Moore's Law for Metal Printing: Where we are and how do we stay on track?

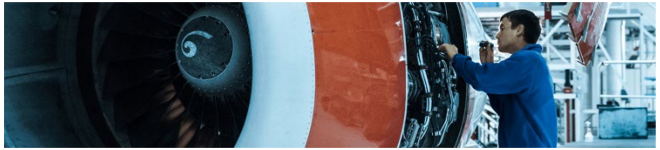
Edward Herderick
VP Science and Technology Development

NSL Analytical

NSL provides independent laboratory testing services to a diverse array of customers within regulated end-markets, where testing ***speed, accuracy*** and ***consistency*** are mission critical to operations.

Our teams of ***chemists, engineers*** and ***metallurgists*** provide scientific expertise in materials testing with a focus on metals, alloys and technical ceramics that are utilized in critical end-market applications.

Spectroscopy	Thermal Analysis	Metallurgical / Failure Analysis
Chromatography	Consulting	Mechanical Testing
Mass Spectrometry	Particle Sizing & Characterization	Microscopy



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Outline of my talk

- Moore's Law for Metal Printing
- Past, Present, Future of Metal Laser Powder Bed Fusion
- Testing approaches to address and grow metal AM

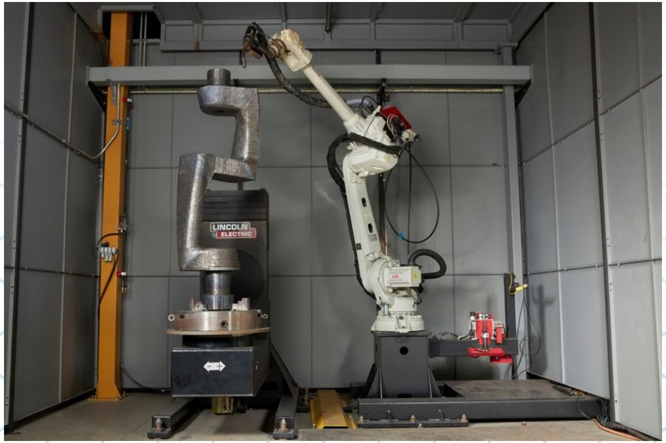
Why focus on Metal Powder Bed Fusion Productivity

Lots going on in metal printing…

Could focus on:

Taking the cost out of metal printing-

Advancing wire based printing------------



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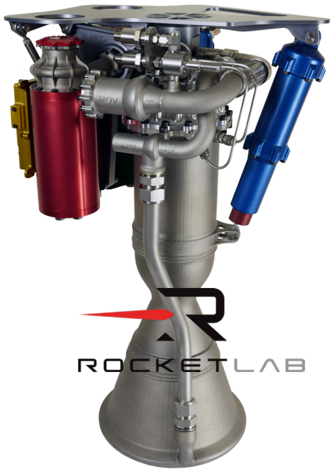
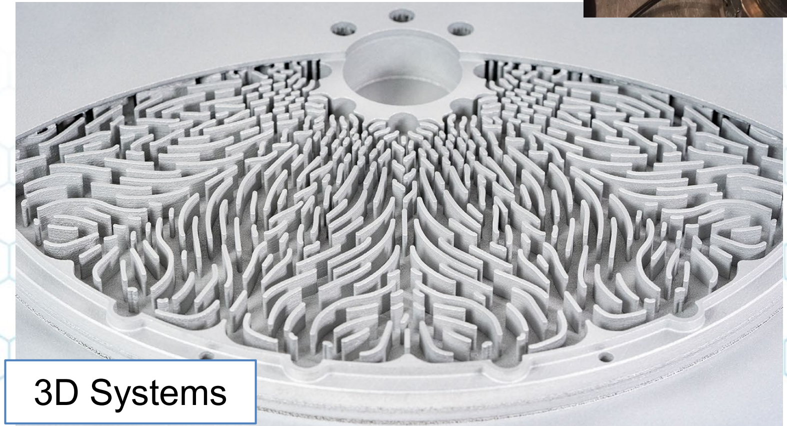
AddUp

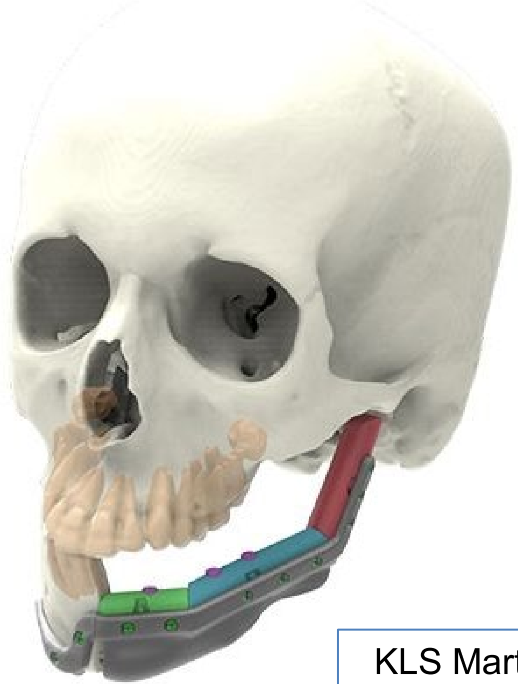
Metal Laser Powder Bed Fusion Applications



David Ellis +
Chris Protz
NASA GRC



3D Systems

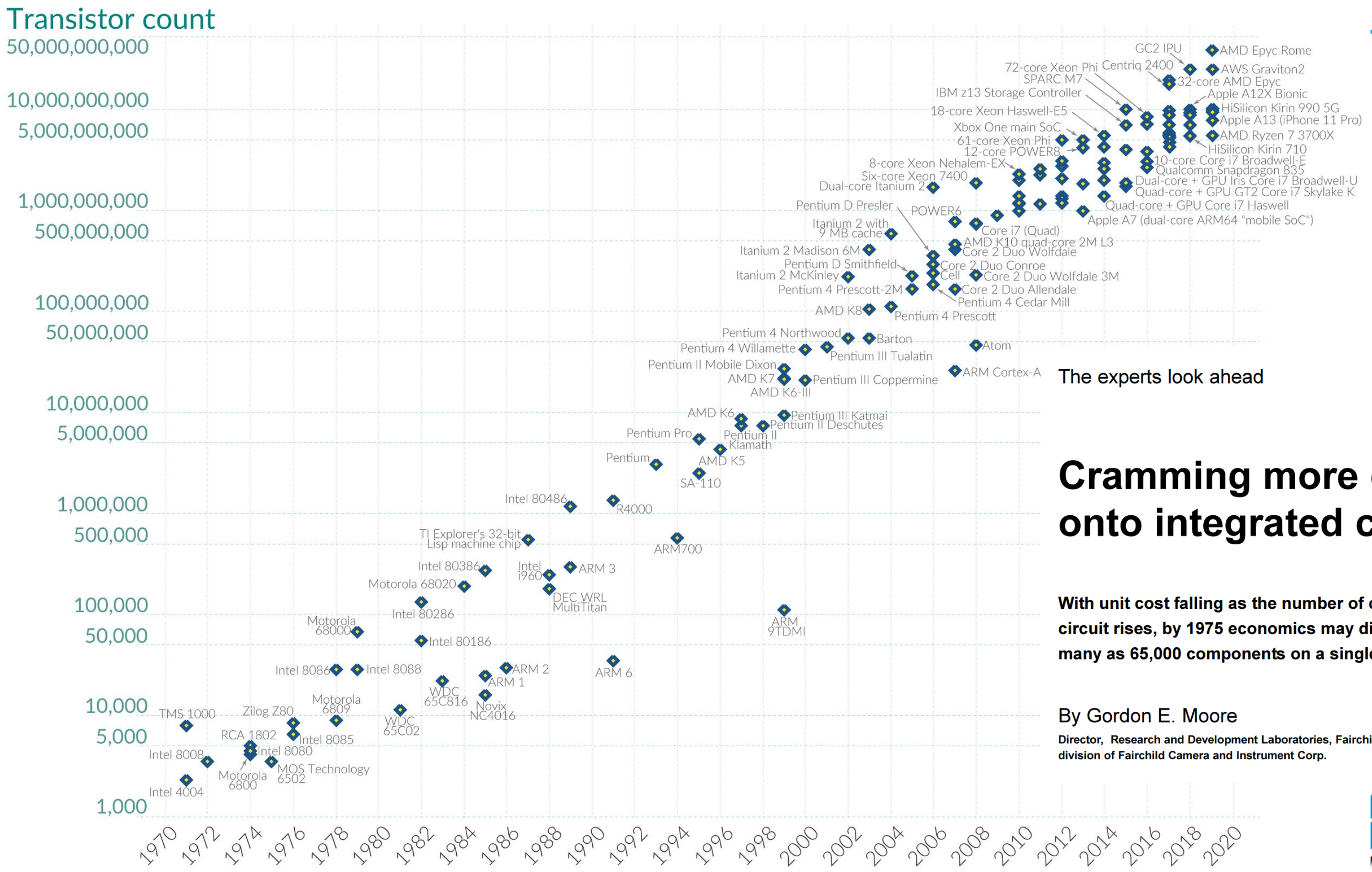


KLS Martin

Moore's Law: The number of transistors on microchips doubles every two years

Our World in Data

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years.
This advancement is important for other aspects of technological progress in computing – such as processing speed or the price of computers.



The experts look ahead

Cramming more components onto integrated circuits

1965

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip

By Gordon E. Moore

Director, Research and Development Laboratories, Fairchild Semiconductor division of Fairchild Camera and Instrument Corp.

Data source: Wikipedia (wikipedia.org/wiki/Transistor_count)

OurWorldinData.org – Research and data to make progress against the world's largest problems.

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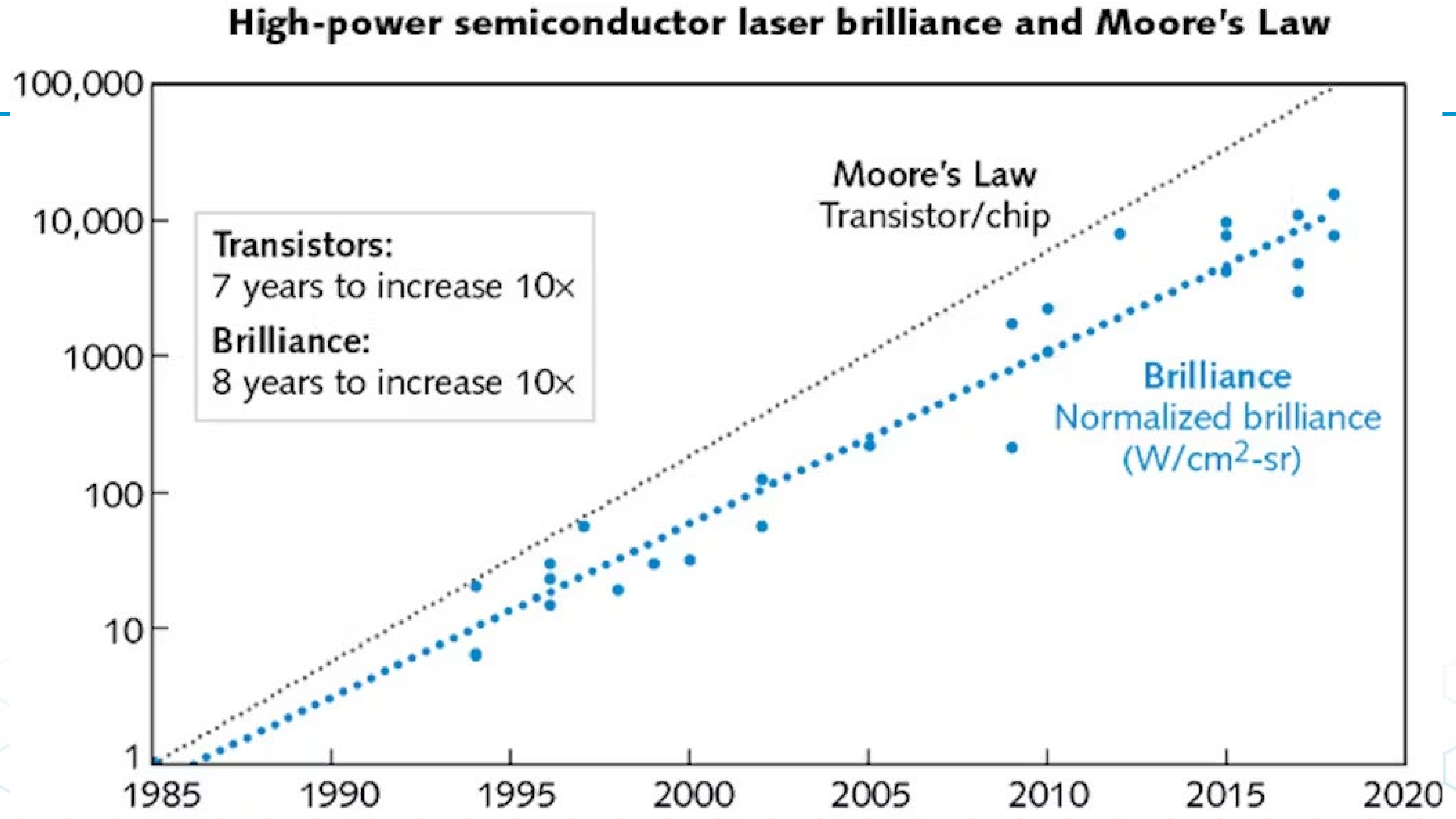
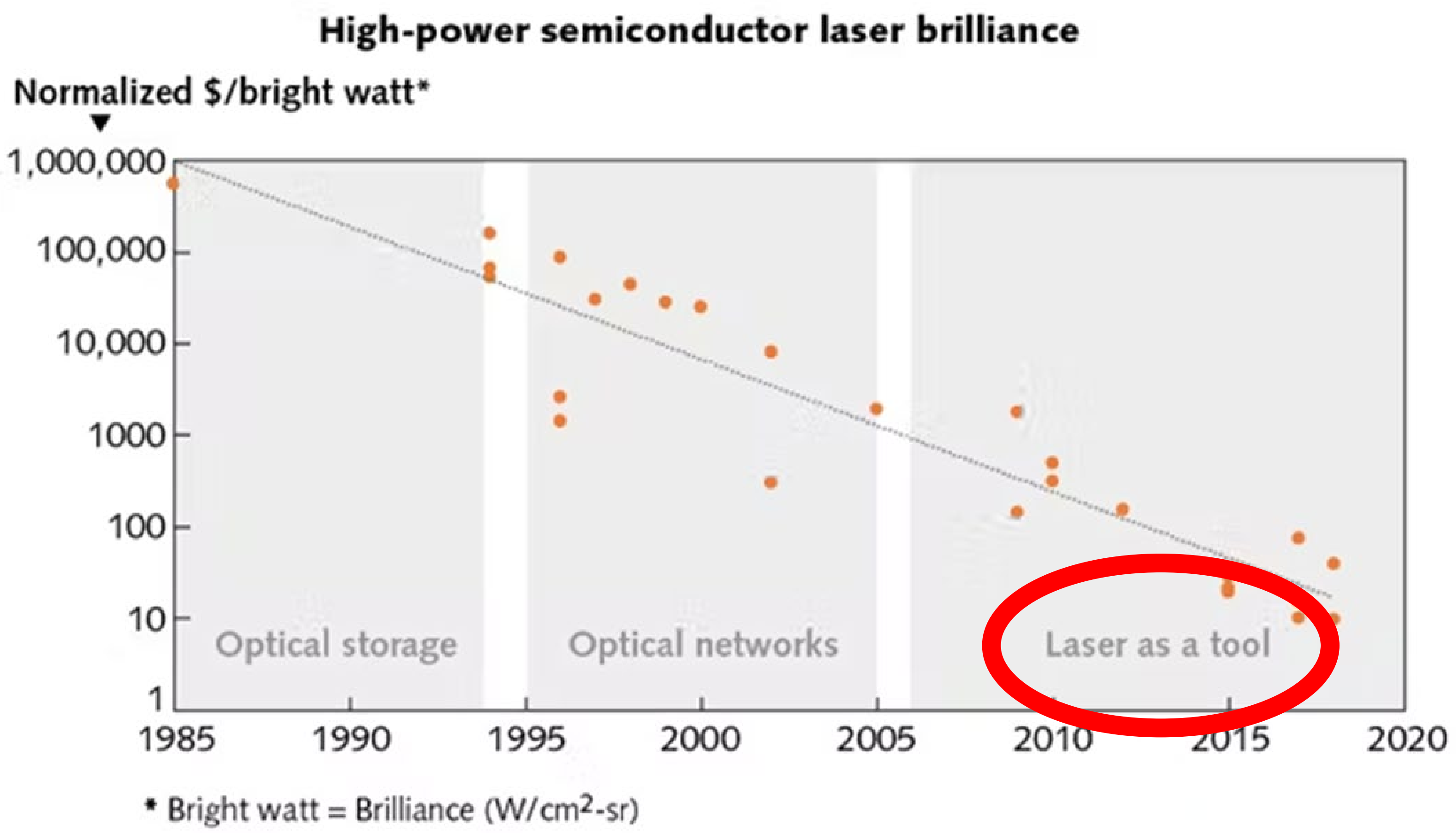
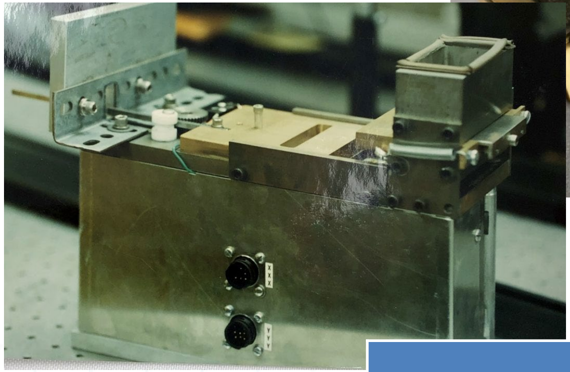


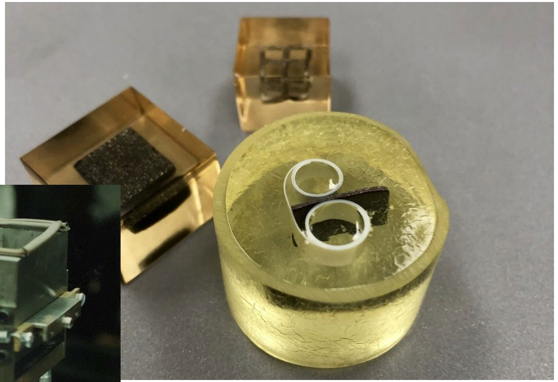
Laser Diodes: The power of brilliance — the past and future of high-power semiconductor lasers



Laser Diodes: The power of brilliance — the past and future of high-power semiconductor lasers

Early work on Metal Laser Powder Bed





1993	
Laser Type and Power	50W Nd:YAG
Build Size	3” x 1” x 1”
As Built Density	35%
Scan Speed	2 mm/sec
Build rate	1/2 cm^3 / hour rate In practice 1 / day

Introduction of Fiber Lasers

1st fully dense metal to 1st production applications at scale

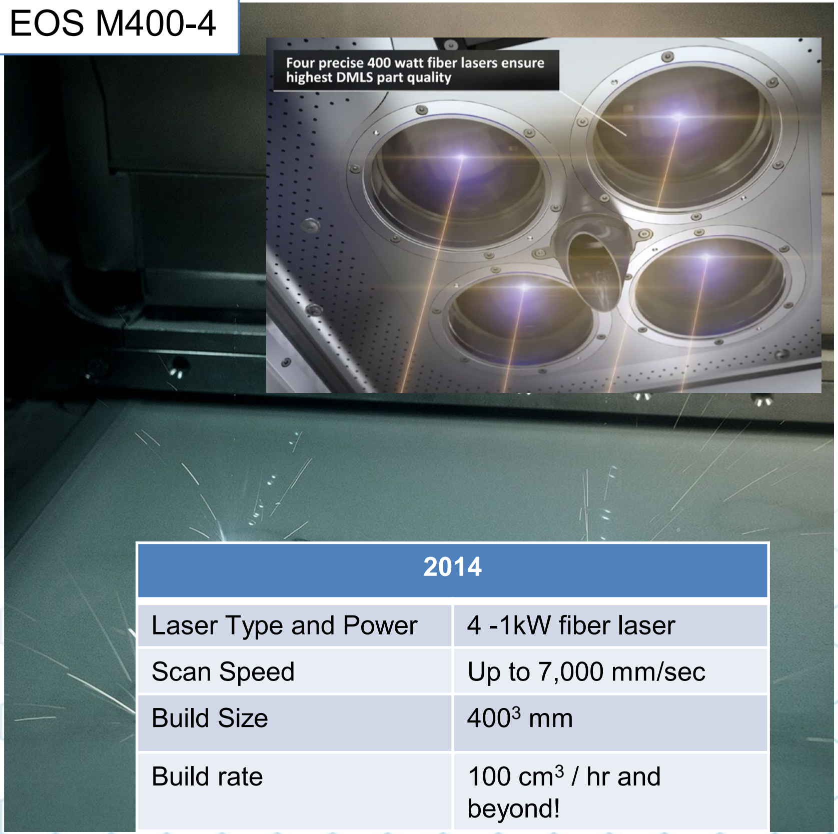
2004	
Laser Type and Power	200W fiber laser
Build Size	250 mm x 250 mm x 215 mm
Scan Speed	200 – 400 mm/sec
As Built Density	Fully dense capable
Build rate	5 cm^3 / hr

2014	
Laser Type and Power	400W-1kW fiber laser
Build Size	250^3 mm
Scan Speed	500 – 2000 mm/sec
As Built Density	Fully dense **PARTS**
Build rate	5 – 35 cm^3 / hr

Multi Laser Machines

4x Productivity and beyond --- Faster Printing means Bigger Parts

EOS M400-4



2014	
Laser Type and Power	4 -1kW fiber laser
Scan Speed	Up to 7,000 mm/sec
Build Size	400^3 mm
Build rate	100 cm^3 / hr and beyond!

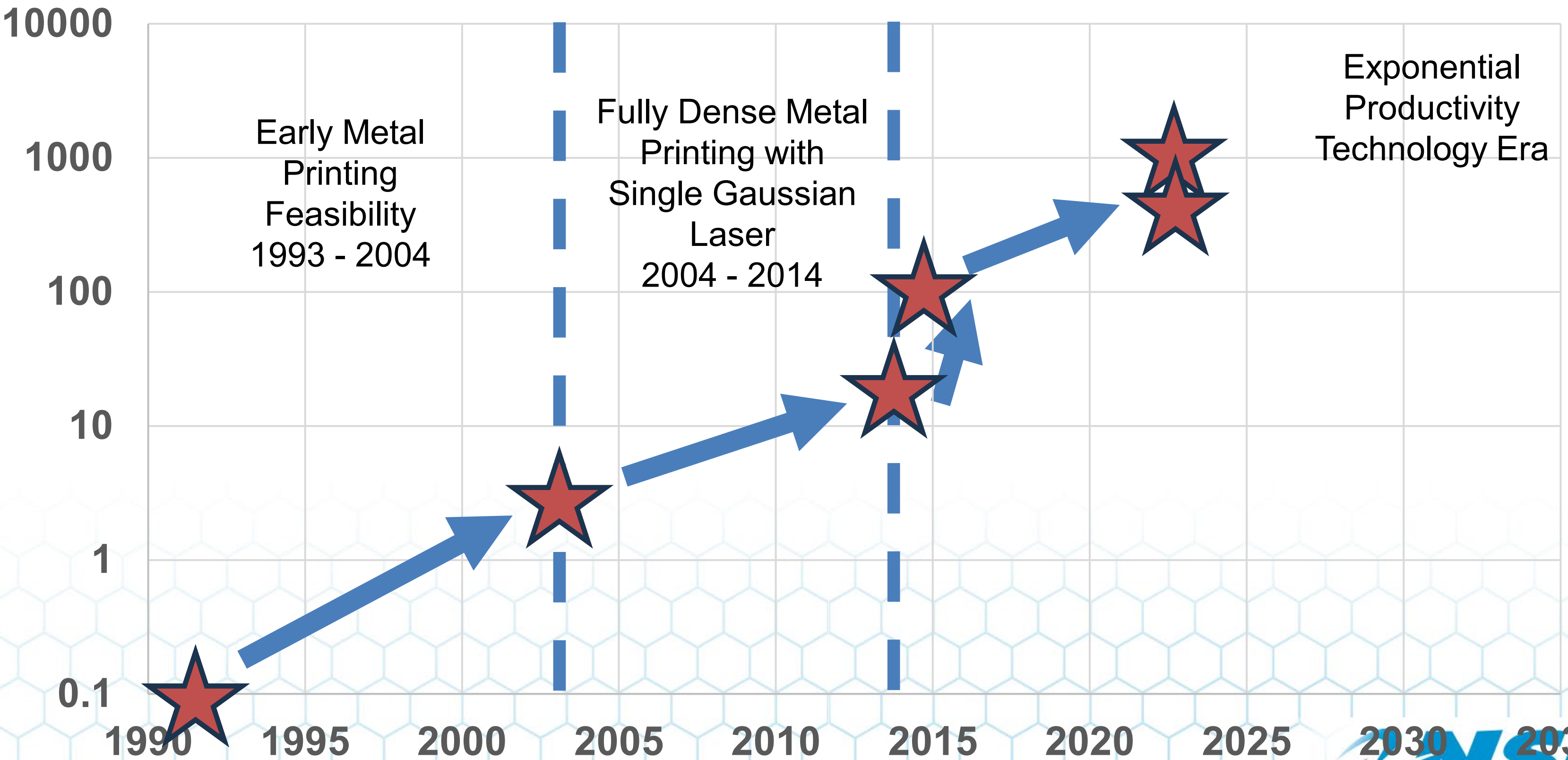
Multi Laser Machines

12 lasers and up to 1000cc/hr

SLM NXG XII 600

2023	
Laser Type and Power	12 1kW lasers
Build Size	600 mm^3
Build rate	"up to" 1000cm^3 / hr with laser jumping

Metal Laser Powder Bed Fusion Productivity in cm^3/hr



Summary

Laser powder bed fusion technology has advanced exponentially from 1 cc / day in 1993 to demonstrated* 1,000 cc / hour in 2023

What research will solidify gains and lead to broad adoption?

- Benchmark standard for productivity
- Advanced Lasers and Optics
- New Materials and Scalable Powder Production
- AI + Big Data
- Rapid Testing + How to Qualify on new platforms?

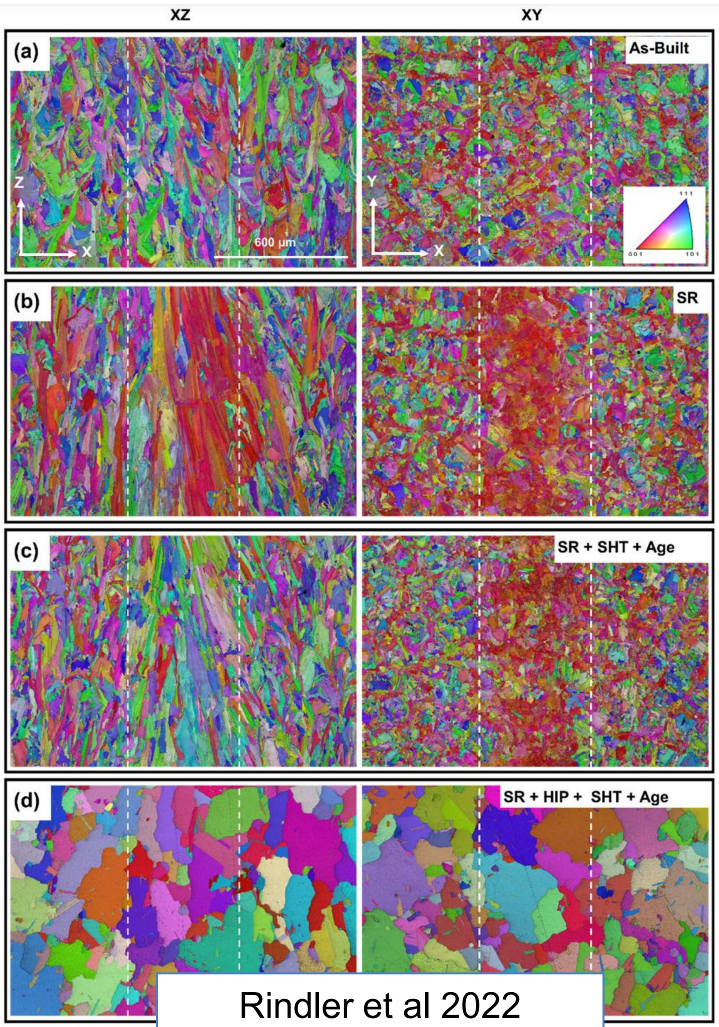
What do we need to do next?

Really important to understand laser stitching effects on specific alloys.

How does the powder hold up over long periods of time?

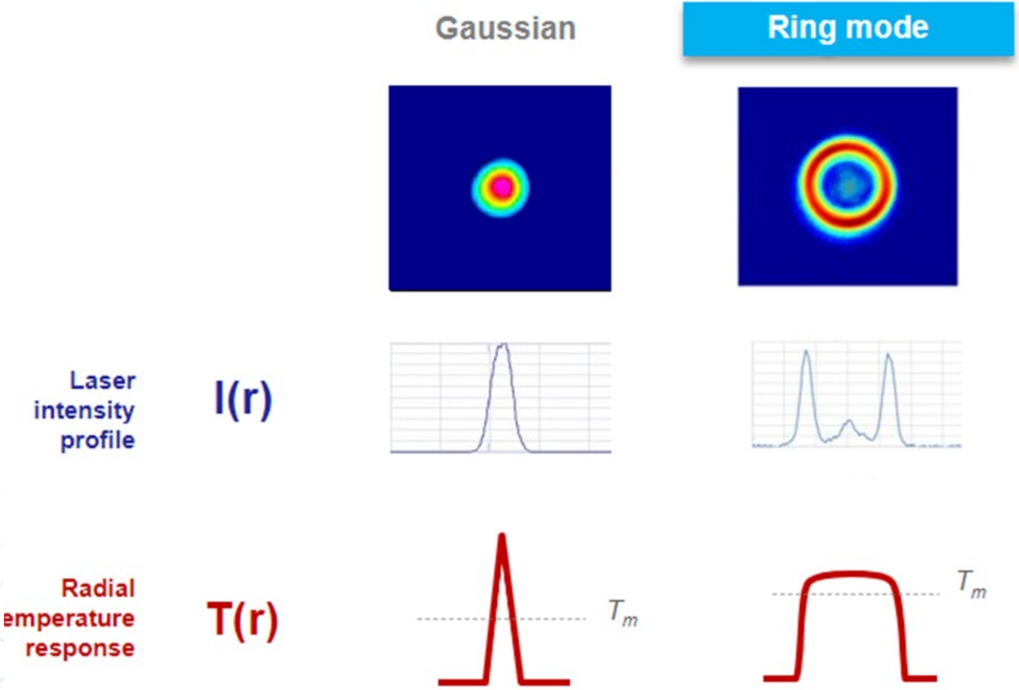
How do we make the process less energy intensive and more sustainable?

Where can AI and Big Data accelerate progress?

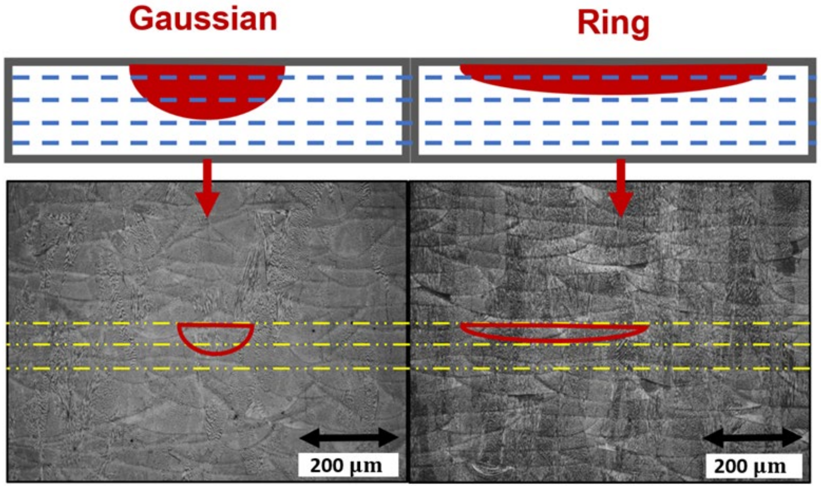


Rindler et al 2022

Dynamic focus lasers



nLight and OSU CDME

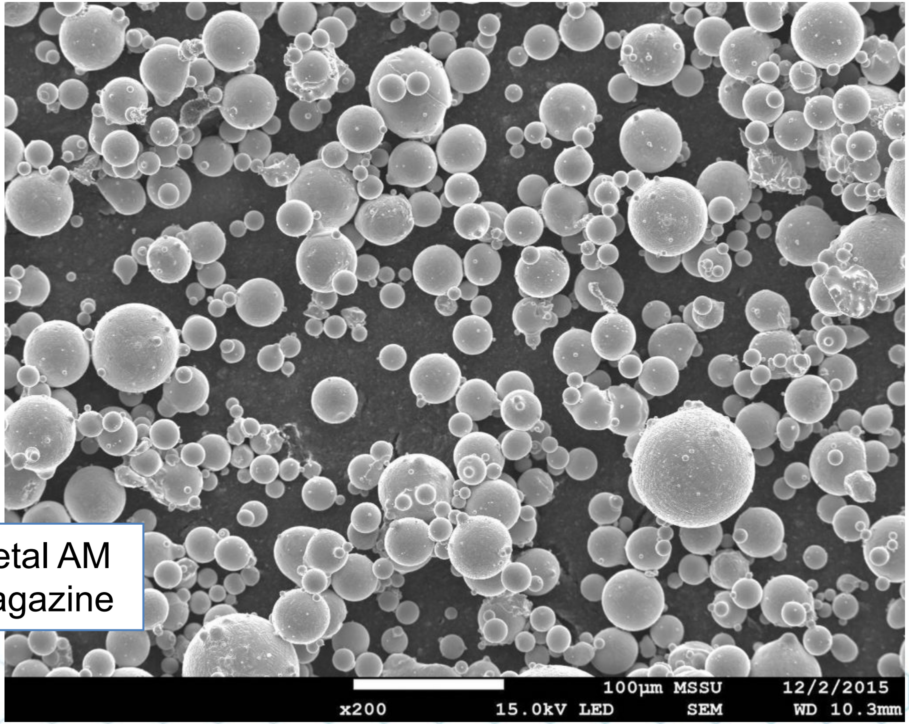


Cozzolino et al 2023

Using AI to Improve Quality

AddiGuru

Gas Atomized Powders for Metal AM



Metal AM Magazine

Mastersizer laser diffraction PSD

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Qualification Builds

Operational Qualification (OQ)

Lines, Cubes, Specimen

Detecting Trace Impurities

10 ppb to 1 ppm:
- ICP-MS, GF-AAS, and CVAA

1ppm to 100ppm:
- ICP-OES, ICP-MS, DC Arc, and Ion Chromatography

New techniques are developing at NSL Analytical.

The combination of phase extractions and XRD can provide insight into the phase composition of an alloy.

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Thank You!

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