existing surfaces!
  - We work with many companies that place metal parts on plastic surfaces. An example is an antenna on a cell phone case.
  - Parts can be built in many orientations, not just along X, Y or Z directions.
- Blend or layered materials!
  - There really isn't any subtractive way to blend materials within layers! Or layer different materials without mechanically bonding them via pins, screws or adhesives.
- Speed matters (constant velocity is important)
  - Changes in speed effects material thickness and width
- Nearby Features can present challenges
  - Side walls may affect printing by blocking gas flow

## *Multi-axis motion (for Optomec systems)*

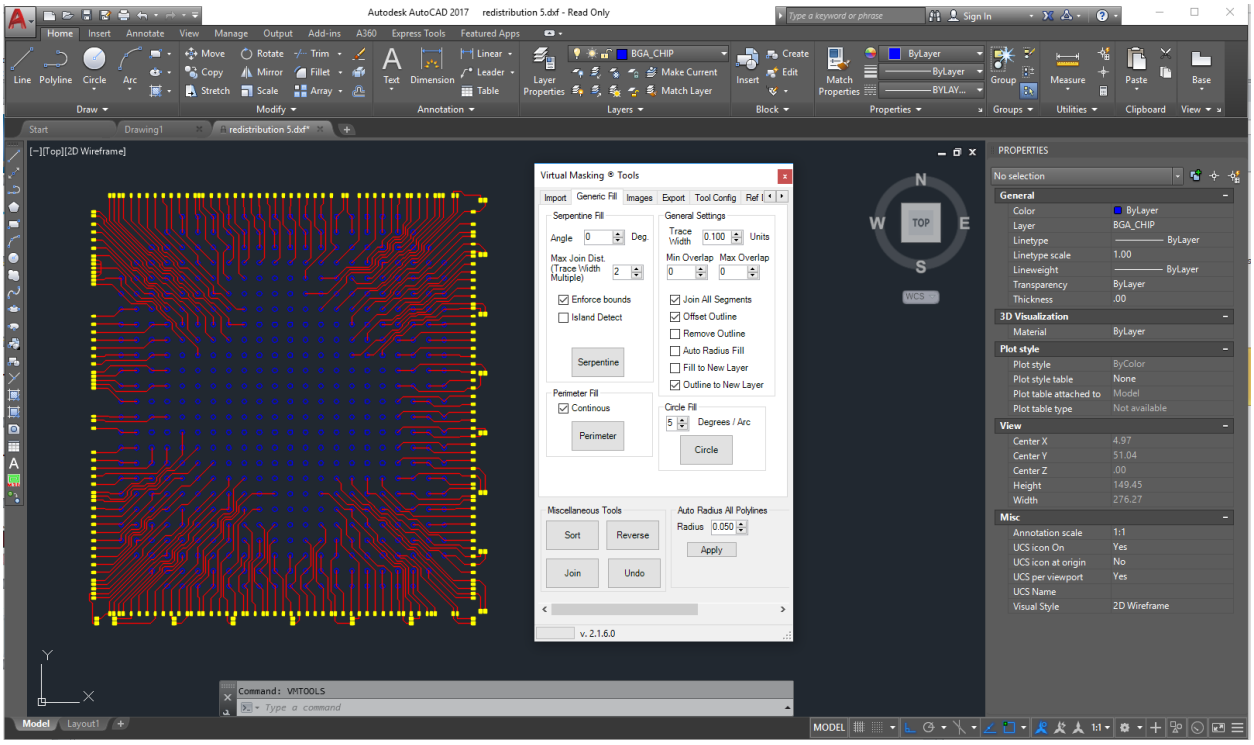
- 2d motion systems use a table that moves in the X and Y plane under our print head. Such systems use motion movements best defined in AutoCAD.
- 3d motion systems involve a table that moves in the X and Y with our print head moving in Z. Such systems use motion movements best defined in AutoCAD or FeatureCAM.
- 5d motion systems involve X, Y and Z movements like above but introduce two additional rotation axes (A and B) which allow our print head to access the part from multiple directions. This type of flexibility allows from printing round or on two more sides of a surface. Such systems use motion movements best defined in AutoCAD or FeatureCAM.

## *Enabling Autodesk technologies – AutoCAD 2017*

It's pretty easy to visualize that you need a map and directions. For advanced additive manufacturing the system needs to know where to go. This can be accomplished in several ways,

- Teach points along a path – Using a preexisting model or part, capture points.
- Define points manually – In the programming language of the motion system write your own pattern.
- Use a CAD tool.

### *Enter AutoCAD 2017*




For 2 and 3d AutoCAD is the perfect choice. Because AutoCAD defines a rich development environment that has everything that you need to import, define and create the design that you want. AutoCAD's intuitive layout and combines all tools in logical ways and places. It allows you to precisely create 2 and 3d designs placing separate sections of the design in layers. This functionality works perfectly with Optomec 3d printers.

In the above images we see Optomec's Virtual Masking tools. This application performs a variety Optomec tasks from geometry import, object filling and sorting, image underlay (for pattern creation or verification) and export (creates Optomec motion sequence instructions). This tool links to AutoCAD via Object ARX API.

From Autodesk's website:

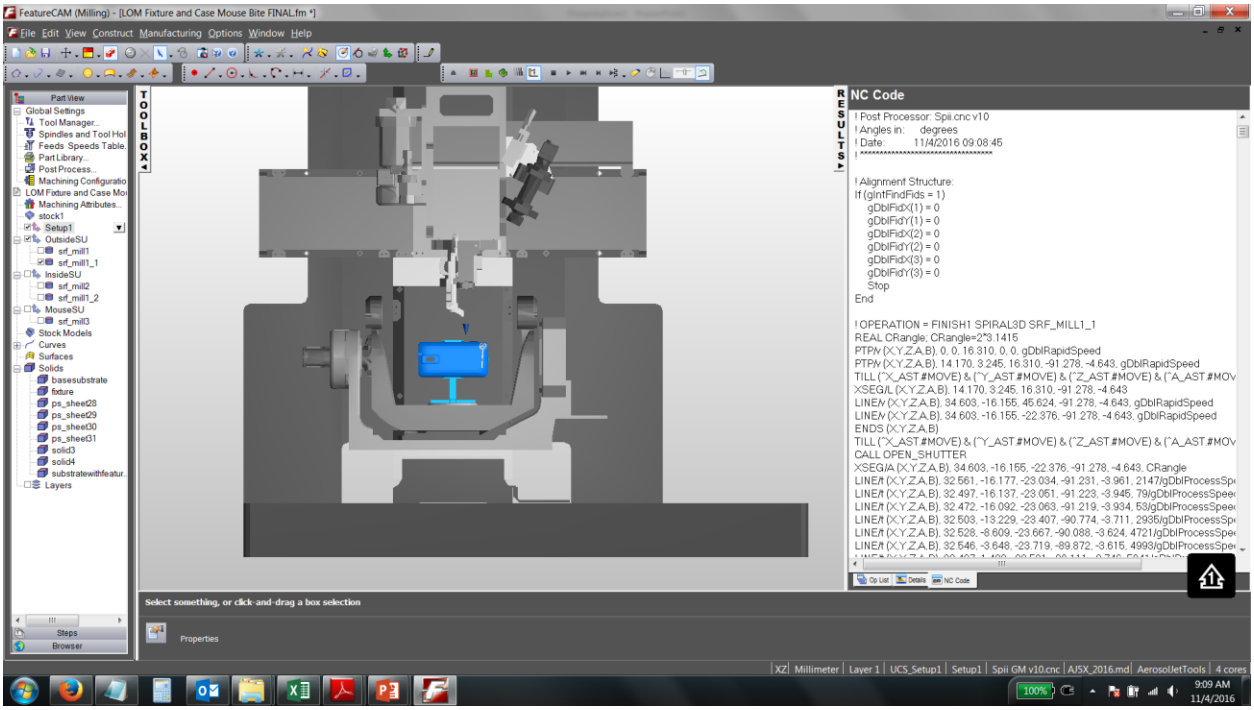
"The ObjectARX® programming environment provides object-oriented C++, C#, and VB .NET application programming interfaces for developers to use, customize, and extend AutoCAD® software and AutoCAD-based products, such as AutoCAD® Architecture, AutoCAD® Mechanical, and AutoCAD® Civil 3D® software. A version of ObjectARX for AutoCAD® for Mac® software is also available, though not all APIs are available in the Mac version.

ObjectARX programming environment libraries provide versatile sets of tools with which AutoCAD API developers can take advantage of the open architecture of AutoCAD software. They also provide direct access to the AutoCAD database structures, graphics system, and native command definition.

ObjectARX technology helps you to develop fast, efficient, compact CAD applications. It enables power users to customize AutoCAD software and frees CAD designers from repetitive tasks. Smaller files, faster drawing operations, and smooth interoperability make an application built with the ObjectARX programming environment your best choice for a design software solution."

## *Enabling Autodesk technologies – FeatureCAM 2014*

When it comes to more complicated motion, like printing on two or more sides of a device, FeatureCAM handles the task with ease.




For 4 and 5d FeatureCAM is the perfect choice. Because FeatureCAM defines a rich development environment that has everything that need to import, define and create the design that you want. FeatureCAM intuitive layout and combines all tools that are needed in logical places. Thought this product is a CAM tool its nomenclature is easy to understand and doesn't rely heavily on machining jargon like other tools. It allows you to precisely create designs and incorporates all of the CAM technologies needed for multi-axis printing. This functionality works perfectly with Optomec 3d printers.

In the above images we see Optomec's 5 axis AJ5X printing tool. This system when paired with FeatureCAM can perform coordinated 5 axis movements to print on several sides of a part and keep the print head perpendicular to the surface for the best possible printing results.

FeatureCAM includes a host of other technologies that enable accurate verification of printing sequences in addition to collision detection that will help to ensure you print exactly what you want without intersecting a surface unintentionally.

## *Conclusion*

Additive manufacturing opens a new world of design possibilities. It is unique and different from subtractive manufacturing. Autodesk products are the perfect enabling technology for additive manufacturing. Optomec makes the best industrial 3d printers and Autodesk products allow our team to craft our stairway to heaven, with precision, daily.