Special Report from Formnext 2022

Introduction

Formnext is big. 800 exhibitors over 3 days means you can't spend more than 2 minutes on each stand if you wanted to visit them all. A lot of time is spent walking between rendezvous meet-ups – getting 10,000 steps every day is easy. Inevitably each visitor winds up sampling just some of what the show has to offer, and each through their own lens. If you manufacture printers then other hardware companies and technologies are probably seen as competitors, but if you make software or feedstock materials, they can all be potential customers. Users of 3D printing are looking for faster, bigger, cheaper solutions - and there were certainly plenty of these on display. This special report produced with the support of NGen and Canada Makes reflects a sampling experience, and inevitably much will have been missed, but for those who could not attend this year's show the report will hopefully provide some flavour and insights from Formnext.

The Canada Makes delegation visiting Formnext was significant, with around 30 representatives from across the country. Several Canadian companies, big and small, had stands at the show which saw nearly 30,000 visitors over the 4 days. One early takeaway was that there has probably never been a better time for German, and European countries to be looking to collaborate with Canada. The supply chain pain felt from the pandemic, a sea change in attitudes towards China, and Russia's invasion of Ukraine have all combined to focus attention on a new collaborative playing field. Canada's easy cultural fit and capabilities that complement, rather than duplicate, German additive manufacturing strengths was frequently apparent. Angela Spreng, from the Ontario Trade and Investment Office in Munich, was our tireless host throughout the visit, and a great resource for anyone needing insight and business intelligence on the ground in Germany.

Figure 1 Canada Makes delegation visited Trumpf in Ditzingen, before official welcome on opening day at Formnext

This report was prepared by Mark Kirby in his personal capacity. The opinions expressed are his own and do not necessarily reflect those of Canada Makes or Next Generation Manufacturing Canada.

Market & Machines

The size, and make-up of the 3d printing market is the subject of much speculation. Two reports for 2021 value the metal printing market at $3.5Bn and plastic printing at $0.8Bn[1]. Metals and metal manufactured products produced by any process are a $11.2Tn global market, vs plastics at $0.4Tn. Given the undeniable size of the metal products market it is perhaps inevitable that much focus is on metal printing and what impact it might have on this huge existing market. It should however be noted that plastic printing applications may well be paving the way for later, larger metal printing adoption.

Metal printing has an installed base of around 15,000 machines globally[2] and is dominated by laser powder bed machines. No other printing technology currently comes close in terms of installed base.

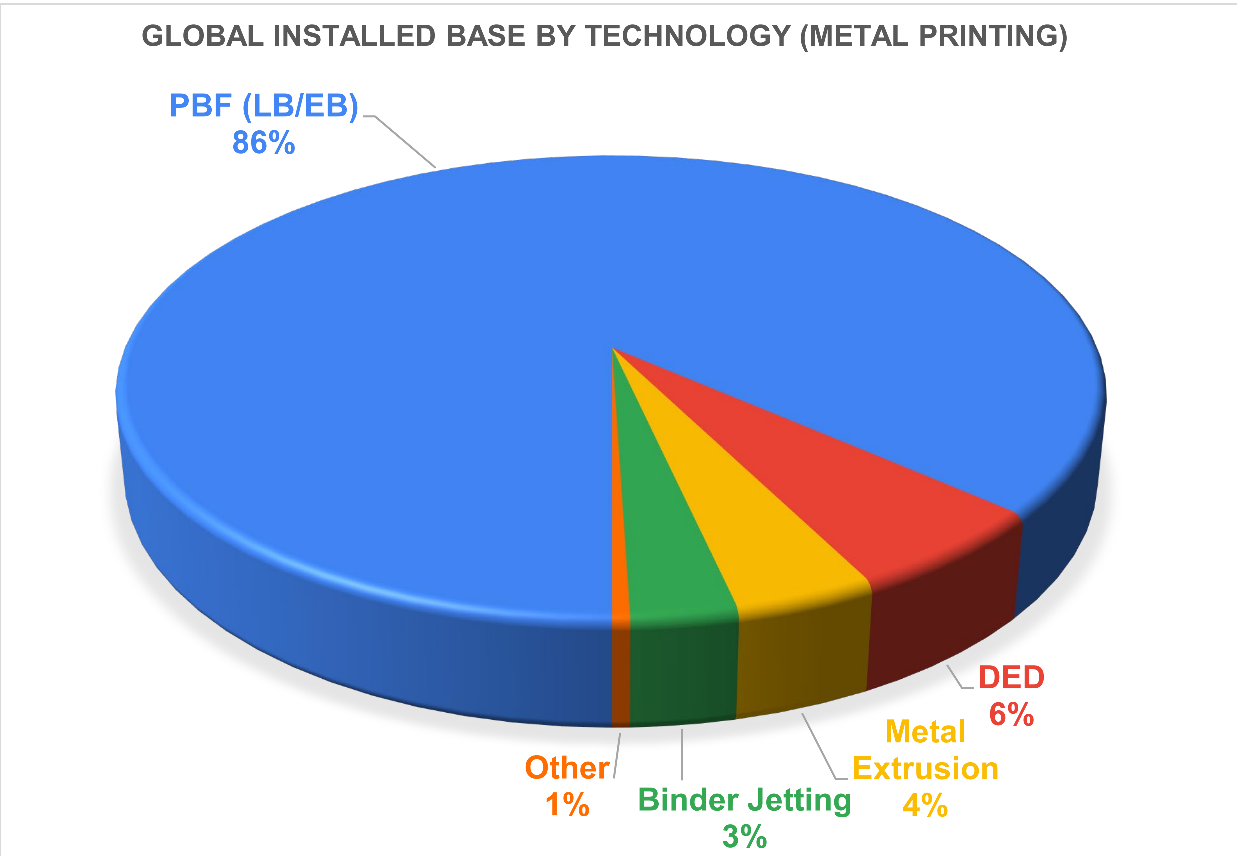


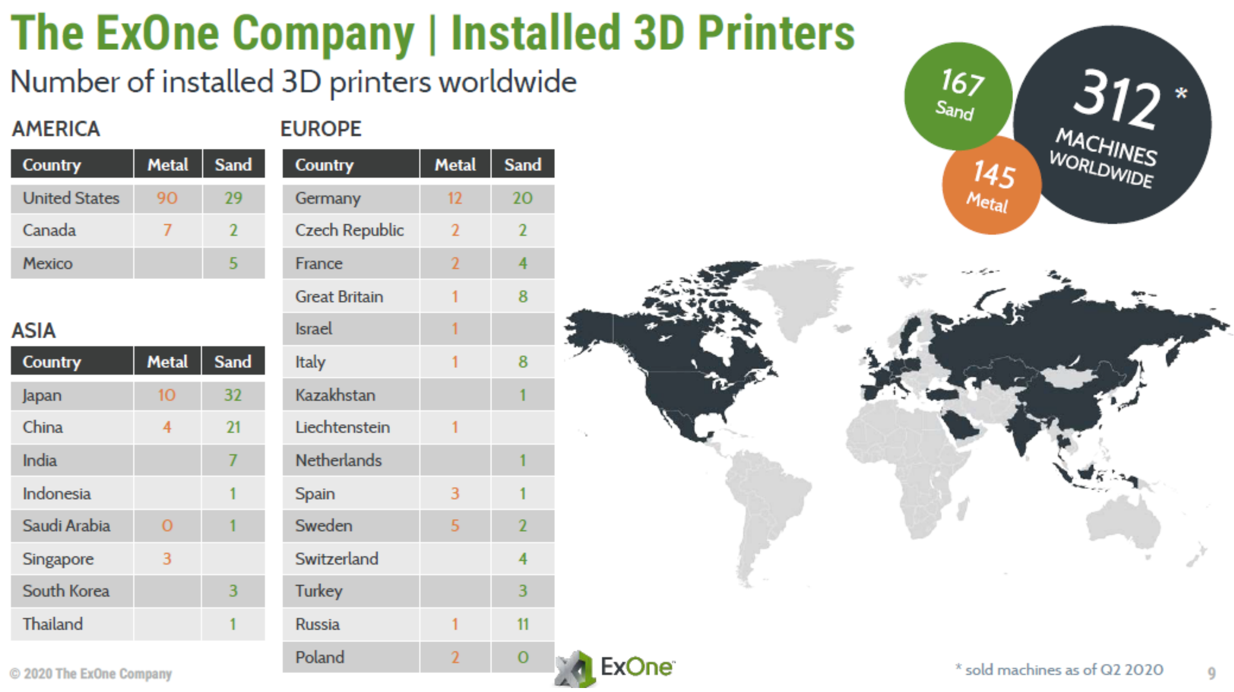
Figure 2 Installed base of metal printing machines by technology

Definitive figures for installed base by manufacturer are obviously hard to verify, but SLM Solutions claim 650 LPBF machines installed (April 2021 Investor Presentation), EOS over 1500 metal machines (2020) and relative newcomer Farsoon have 700 installs with a 50/50 split between metal and polymer

[1] Grandview Research

[2] Estimate from AM Power report 2020 of installed base of 9111 machines, and delivery data averaging 2000 machines per annum 2020-2022 period, from Wohlers 2020, and Context.

machines. By comparison ExOne, with probably the largest installed base of binder jet machines, show 312 machines globally, with only 145 of these being metal vs sand printers.



AMERICA

Country	Metal	Sand
United States	90	29
Canada	7	2
Mexico		5

ASIA

Country	Metal	Sand
Japan	10	32
China	4	21
India		7
Indonesia		1
Saudi Arabia	0	1
Singapore	3	
South Korea		3
Thailand		1

EUROPE

Country	Metal	Sand
Germany	12	20
Czech Republic	2	2
France	2	4
Great Britain	1	8
Israel	1	
Italy	1	8
Kazakhstan		1
Liechtenstein	1	
Netherlands		1
Spain	3	1
Sweden	5	2
Switzerland		4
Turkey		3
Russia	1	11
Poland	2	0

Figure 3 Installed base of ExOne machines (ExOne data)

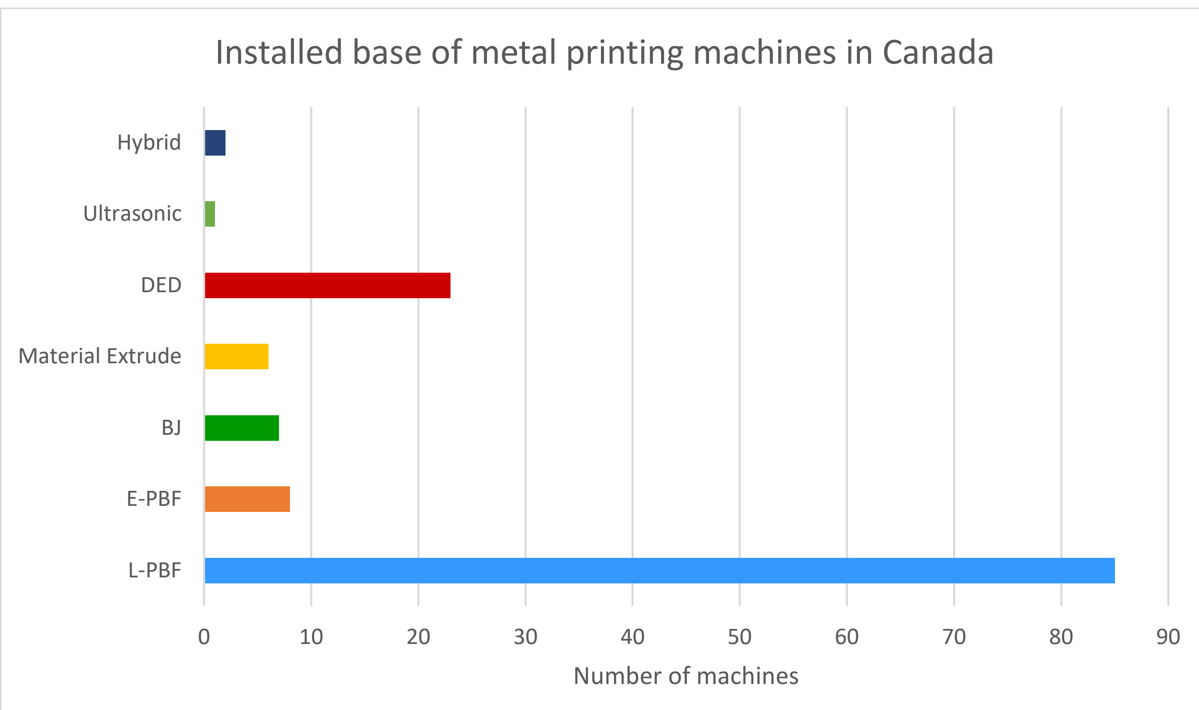


Figure 4 Approximate installed base of metal printers in Canada (Canada Makes data)

Canada's installed base of metal printers also shows laser powder bed machines significantly outnumber other metal printing technologies. So, to begin the review of Formnext it makes sense to first look at some of the established hardware OEMs in the metal LPBF space.

Formnext 2022 did not see any big new machine announcements from the established laser powder bed players. SLM's NXG XII 600, a 12 laser monster machine, with a 600mm envelope and a 1000cc/hr build rate was one of the last big announcements 2 years ago. SLM claims orders from Morf3D, Divergent Technologies, MAN Energy Solutions, Collins Aerospace, Sintavia and Elementum 3D. The 600E with an extended Z axis of 1.5m was announced just before Formnext this year, and Nikon's takeover of SLM was completed just after the show (subject to foreign investment control clearance in the United States, expected in Q1 2023). It will be interesting to see if Nikon's takeover reduces momentum at SLM, as different expertise, vision and cultures either coalesce or collide. Other acquisitions in the additive space, eg GE and Concept Laser/Arcam, Renishaw and MTT, as well as Desktop Metal and ExOne have produced mixed results in terms of the pace of innovation.

The theme from EOS was more continued evolution rather than revolution, with a clear focus on reducing cost per part to increase the addressable market. Current metal print costs are anywhere in the range of $100 to $1 per cubic centimetre, and a further order of magnitude reduction is needed to compete with existing manufacturing methods. EOS are working on beam shaping to improve productivity and better match laser beam energy to application requirements. Smarter energy input may for example reduce spatter. Expect therefore to see not just more lasers in machines, but different beam shapes. Toolpathing will inevitably also need to evolve as the complexity of the laser beams ("tools") in the carousel increases, and all these tools need to work together to give both good metallurgy and metrology.

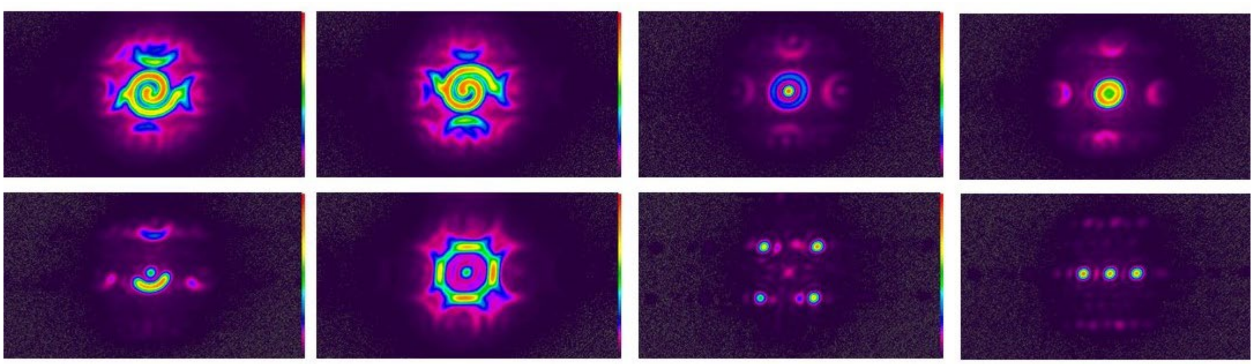


Figure 5 Beam shaping will become more common

EOS are also working to reduce material cost with new powders and size distributions from Uniformity labs. This may lead to improved productivity with higher process stability and increased layer thickness. Another materials related development is Cold Metal Fusion using MIM powder, binder and SLS machines. The use of lower cost powder (MIM) and machines (SLS) relative to the conventional LPBF process may be promising, although parts do still require a sintering step.

Figure 6 Cold Metal Fusion process uses MIM powder + binder, SLS printing followed by sintering to produce metal parts. The Cold Metal Fusion Alliance now includes Farsoon, Carbolite Gero, Sintratec and Miba.

After machines and materials, the third leg of cost reduction is post-processing improvement. Like many others EOS are "industrialising" support free build strategies with their "kNOw SUPPORTS" offering. Eliminating, or significantly reducing, the support structures in LPBF saves print time, material cost and can dramatically reduce post-processing lead-time, cost, and variability.

Most of the major powder bed OEMs have demonstrated they can print parts with low angle overhangs and no supports. However, transferring that know how to the user is often not so straightforward. Velo3d have done this with their proprietary Flow software (and contactless recoater). It remains to be seen how kNOw SUPPORTS from EOS, Free Float from SLM (available at no charge) and other 3rd part solutions will gain traction and erode Velo's perceived advantage. The evolution of support free printing may mimic the development of support free machining, where parts are machined from a block in a single setup and left hanging by thin tabs. Despite this being "common practice" for many years the exact recipe for doing this successfully still seems to be tribal knowledge. Interestingly Autodesk (the self-proclaimed Democratizer) were granted a patent on this in 2022 and may incorporate tabbing strategies into their Fusion360 CAM software, but it's not released yet.

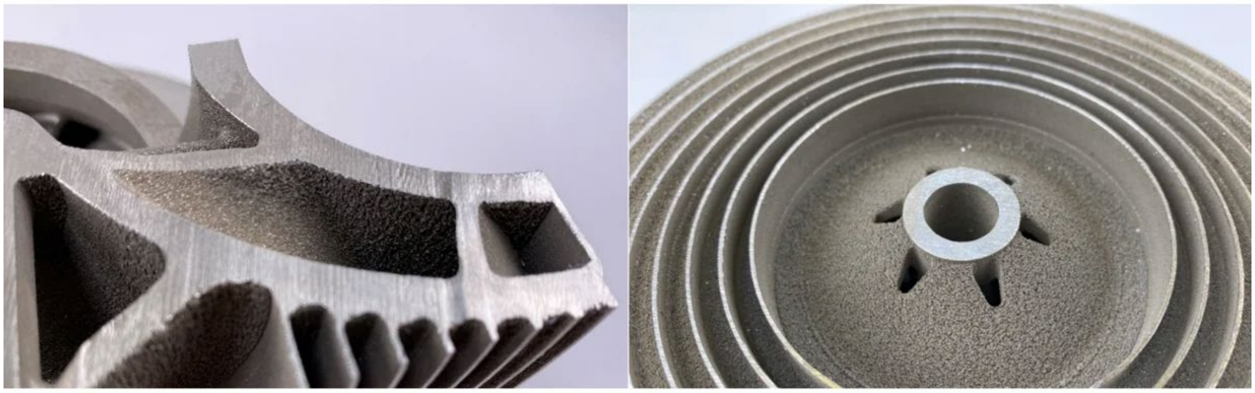


Figure 7 EOS impeller produced using their kNOw SUPPORTS solution

While EOS are working on beam shaping, Renishaw continue to innovate with a new patent on beam steering, adding a fast response, small amplitude system to the established galvo mirror systems. Exactly how (and when) this will provide benefits to users remains to be seen, but novel strategies are shown. The parallel with Renishaw's high speed 5-axis Revo metrology head added to the slow-moving frame of a coordinate measuring machine is striking for several reasons.

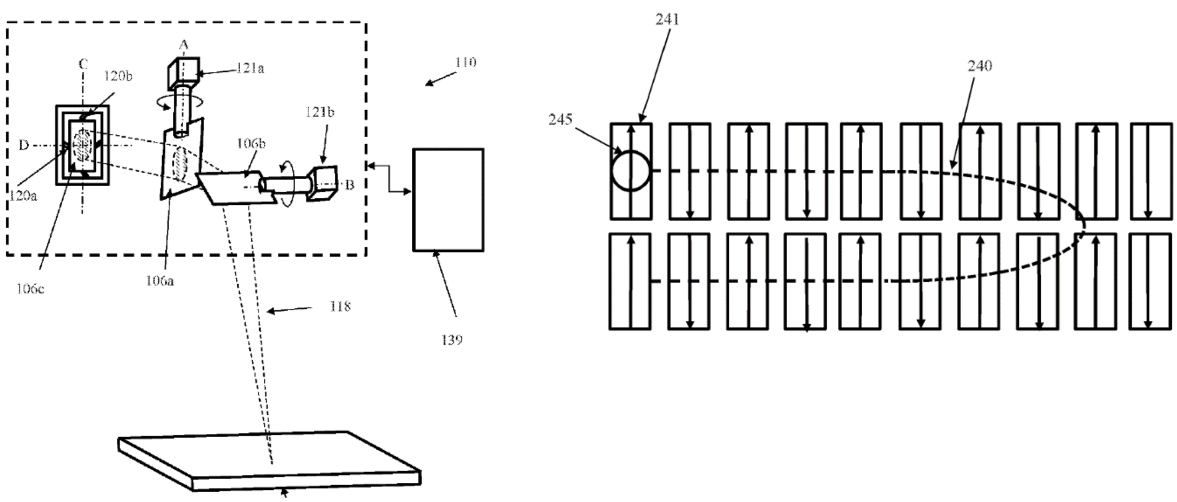
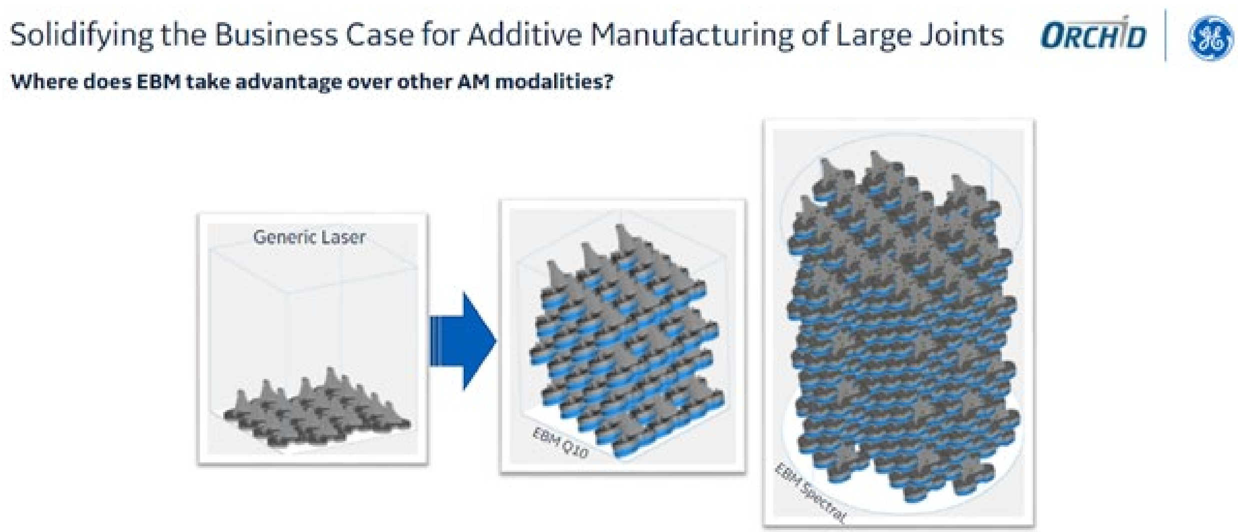


Figure 8 Renishaw patent showing fast beam steering and novel scanning strategies

It is interesting that Renishaw sold these high-speed Revo systems to a variety of OEM's before more recently developing their own complete CMM platform. It would be harder to redesign the bespoke optical system for Renishaw's additive machines to fit other LPBF machines, but not impossible. Selling high precision modules into the OEM capital equipment market is a business Renishaw has historically excelled at. However, it is more likely that Renishaw will continue to promote and develop its quad laser flagship as a high-performance niche product for demanding, regulated industries – a sort of Hermle vs

Haas machine tool model. Headwinds can be expected as industries scale and farms of machines look unattractive vs larger platforms or different technologies. For example, Orchid Orthopedic Solutions have recently announced a commitment to GE's SpectraL EBM platform as they seek to scale to 500,000 large medical implants per annum. Orchid sees running fewer machines with longer cycles as being both less risky ("fewer times the door is opened") and more cost effective than managing many LPBF machines.



	Laser - Generic	EBM - SpectraL
Tib Trays	15-20 parts / 10-15 hours = **1.5 parts/hour**	250-345 parts / 100-150 hrs = **2.5 parts/hour**
Knee Fem	25-30 parts / 25-35 hours = **1 part/hour**	200-250 parts / 125-150hrs = **1.6 parts/hr**

Figure 9 Orchid Orthopedic/GE presentation claiming EBM advantage over LPBF for large medical joint manufacturing

Finally, Renishaw might yet produce a larger "casting killer" platform, via the UK government funded Large Scale Additive Manufacturing for Defence and Aerospace (LAMDA) programme. However, this multi-laser, automated platform is only initially targeted at components up to 500mm size, with a completion date still over a year away.

Velo3D are a company "full of cash and energy", with a solution that "just works". CEO Benny Buller talks regularly with Elon Musk at SpaceX, a key customer for Velo3D, and both share a physics driven, first principles approach to problem solving. Velo's relatively large platforms (up to 600mm dia by 1m in z) and integrated software for build prep with no/few supports, and quality assurance, have made them the preferred choice for US rocket companies. Whether this success (and premium) will translate to other market sectors, and critically whether Velo can penetrate outside of the US remains to be seen. Velo, as a genuine US manufacturer, would we be well placed to become a defense supplier for the US DOD (maybe alongside 3D Systems)? Montreal based space launch company Reaction Dynamics have the first Velo machine in Canada, a Sapphire running Inconel 625.

GE’s additive portfolio seems to face competition on every front. With patents expiring there have been new entrants and innovation in the EBM space, like Wayland in the UK and Freemelt from Sweden. Exergy Solutions have just taken delivery of the first Wayland machine in Canada (and possibly the first machine outside the UK). However, GE’s recent success with its SpectraL for medical implant manufacturing at Orchid is a significant vote of confidence in their technology solution.

Figure 10 GE/Arcam’s monopoly on EBM is under threat from new entrants now patents have expired. Exergy Solutions in Alberta received the Calibur EBM from UK startup Wayland Additive just before Christmas.

On the binder jet front GE is promoting the cost effectiveness of the technology (“100x faster than single laser”), with a target to reduce cost from $1/cc to $0.25/cc to increase the addressable market (same story as EOS, but a different technology solution!) Distortion prediction (during sintering) and control is addressed with GE’s Amp software.

Our Canada Makes delegation visited Trumpf’s Ditzingen (Stuttgart) factory the day before Formnext opened. There is no denying Trumpf’s deep industrial knowledge of lasers, manufacturing, and automation. After producing its TrumaForm laser powder bed machine over 20 years ago, Trumpf concluded the market was not ready, and withdrew, only to re-engage in 2015 with its Truprint 1000. “Looking back, TRUMPF’s decision to shelve its work on powder bed additive manufacturing was the wrong one” – candid words from Trumpf’s own website! Trumpf’s late re-entry in 2015 helps explain why it does not currently command more market share in laser powder bed. However, the competencies and customer network it owns make it a potential powerhouse going forward. It should also be noted that Trumpf never ceased developing Directed Energy/cladding applications.

During the Canada Makes visit we saw how easily the powder module could be changed (a “pop quiz” test to validate the engineering design.) The cell leader, Niko Werner, also demonstrated how layer process monitoring and automatic recoating are genuinely routine procedures for production on Trumpf machines. In Canada Trumpf machines are few and far between – with Burloak having Truprint 1000 and 2000 machines, and the larger, high temperature Truprint 5000 now installed at NRC’s new Winnipeg facility.

Figure 11 Trumpf demonstrated its easy powder handling and advanced in-process controls "live" to the Canada Makes group during the factory visit to Ditzingen.

Figure 12 In Canada the largest Trumpf machine, the TruPrint 5000, has been installed at NRC's new Winnipeg facility

Materials

The cost of material used by additive as feedstock, whether it is for example metal powder or polymer filament, remains a hard limit and a barrier to adoption. Cost targets for finished parts to be (much) less than $1/cc can never be achieved if the feedstock price is already this high, no matter how efficient/fast/affordable machines become.

The lowest price for metal powder feedstock is around $0.4/cc, with an average price closer to $1/cc ($1000/Litre), as shown in the figure below. Note that all additive feedstocks are more expensive by typically an order of magnitude or more than their "conventional" forms.

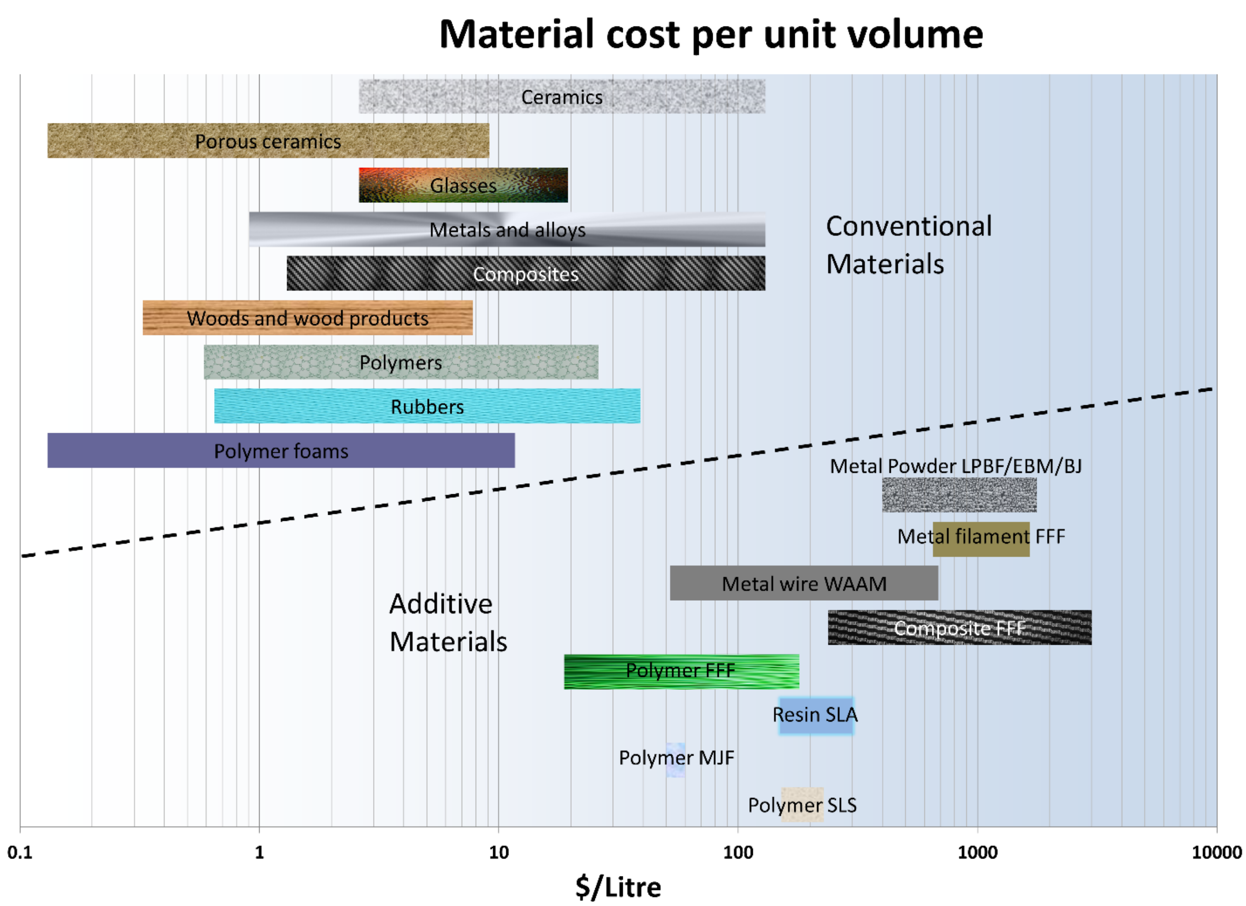


Figure 13 Conventional material costs compared to Additive material costs per unit volume (University of Waterloo, MSAM data)

Metal powder has historically been more expensive than its solid form as it (usually) needs to be melted again to form powder, and the size distribution of particles produced often means much of the solidified powder is either too big or too small, and so the yield is low. A particularly exciting development is the new process patented by Metal Powder Works (MPW) for producing feedstock without any extra melting. The MPW process takes a bar of material and turns it into feedstock chips using a lathe with novel, ultrasonically excited, cutting tools. Although the chips produced are not perfectly spherical, they are very consistent, and the process yield is much higher than the 40% typical for atomizing. These particles may even be better for processes like cold spray and binder jetting (with increased contact/sintering area), and possibly reduce spatter in laser powder bed. Initially MPW will focus on aluminum and copper (softer) alloy production, and parts have already been printed successfully on EOS and Renishaw LPBF machines at Waterloo and Beehive Industries.

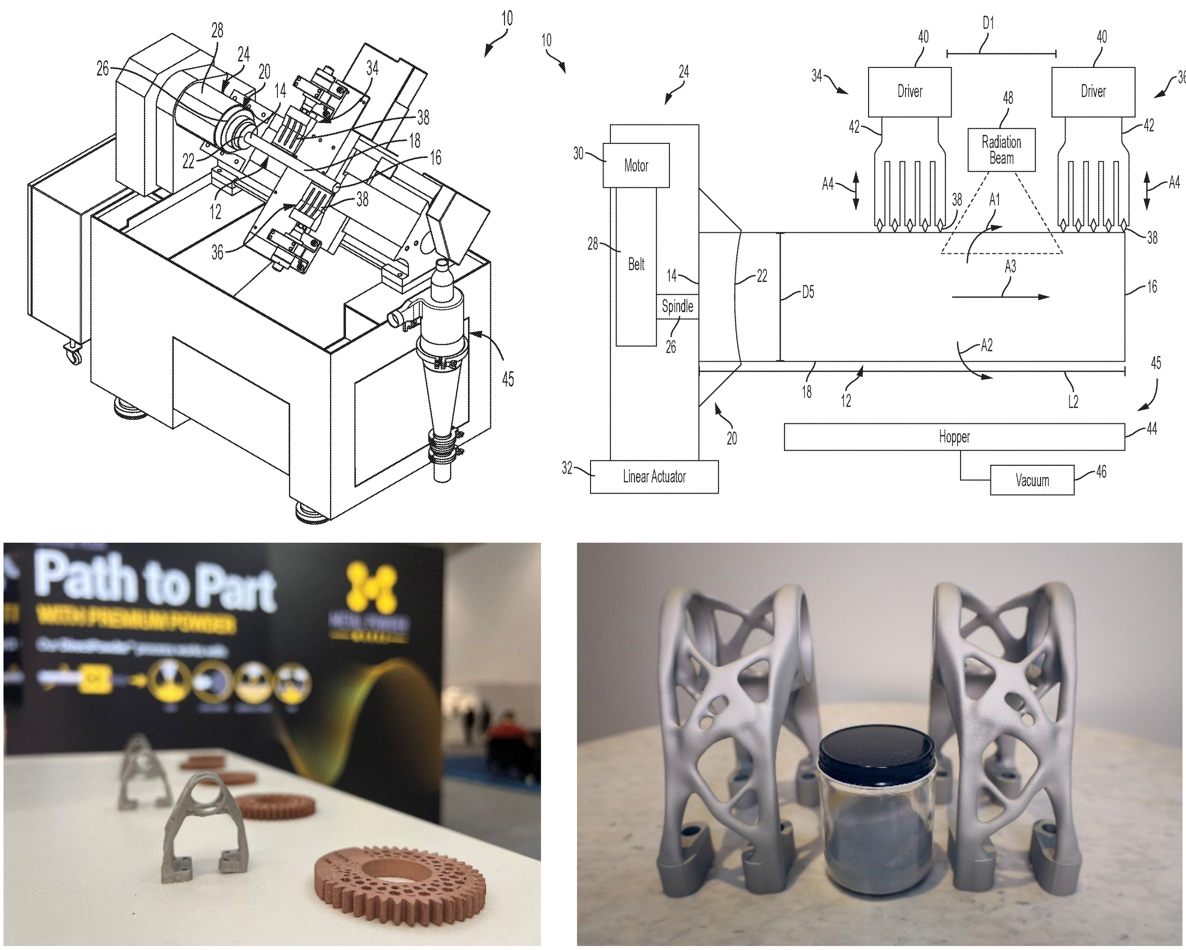


Figure 14 Metal Powder Works patented method for producing feedstock from bar material. Parts printed by University of Waterloo and Beehive Industries in C14500 and Al7075.

Ottawa based Equispheres announced during the show a new non-explosible aluminum alloy, NExP-1. It maintains the ability to produce high-quality prints at high throughput rates, but unlike other metal powders for AM, it is dust-free and characterized as non-explosible per ASTM E1226, Standard Test Method for Explosibility of Dust Clouds.

Fraunhofer and Metrom demonstrated both impressive speed and lower material cost on the polymer front with their SEAMHex machine. The SEAM (Screw Extrusion Additive Manufacturing) Unit was invented by the Fraunhofer Institute IWU and is today distributed by 1A Technologies. The unit can deposit at up to 8kg/hr and features a bypass module to handle geometry changes (corners) as well as allowing jumping from point to point. The unit uses pellets (which can be granulated and reused from the bypass) and material costs are the order of $6/kg instead of $100/kg for filament! The hexapod platform from Metrom allows 1g, 5-axis motion. The machine at Formnext did not have the correct (pretensioned) ballscrews fitted (supply chain issues again!) and was therefore running much slower as a result, but it was still impressively quick.

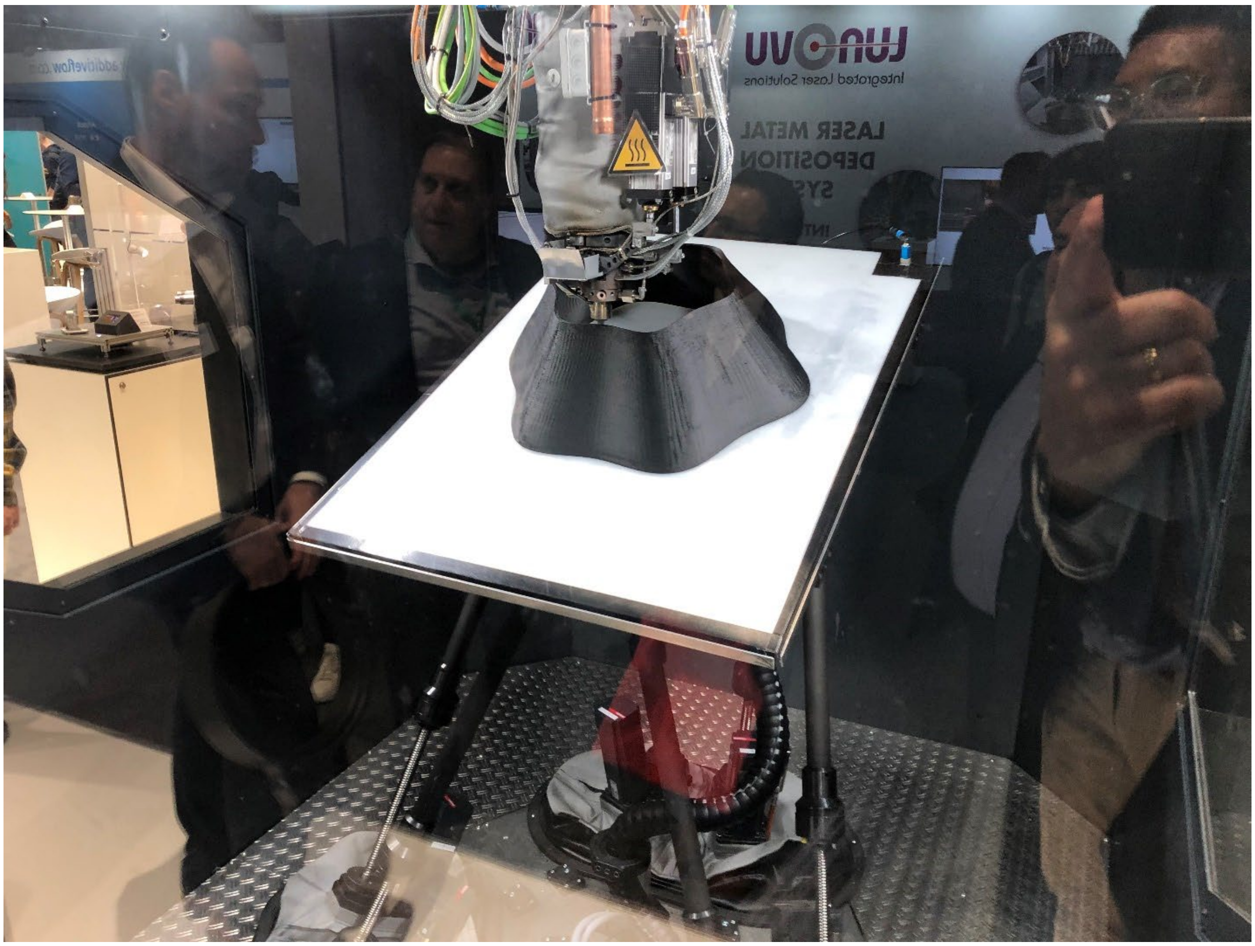


Figure 15 SEAMHex platform from Fraunhofer and Metrom running at high speeds with low material cost

Montreal based Dyze Design, with its lofty mission statement “to become the ‘Intel Inside’ for all printers operating under the material extrusion principle” displayed its pellet fed Pulsar extruder head, capable of depositing a very impressive 3kg/hr. Their web site has a nice cost calculator to compare savings with pellet feed vs filament for a variety of materials.

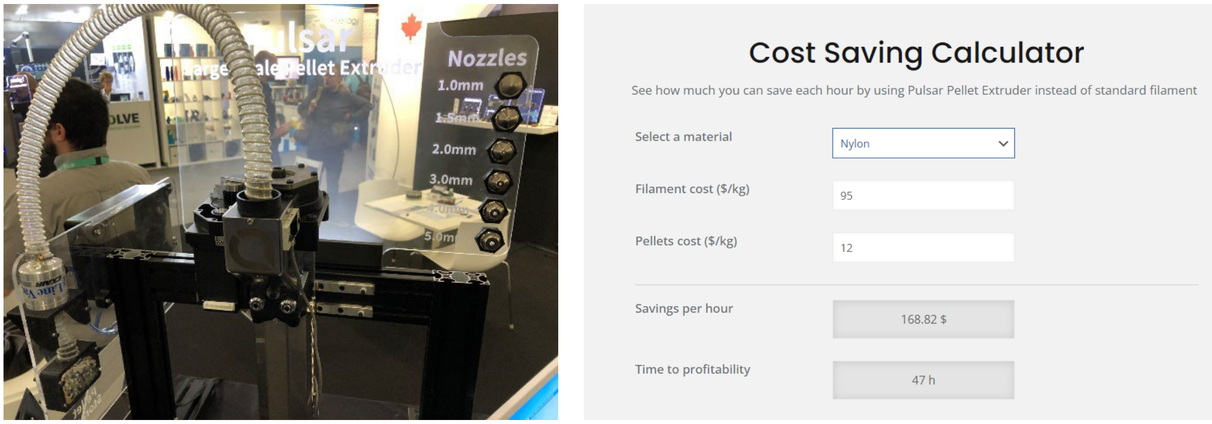


Figure 16 Dyze Design showing pellet feed extrusion, and cost calculator tool

As well as the SEAMHex polymer printer, Metrom also displayed some innovative, transportable, combined DED and 5-axis machining solutions for metal structures. In one form (Mobile Smart Factory) the pentapod structure is inside a shipping container, and WAAM welding units and milling heads can be exchanged to perform repair or construction. A unit like this is being trialled in the port of Hamburg. A use case here being ships needing specialist spare parts/repairs that cannot economically be provisioned for. An early success was producing new porthole window frames to replace ones damaged by storms.

Figure 17 The Mobile Smart Factory uses a hybrid machine from METROM for component production and parts repair service. Based on a patented parallel kinematics concept the machine combines a WAAM module with a milling and drilling unit

Another version is the PM-Series, described as a CNC machining robot, but with its pentapod structure giving it 10 times the accuracy and 100 times the stiffness of a conventional robot. The structure is moved to the job site and can be repositioned multiple times to perform in situ work on massive components.

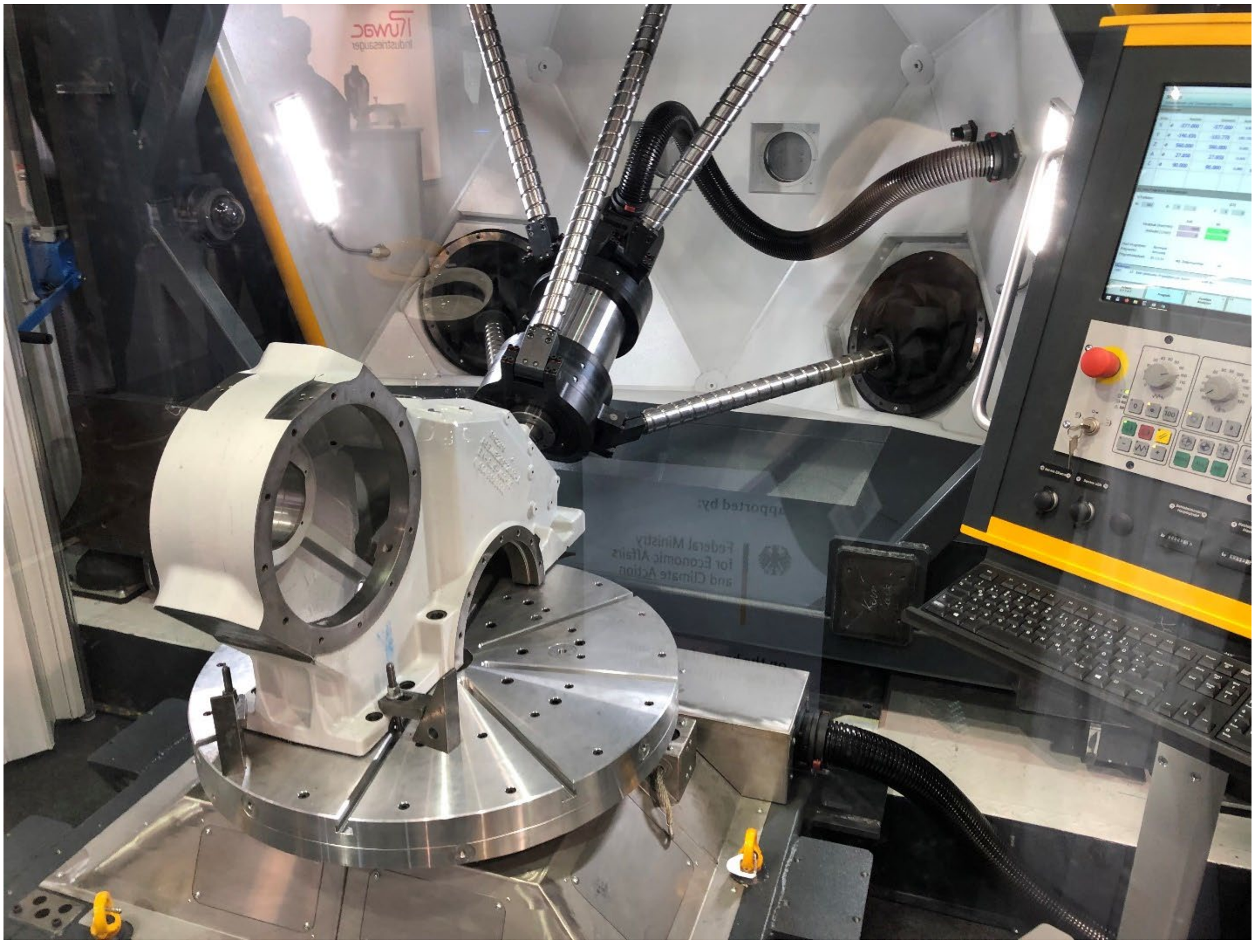


Figure 18 Metrom PM-Series CNC Machining robot can be transported to the job site and repositioned for large structure machining

Post-Processing/Automation

The total cost of a printed part depends not just on the machine price/print time plus material consumed, but critically on all the additional steps needed after printing. For production to scale economically and robustly it is important that human touch points be eliminated as much as possible. Every touch takes time, costs money and introduces the possibility of error. For metal printing downstream bottlenecks can be support removal, machining, and quality assurance. For polymer printing of a high mix, low volume population simply sorting the parts can become a costly bottleneck.

There was certainly no shortage of robots at Formnext, whether being used with some form of print head or to move parts - as Stratasys showed with its P3 (Programmable Photopolymerization process) cell.

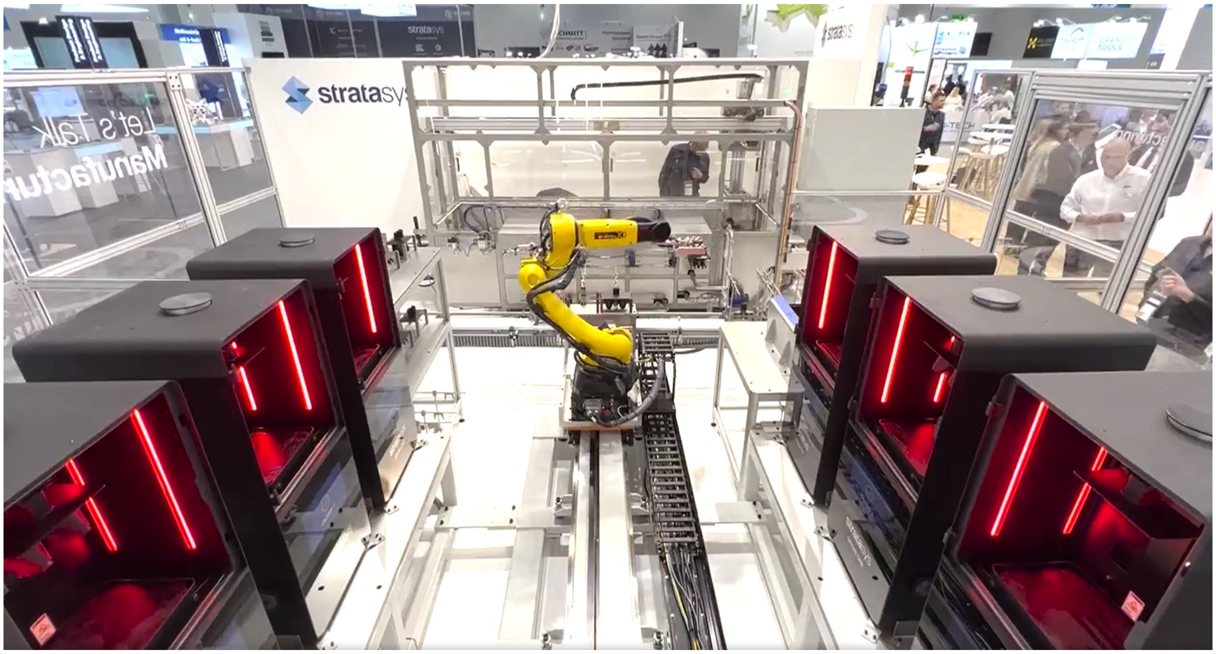


Figure 19 Robot tended P3 cell (Stratasys)

A very ambitious German demonstration project, IDAM, included full automation of workflows for EOS 300-4 and Trumpf Trupint 5000 machines, at GKN and BMW respectively. Automation included depowdering, transport and saw removal of parts from the build plate.

Figure 20 EOS300-4 automated depowdering solution implemented as part of IDAM project

Rivelin Robotics, a UK company, are tackling the literally thorny issue of removing supports and the resulting “stubble” from LPBF parts. Founder Robert Bush used to be responsible for metal part finishing operations at one of the UK’s largest 3D print bureaus, 3T AM, and so has a deep understanding of both the problems as well as the tools and strategies needed to finish high value parts. Rivelin has started with this hard-won process knowledge and looked to automate solutions using software, vision systems and force sensing. The result is not hardware centric (as the IDAM solutions are), but a flexible, agnostic approach where the human is still in the loop but robots deploy different tools and strategies, repeatably and non-stop. Rivelin are suggesting customers can view this as an operational expense, “a 12-month labour contract”. The Ministry of Defence are showing keen interest in applications for repair and maintenance, and other big players were circling the Rivelin stand. Don’t expect this company to stay small for long, but for now you would be hard pressed to find a better group to work with, whether it is support removal or the much broader “targeted finishing” they offer.

Figure 21 Rivelin Robotics have built a true digital twin while developing automated support removal and targeted finishing using force sensing

Formnext saw the launch of AM-Flow’s inline AM-QUALITY module that can identify parts in just 0.2 seconds, and dimensionally inspect them using structured light in less than 10 seconds. This capability means that high mix parts can be identified in a continuous flow line process and downstream processing actions taken – sorting, moving, part-marking, bagging etc.

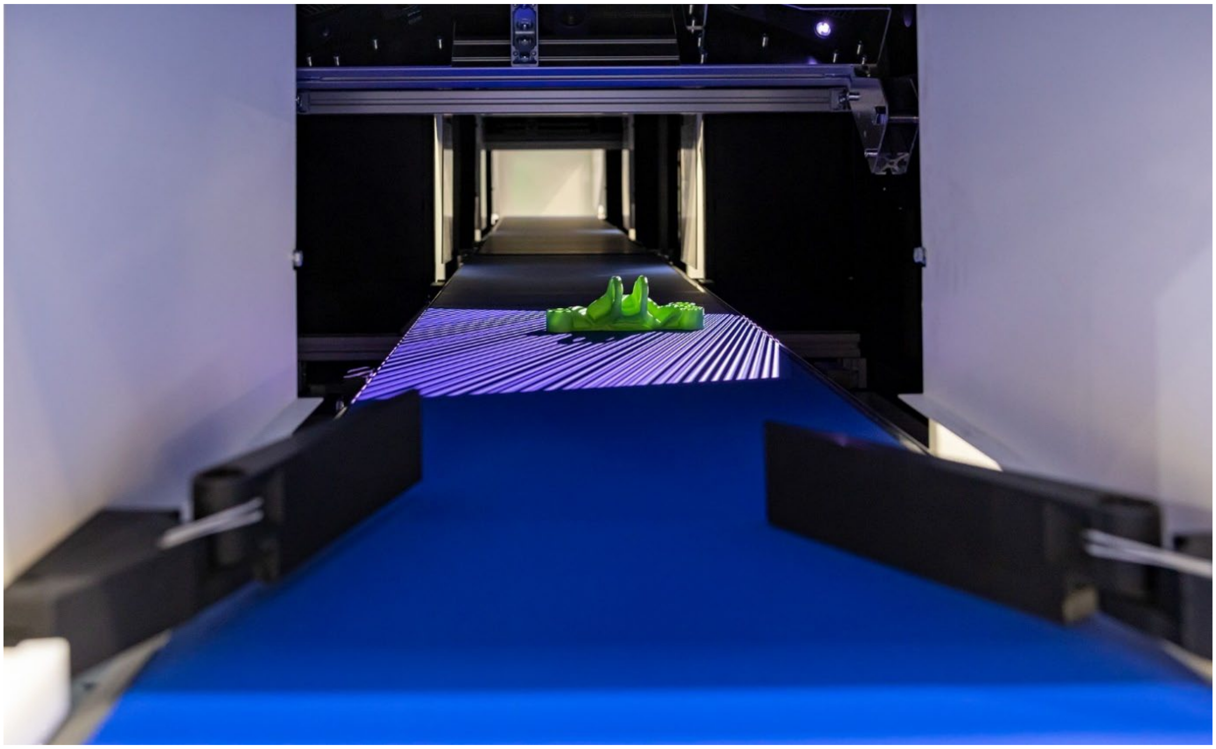


Figure 22 AM-Flow launched their new AM-QUALITY in line inspection module using structured light

Inside the AM-QUALITY module the part is scanned and then flipped “upside down” (using a conveyor sandwich mechanism) and scanned again. A dimensional report matching the print geometry to appropriate CAD model is automatically compiled with a claimed accuracy of 0.05mm. This is a great example of the maturing status of additive manufacturing, removing expensive (but low value) human touch points. Only a few years ago 100% CT inspection of fuel nozzles threatened to become a critical bottleneck for GE as production on the LEAP engine scaled. (GE subsequently developed faster CT technology – necessity being the mother of invention!) AM-Flow's real time inspection of randomly sequenced parts is a significant step forward, even if it is "just" dimensional. Think how long it can take to programme a part for inspection on a CMM - could you even find and load the CAD file for a random part (never mind inspect it) in less than 10 seconds?

Mosaic showed Element and Array, the printer building block and the automated printing system respectively. The Array machine is much more than simply 4 Element printers, as the automation onboard allows these printers to run continuously, unattended for up to 72 hours. This continuous running can produce a 10 fold improvement in productivity according to Mosaic's data, and it's not hard to imagine with a printer now "triple shifted" running 24/3 and four of these in the Array. Mosaic's CEO, Mitch Debora, announced at Formnext that Mosaic are expecting some customers to install "hundreds" of Array machines capable of running thousands of material combinations. Mitch described the challenger this way on his recent podcast with Canada Makes – "You need reliable automation and then you need the software pipeline which is not something that's really been dreamed of before you. It's less of a slicer or utility software, it's more of a workflow manufacturing execution system software."

Figure 23 The back of Mosaic's Array machine, capable of running for 72 hours unattended with multiple materials

Directed Energy

Just as Formnext 2022 showed a proliferation of Laser Powder Bed systems, the same was also true for Directed Energy (DED) systems and components. Fraunhofer displayed a range of DED nozzles, with impressive fine detail from their COAXwire mini head. (The Canada Makes delegation had also seen a vast collection of Trumpf laser DED heads during the factory visit to Ditzingen). UK based AI Build have been working with all forms of DED and observed that the lower heat input from laser systems typically mean they are easier to get running than Wire Arc systems, with WAAM offering faster deposition but the high heat input sometimes requiring more development time to get good results.

Figure 24 Fraunhofer detailed an impressive range of DED heads during their presentation to the Canada Makes delegation

A fascinating debut was from German start-up Ponticon, with a parallel kinematic platform capable of 5g acceleration, 100m/min feedrates and 0.03mm accuracy – a remarkably quick beast! The machine uses the Dynamic Material Deposition (3DMD) principle developed by Fraunhofer ILT and RWTH Aachen University. Here the powder stream is melted *above* the surface, while a portion of the laser beam also melts the surface, resulting in a bond with a very shallow heat affected zone. The chief engineer for the project, Thomas Horr, had an interesting background that included designing high speed sausage filling machines. The rapidity of this platform really has to be seen to be believed. It has clearly been engineered with the exclusive objective of speed and accuracy - from the carbon fibre struts, CNC milled aluminium table, special zero tolerance bearings to the massive weight of the machine frame designed to resist the dynamic loads. Ponticon envision applications from coating to precise manufacture of thin wall structures. Development of new alloys is also possible exploiting the wide range of cooling rates possible on the machine – from 100 deg/second all the way to 10 million deg/second.

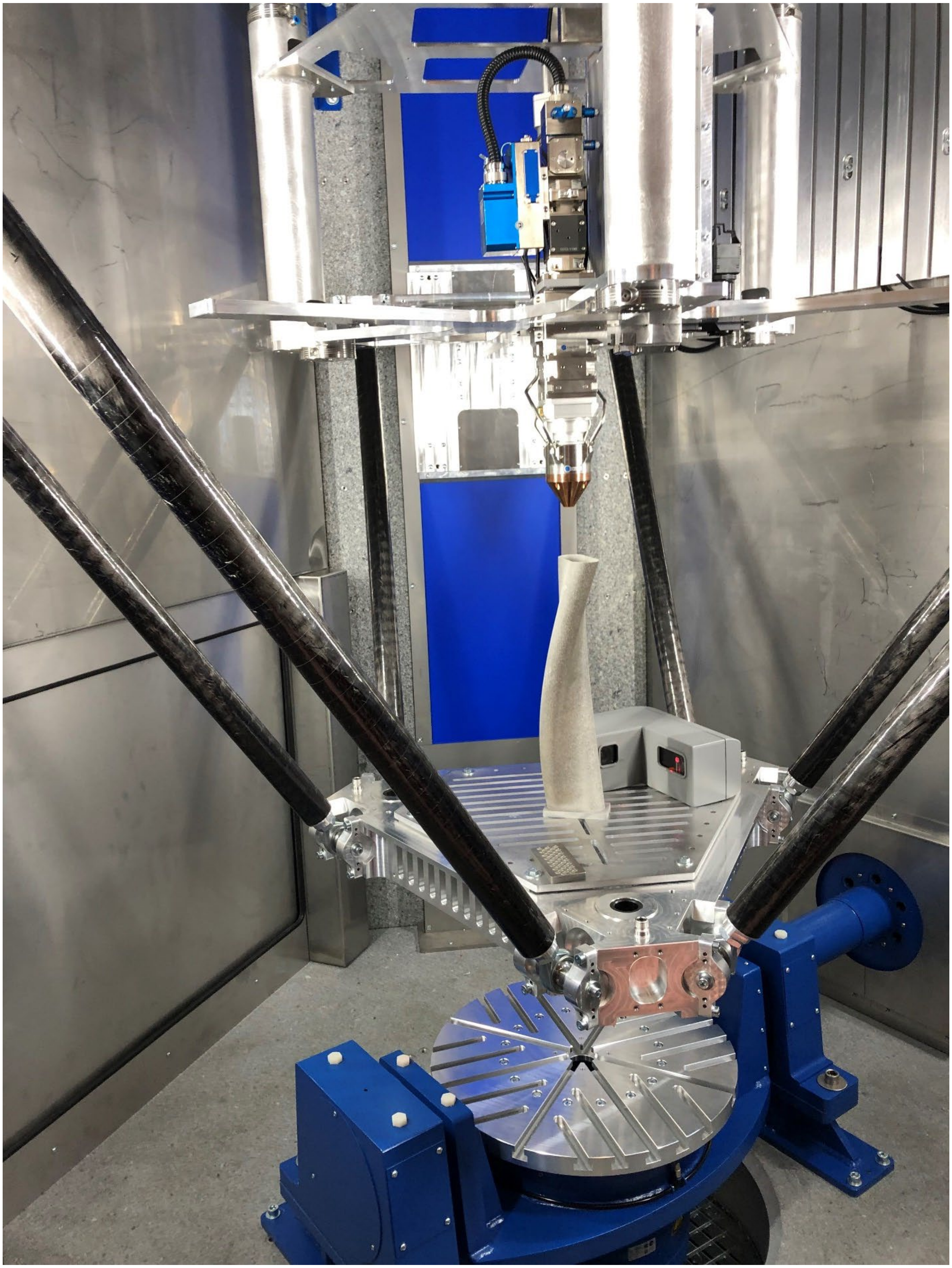


Figure 25 Ponticon pE3D – capable of 5g, and 100m/min feedrates – with a 7000kg granite frame to resist dynamic loads

Big Stuff

Bigger machines, and larger demo parts, were certainly a noticeable trend at Formnext, whether it was polymer, composites, powder bed or DED. Powder bed is pushing towards a 1m envelope, at which point the investment in the tonnes of powder to run the machine will be an eye watering figure. The working capital needed to finance the largely unused “block” of powder filling the build chamber may become as much of a barrier as the capital investment in the machine. Gas flow over a large surface area is increasingly difficult to control, and Fraunhofer showed a (dummy) gantry mechanism to locally melt and shield on an 800mm diameter test bed.

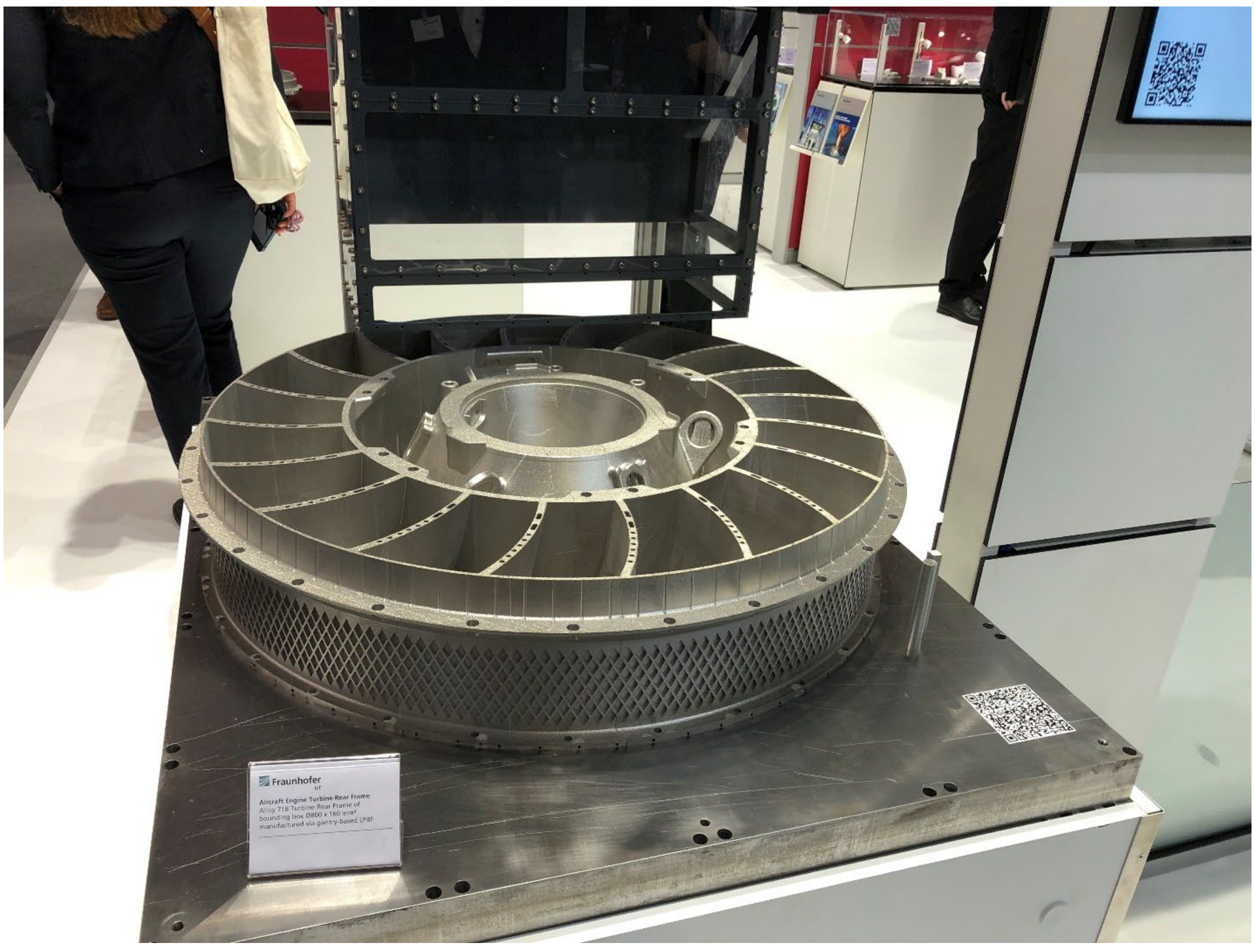


Figure 26 Fraunhofer local gantry solution for very large powder bed parts (gantry is mock up at rear of part, provides local gas shielding)

For very large objects DED seems naturally better suited than powder bed, as no “block” of powder is required. Perhaps the ultimate example, and test, of DED’s ability to print big objects, is Relativity Space’s Terran 1 rocket. The 4th generation of their Stargate DED wire-fed system now prints aluminum tanks horizontally, 24 feet in diameter by 120 feet long, and seven times faster than earlier systems. Relativity’s founder and CEO Tim Ellis claims “large-scale products that are designed to fly will inevitably be 3D printed", in particular because of the positive feedback inherent in printing - making parts lighter also makes them faster to print. He also sees design iterations with no tooling cost or lead time driving faster progress in aerospace. Relativity Space's long-term plan with 3d printing may be to use the revenue from rocket launch services to disrupt the much larger aerospace manufacturing market by printing monolithic structures and eliminating much of the tooling cost associated with conventional manufacturing. Surface finish remains rough/wavy on the rocket tanks, but aerodynamics is much less important for this mission than for aerospace vehicles cruising in the atmosphere. Early applications for DED are likely to be part consolidated structures rather than aerodynamic skins.

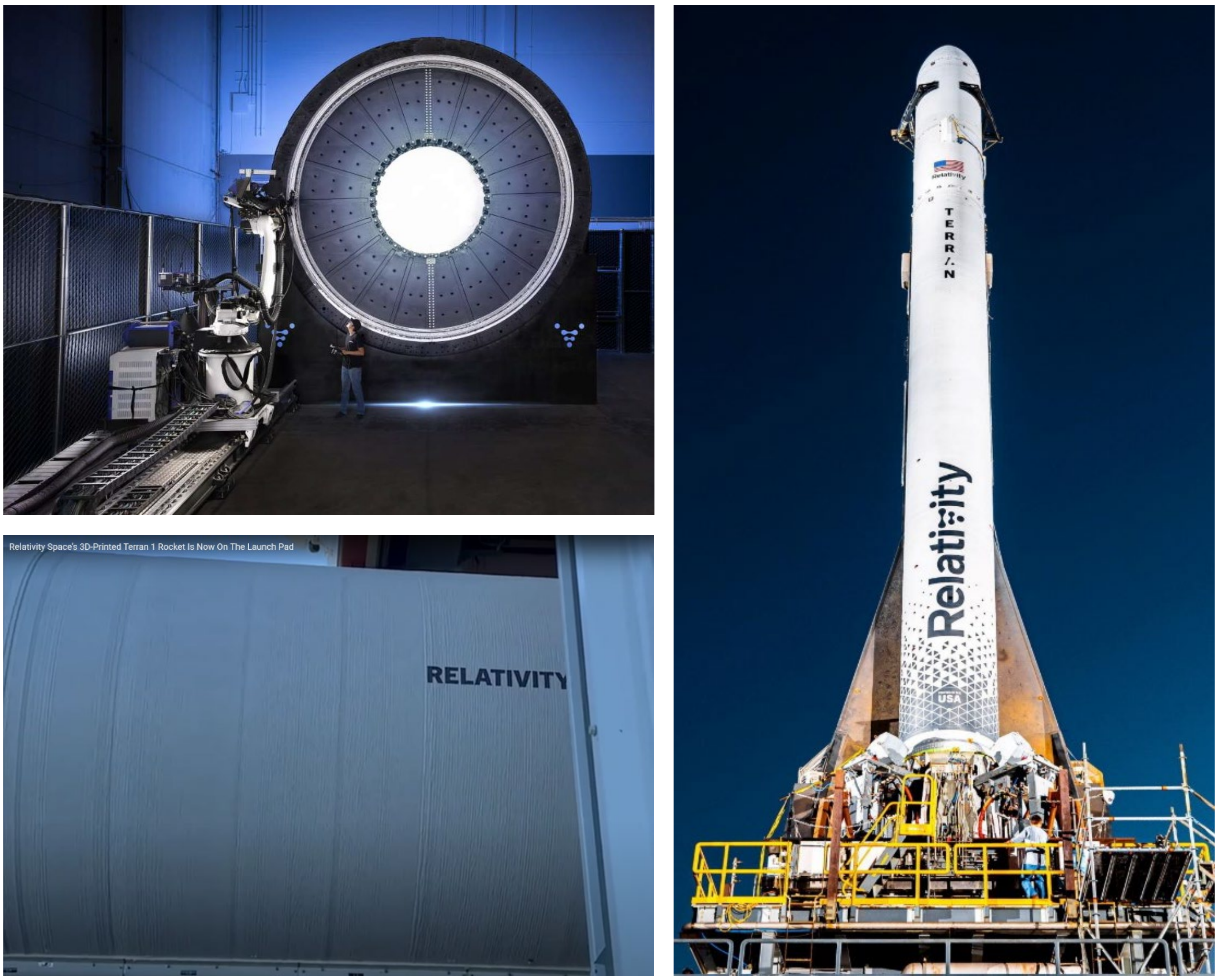


Figure 27 Relativity Space Stargate4 DED printer capable of 24 feet diameter x 120 feet long

Gantry and robot polymer systems were both prominent at Formnext. Pellet fed extrusion heads capable of both high deposition rates, and low material costs, seem to be a natural fit for bigger polymer parts. Toronto based Xaba have just shown the APMA Canadian produced Project Arrow electric vehicle at CES. Xaba collaborated with Italian machine tool builder Breton, on their new polymer Genesi gantry machine range, with the smaller E2 machine shown at Formnext. The chassis for Project Arrow was printed in just 5 parts on the massive Genesi E3+M, capable of depositing 200kg/hr, followed by 5-axis finish milling on the same machine.

Figure 28 Toronto based Xaba have collaborated with Italian machine tool builder Breton on their Genesi extrusion and milling machines. The chassis for Project Arrow, a Canadian prototype EV, was manufactured using this technology.

Black Stuff

The breadth and depth of solutions at Formnext this year also extended to composite printing. There was a novel CNC sewing machine from German embroidery company ZSK that knitted carbon filament tows into the desired shape on a compatible base layer. This procedure replaces unlike the conventional approach of weaving the fibres of a composite into a perpendicular arrangement then cutting the fabric to the required shape. This “Tailored Fibre Placement (TFP)” process is claimed to cut fibre wastage to just 3 % instead of the usual 30-70 % on a typical automotive component.

Figure 29 Tailored Fibre Placement from DSK allows efficient production of composite parts for subsequent molding/resin infusion

Software snippets

Software from US company Dyndrite sometimes seems to be as misunderstood as 3d printing itself was a few years ago. The language used to describe what they do is hard to decipher - In their own words, “Dyndrite make a software Application Development Kit (ADK) for Additive Manufacturing. The ADK comprises of a GPU accelerated geometry Engine, plus CAD to Print Python APIs and an UI development framework.”

Steve Watson was a propulsion lead and later Director of Additive Manufacturing for Blue Origin. The unique convergence of chemistry, catalysts, computation, and additive manufacturing was what attracted him to the space race. That he left this to focus more on the computation challenge, with Dyndrite, speaks volumes. He explained how complex expert user workflows (think of “picks and clicks” through many different pieces of software) can be captured automatically as Python scripts. This codification of user know-how creates modifiable scripts that can (re)generate build files, slice and toolpath complex geometry quickly on demand. Codification also brings standardisation and reduces variability, errors, and failed builds, thus enabling high volume, high mix production.

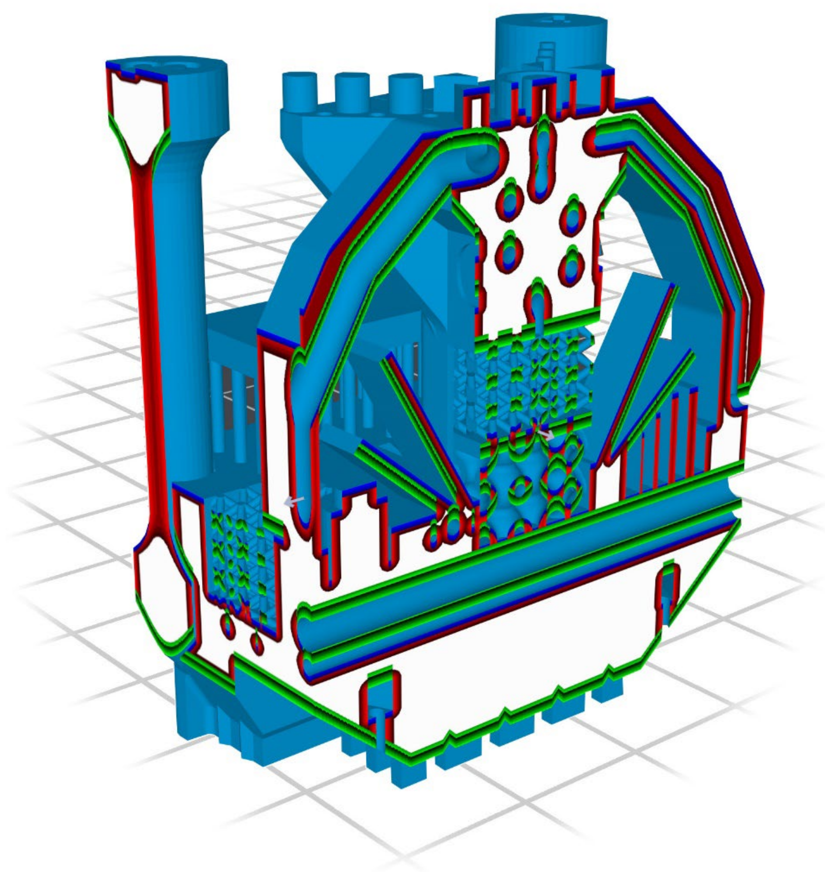


Figure 30 Dyndrite’s 3D volumetric segmentation uses a voxel engine to power 3D geometric queries, so that machine parameters can easily be varied between upskin, downskin, and thin feature regions

UK company Additive Flow started life as a hardware company building a multi material extrusion printer handling different recycled feedstocks. They then discovered there was no software that was good at deciding what materials should (or could) go where across each part, and with what print parameters. So, they have pivoted into developing software for process mapping, where performance data can be ingested, and trade-offs determined while engineering limits are respected. Expect to see parts printed with much more nuanced parameters than simply core and skin. Toolpathing is a fast, one click export from Additive Flow to Autodesk's Netfabb. Oak Ridge is one important AM site currently testing the software. During the Formnext conference programme Zeiss co-presented a heat exchanger built using this workflow ("How Simulation can Drive AM Qualification").

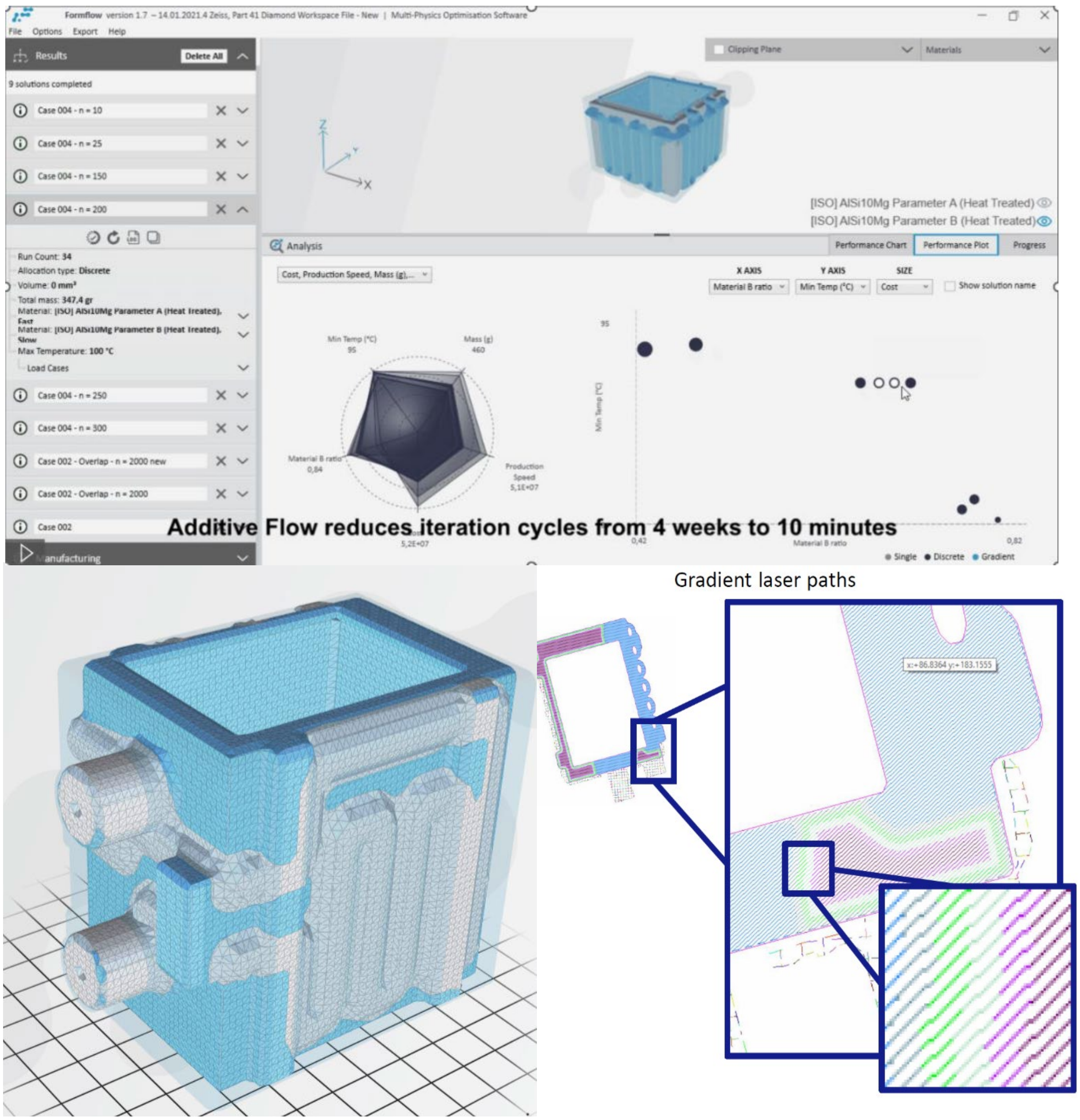


Figure 31 Process mapping and Zeiss heat exchanger produced using Addditve Flow

Long Shots

Two US companies that were not present on the floor at Formnext were Seurat Technologies and VulcanForms.

Seurat are developing area printing and claim they are "already 10 times faster" than LPBF and will be 100 times faster by 2025. Their part pricing claims are $150/kg by 2025 falling to $25/kg by 2030. Material prices will have to tumble to achieve this, as well as Seurat producing a very capital efficient machine. So certainly a longer time frame, if not a long shot.

VulcanForms are building a 100kW platform and have plans for their first factory to have 2MW of lasers, in what they describe as the World's most powerful additive foundry. They are not planning to sell machines as much as they are expecting to sell capacity. The bet is on reshoring and improved economics offered with digital manufacturing. Two facilities are being stood up, both in Massachusetts, but 50 miles away from each other. One will handle printing, the other CNC machining/post-processing and assembly.

Hadrian Manufacturing, headed by Chris Power in California share the same target aerospace customers as VulcanForms, but are focused exclusively on subtractive machining, initially of aluminum. Hadrian are trying to disrupt the supply chain of small Mom and Pop machine shops that still service almost all the aerospace primes in the US. Hadrian are betting on automating workflows with state-of-the-art CNC equipment to deliver radical improvements in throughput. They see themselves becoming the Amazon of aerospace parts.

"VulcanForms brings forth metal additive manufacturing as a scalable industrial process, and as a cornerstone of breakthrough digital production systems," said VulcanForms Co-Founder John Hart, also a Professor of Mechanical Engineering at MIT. "Integrated digital production facilities are critical infrastructure which will accelerate domestic and global innovation and draw top talent to the manufacturing sector."

It's going to be interesting to see if any of these companies' ambitious domination plans can be executed.

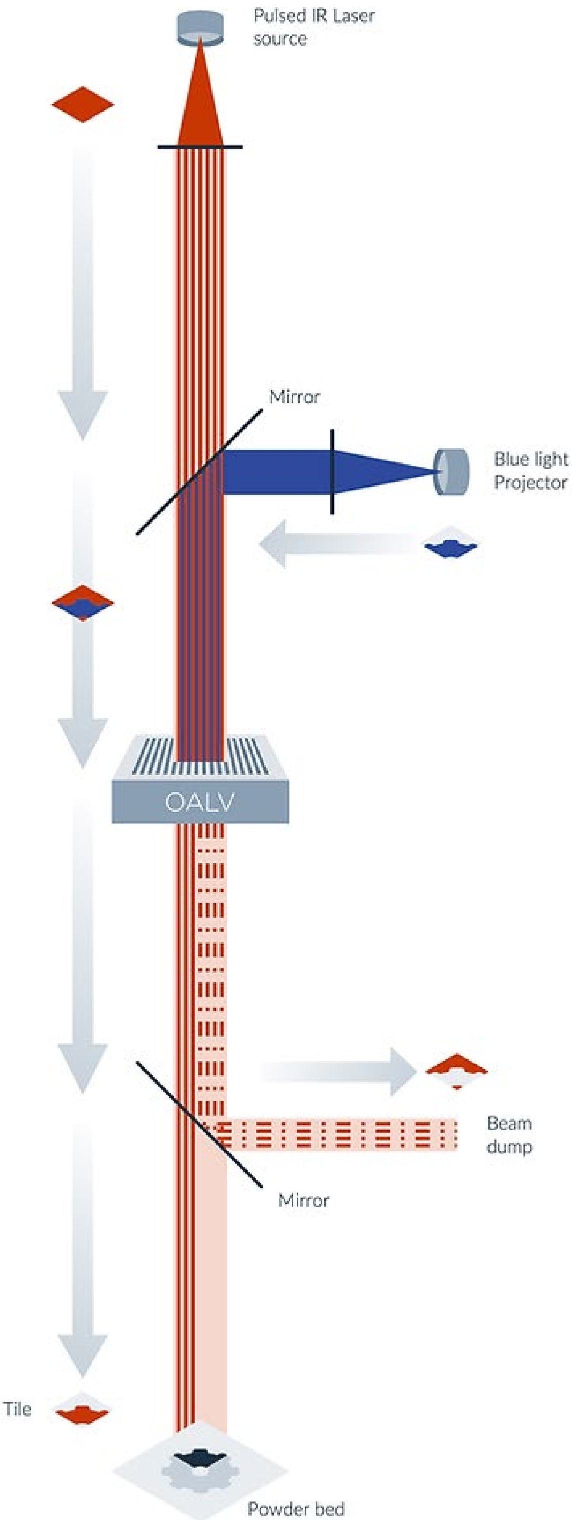


Figure 32 Seurat's area printing long shot explained

Figure 33 John Hart sitting inside one of VulcanForms 100kW machine shells.

“I’m sorry (insert the name of your favourite 3D printing CEO here), I can’t execute that plan.”

Canada Attendees at Formnext 2022

The Canadian companies attending Formnext either as part of the Canada Makes delegation, and/or exhibiting are listed here.

Dyze Design Inc.	Axis Prototypes
Equispheres Inc.	TronosJet
Metafold3D	Precision ADM
Mosaic Manufacturing Ltd.	Centre Métalurgique du Québec (CMQ)
Polyga Inc.	Pantheon Design Ltd
Rapidia Tech Inc.	NanoGrande
Tekna Plasma Systems Inc.	Syncrude/Suncor
Xiris Automation inc	AON3D
Canada Makes	MSAM, University of Waterloo
NGen	Voltera Inc

Canada Makes videos from Formnext, including interviews with many of these companies can be found at https://canadamakes.ca/news

Figure 34 Canada Makes networking at Formnext 2022