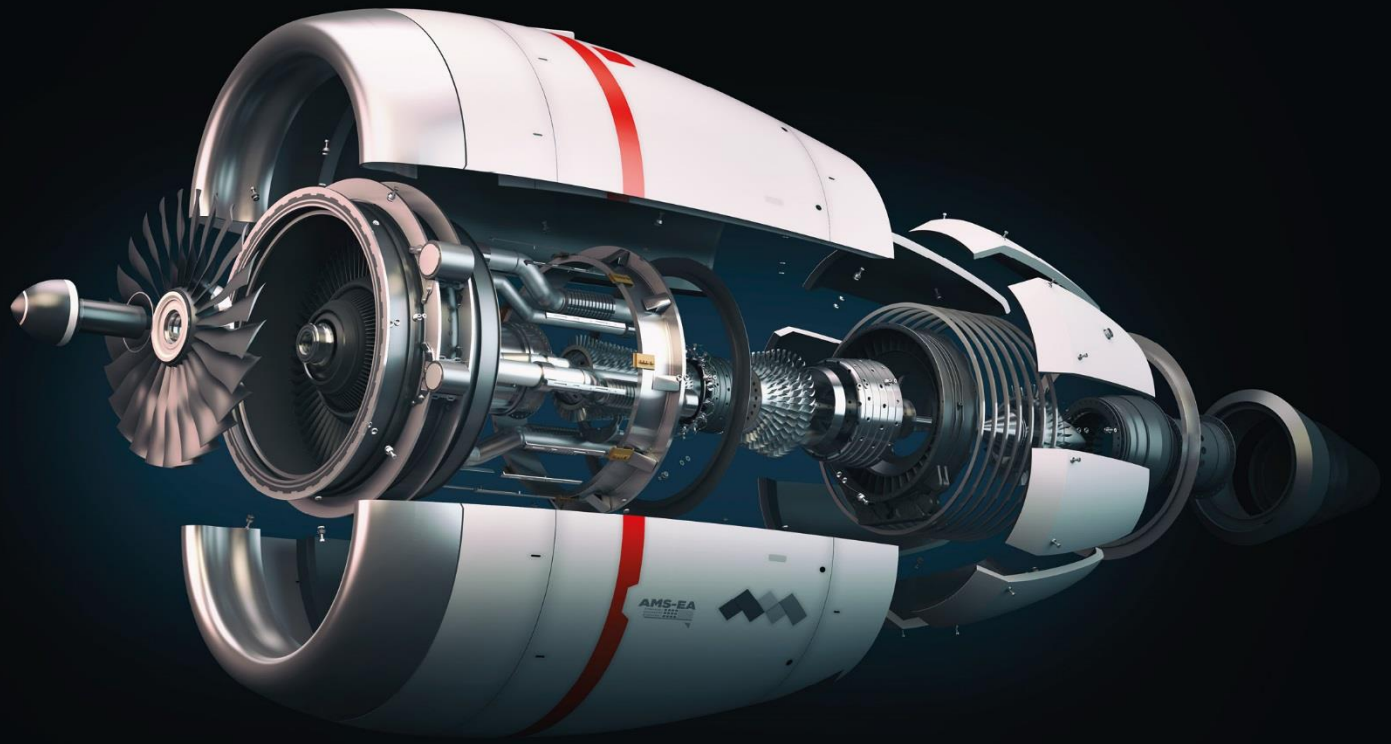
Lawrence Gasman
President
SmarTech Publishing



ADDITIVE MANUFACTURING EUROPE 2016
28-30 JUNE • AMSTERDAM

THE NEXT INDUSTRIAL REVOLUTION IS HERE

SmarTech Publishing is the only company focusing entirely on industry analysis & forecasting for the AM sector:

- **Regularly publishes reports on AM aerospace and have carried out many consulting assignments in this area**
- Our ***reports*** provide insight for on AM equipment, materials, services, and software, as well information for end users
- Our ***forecasts*** provide clients with compelling evidence to support important strategic decisions
- We offer ***candid market assessments*** based on today's best strategic thinking, not just data dumps from the Internet

Agenda for Today

- A prolog – market structure, potential market size and activity
- The future of AM in civil aviation
- New materials trends for aviation and what it will mean for AM.
- New trends in AM and what it will mean for aviation

Potential Available Markets for AM in Aerospace

Sector	Fleet Size (units)	Surface Area (Millions of Square Meters)
Commercial airliners and large cargo aircraft	20,000	48.0
General aviation	360,000	54.0
Military aircraft and helicopters	40,000	4.8
UAVs (1)	5,000	0.5
Spacecraft -- satellites and guided missiles	20,000	1.1

(1) Excludes consumer products, toys, etc.

Source: SmarTech Publishing

Established Uses of AM in Aerospace

Activity	Benefits	Evolution Pattern
Prototyping	Increased creativity	Trickling down to small suppliers
R&D	Breadth of applicability – new materials, quality assurance, process monitoring	Diversifying into new areas

Source: SmarTech Publishing

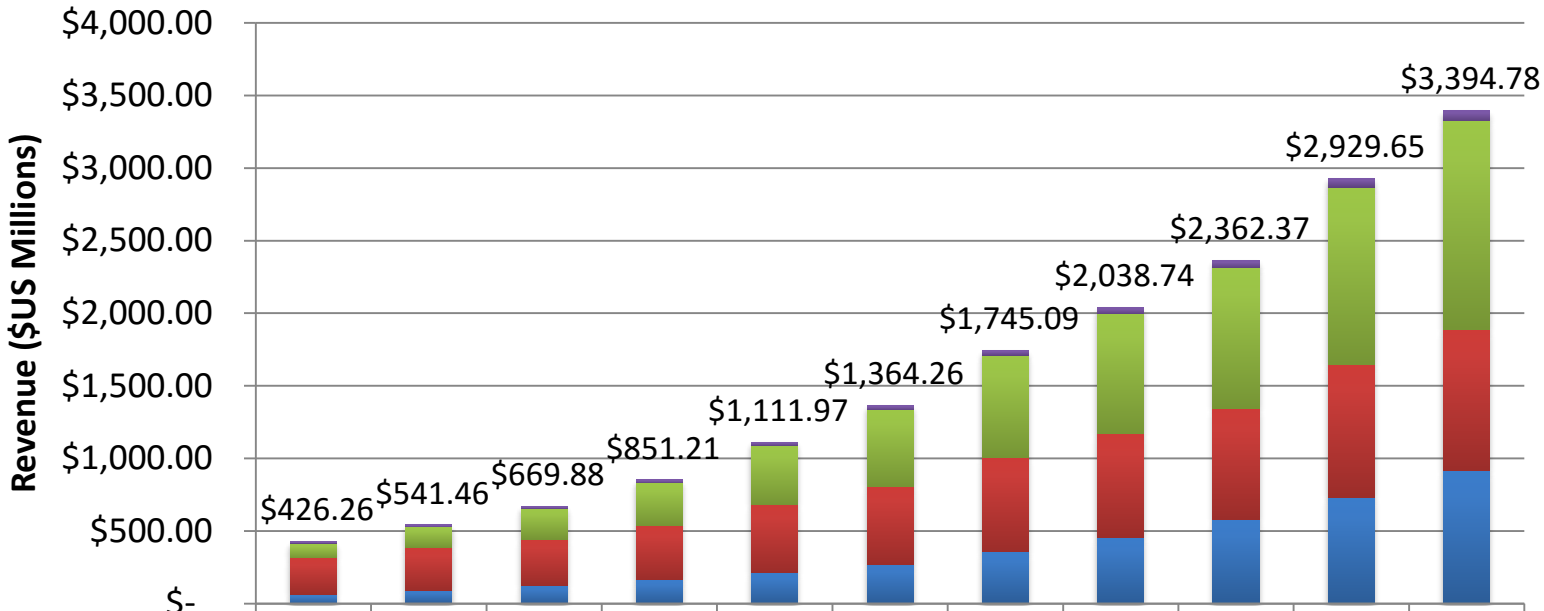
Current Use of AM in Military Aviation

	Deployed or in Testing	In Development
Moderate to high volume	Fuel nozzles Cockpit components Brackets and mounts	Heat exchangers Turbine blades
Low volume	Wind spars Major structural components	

Source: SmarTech Publishing

The Future of AM in Civil Aviation

General and Commercial Aviation: AM Revenues



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	$426.	$541.	$669.	$851.	$1,11	$1,36	$1,74	$2,03	$2,36	$2,92	$3,39
Software	$11.0	$13.4	$15.5	$18.6	$23.9	$28.5	$36.4	$41.6	$48.2	$60.1	$69.1
Services	$100.	$142.	$209.	$294.	$408.	$527.	$699.	$826.	$968.	$1,22	$1,43
Hardware	$251.	$295.	$321.	$376.	$467.	$537.	$653.	$715.	$767.	$914.	$975.
Materials	$63.8	$90.8	$123.	$162.	$211.	$271.	$355.	$454.	$578.	$733.	$913.

Source: SmarTech Publishing

Recent Developments of AM in Aerospace

Activity	Benefits	Evolution Pattern
Tooling	Cost, time to customer, etc.	Expanding to new applications . Starting small with assembly tooling but expanding into new applications
Flight test parts	Ability to modify existing parts. Potential for transition of actual flight parts	Expanding into new applications
Remanufacture and repair	Reduces the the time and cost of repair	Ongoing work and improvements
AM skills and competences	Growing essential skillsets in AM, especially in smaller companies	Prototyping and restricted skills now but focus will shift to final parts

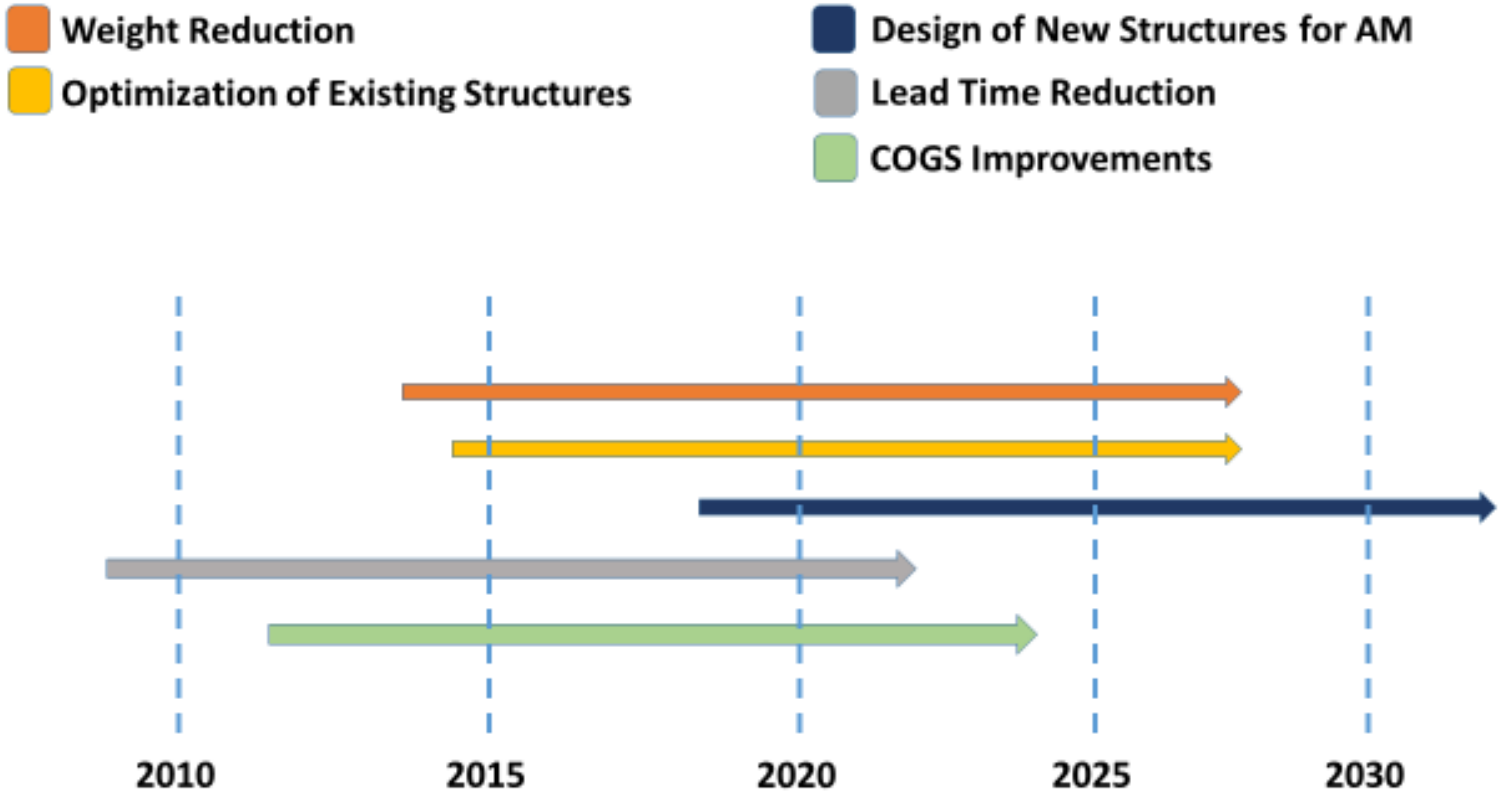
Source: SmarTech Publishing

Experimental Developments in AM in Aerospace

Activity	Benefits	Evolution Pattern
Spare flight parts	Makes it possible to create spares for older craft where spares do not exist. Can improve uptime/downtime ratios	Near-term development
On demand products	Serial manufacture of aircraft engine parts – customization	Long-term goal

Source: SmarTech Publishing

Timeline for AM-related Benefits in Aerospace



Source: SmarTech Publishing

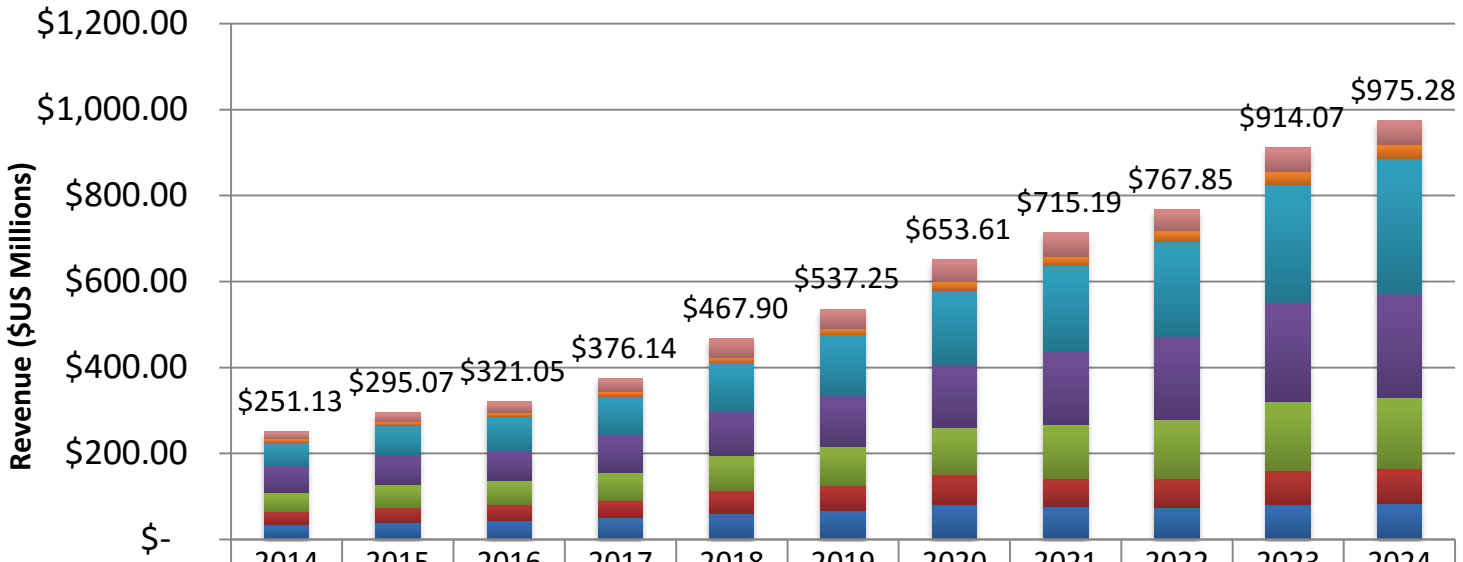
Two Models for AM Deployment in Aerospace: Manufacturer-control

Reminiscent of the rapid prototyping industry of the past, where 3D printer manufacturers develop solutions and print material supply chains internally to create the market for 3D printing in aerospace themselves

Potential for turnkey solutions exist, high degree of profitability for 3D printer manufacturers

Slow to develop complete aerospace solutions, industry-wide adoption is slowed due to standardization differences from one vendors technology to the next

Hardware Shipments by Type of AM Technology



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total	$251.	$295.	$321.	$376.	$467.	$537.	$653.	$715.	$767.	$914.	$975.
Directed Energy Deposition	$17.0	$20.8	$24.9	$30.6	$42.7	$44.7	$52.8	$55.1	$48.1	$56.1	$54.5
Binder Jetting	$8.21	$8.27	$9.26	$11.0	$13.3	$15.8	$19.3	$22.0	$25.2	$30.9	$33.9
Metal Powder Bed Fusion	$53.2	$69.3	$78.1	$90.7	$112.	$141.	$172.	$198.	$222.	$274.	$312.
Plastic Powder Bed Fusion	$62.6	$68.5	$69.9	$87.0	$103.	$118.	$147.	$170.	$191.	$229.	$241.
Photopolymerization	$45.3	$52.9	$56.2	$65.2	$80.4	$90.0	$110.	$125.	$138.	$162.	$166.
Material Jetting	$30.1	$34.5	$36.9	$40.3	$53.8	$58.9	$68.8	$65.6	$67.4	$77.6	$81.1
Material Extrusion	$33.5	$39.9	$44.6	$50.2	$60.6	$67.1	$80.9	$76.0	$74.0	$81.1	$84.0

Source: SmarTech Publishing

***New materials trends for aviation: What it will mean for AM**

*** New trends in AM: What it will mean for aviation**

New Developments in AM: Implications for Aerospace

Development	Description	Implications for Aerospace
Very low-cost printers	High-performance printers available for under $3,000	On-demand prototyping at low cost
3D printed electronics	Mostly ways to create innovative PCBs	Specialist aerospace ICs and PCBs are low volume and may be lowered in cost and increased in functionality with AM
AM composites	Emerging technology for printing with composites	Potentially vital for aerospace. Some aircraft wing/fuselages are 40 percent composite
AM ceramics	Emerging technology for printing with ceramics	May have implications for printed engine or HVAC components

Source: SmarTech Publishing

New Developments in Aerospace: Implications for AM

Development	Description	Implications for AM
New materials	More use of composites	AM is beginning to embrace composites which will help its continual penetration of the aerospace sector. Composites are "delicate" and need more monitoring and repair
SHM, smart skins, etc.	Embedded sensors for monitoring	3DP may have a role in creating embedded sensors
Futuristic trends	Morphing wings and metamaterial cloaking	Fine fabrication of 3D surfaces in modest volumes. Seems well suited to AM

Source: SmarTech Publishing

- **Ask me questions**: lawrence@smartechpublishing.com

- **Find out more about SmarTech Publishing:**
- www.smartechpublishing.com - 434-872-9008

- Visit SmarTech Publishing in the exhibit hall booth 1006

- Join us for the panel discussion later this afternoon