CEOI-ST
Enabling Additive Layer Manufacture for S/C Propulsion Systems

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8th February 2016

AIRBUS DEFENCE & SPACE

Agenda:

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- Roadmap
- Modular Propulsion System
- Hardware Produced
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  - Simple & Organic Manifolds
- Surface Finishing
  - External
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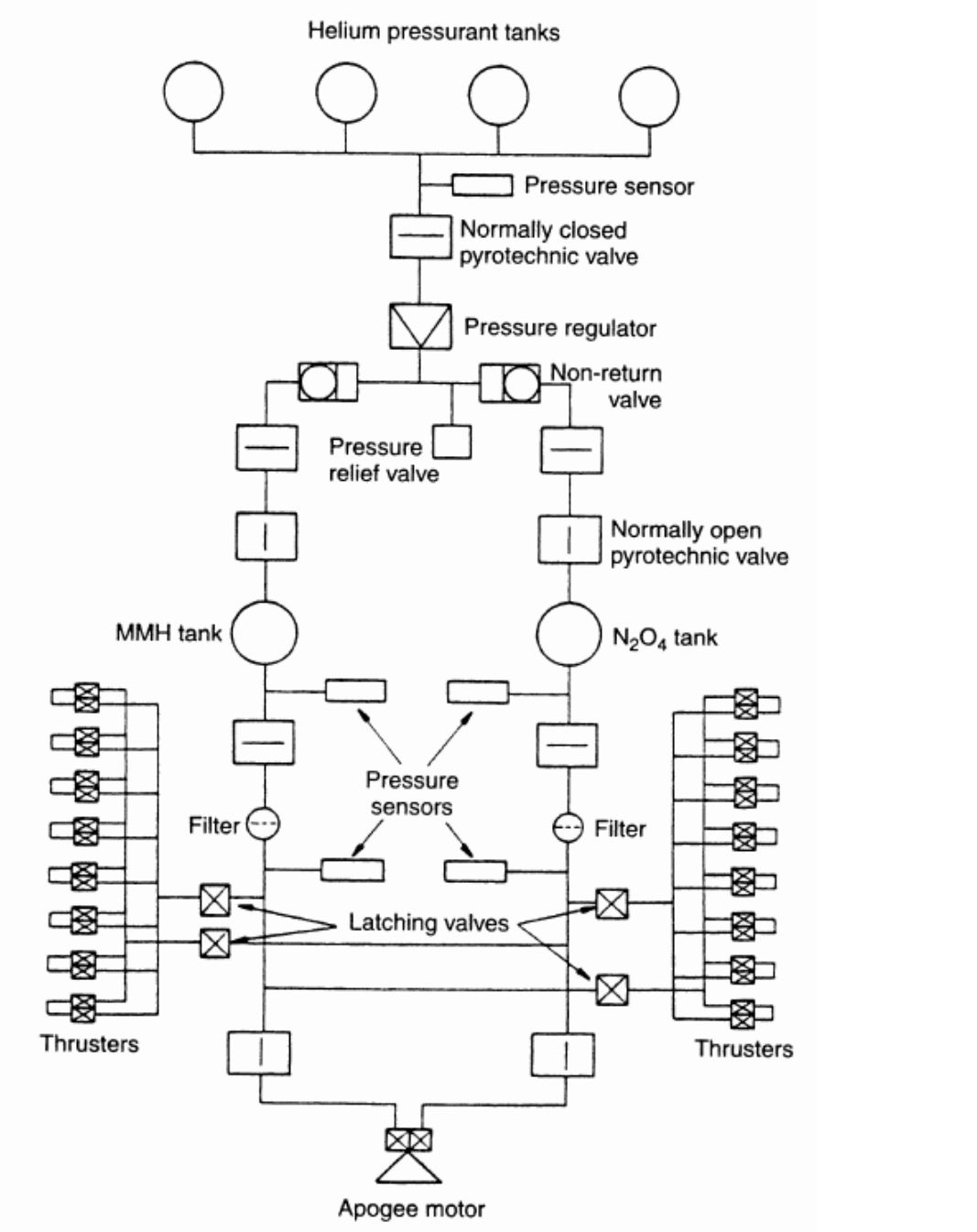
- Conclusion

Project Objective and Overview

"The specific goal of the programme is to achieve early hardware that will support higher levels of product evolution.
The road map to hardware necessitates understanding and controlling the diverse aspects of ALM material and manufacturing processes for use within fuel systems compatible with space grade propellants".



Background

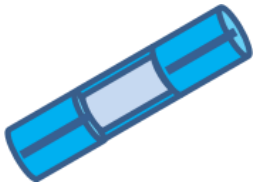
Airbus Defence and Space have been working with the CEOI for the last 12 months on advancing ALM for propulsion components.

Previously ADS had been working under an NSTP programme and identified that savings could be made by using ALM for the manufacture of simple manifolds for the pipework systems

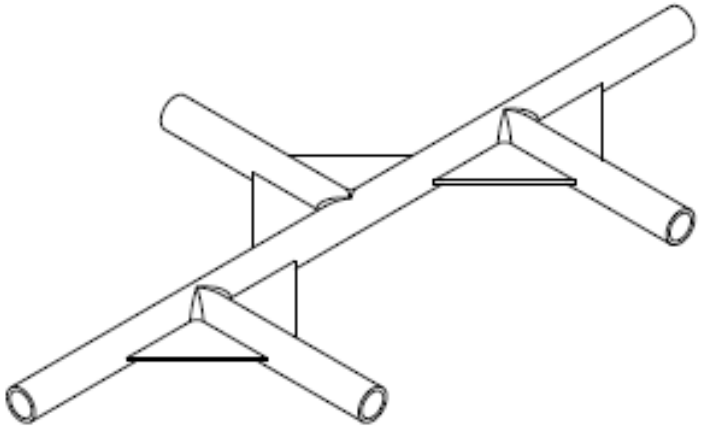
Some basic testing was carried out in the manufacture of tensile test pieces manufactured at 0º, 45º and 90º and also tube test pieces. The mechanical properties were tested and finally burst tests were also conducted.

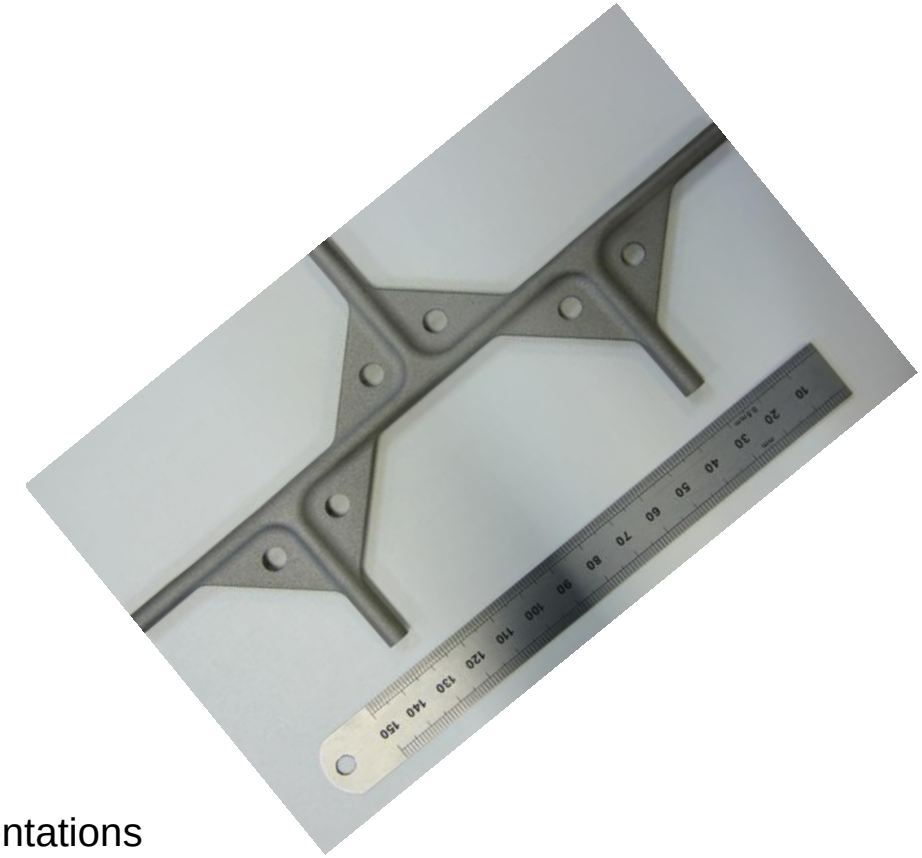
The mechanical properties were comparable to products manufactured from solid material by conventional methods

It was noted however that the surface finish was inadequate for the bores for propulsion systems and post manufacturing operation was required to improve finish.

		
0º	45º	90º

Achievements under NSTP 1

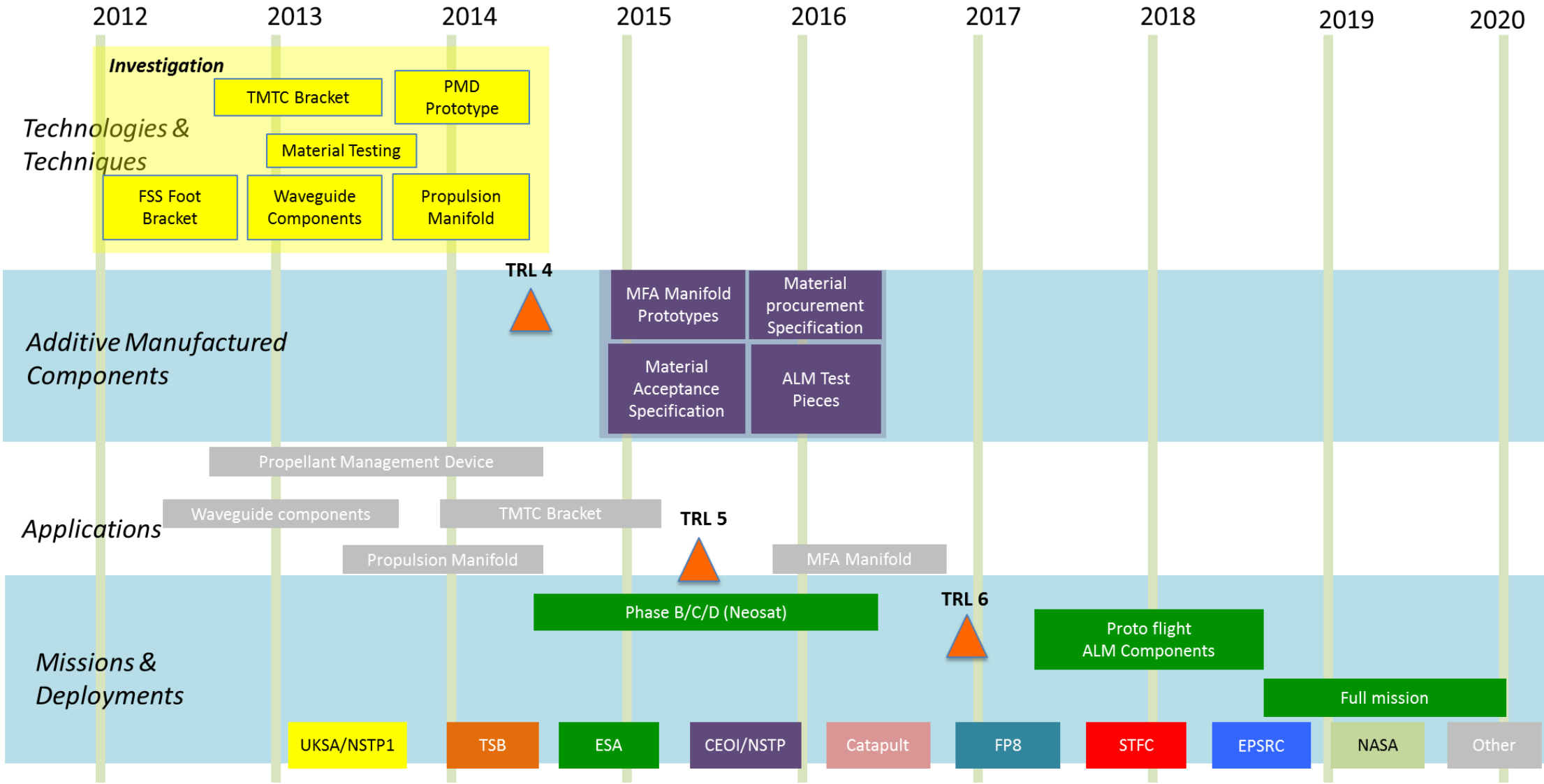




Under NSTP 1:
Material test campaign, with test pieces, produced in 3 orientations
Tensile, metallurgical, weld samples, tubular section, burst testing of welded components, resulting in the following documents:

NGMP.RP.00034.DP.S.ASTR	Mechanical Properties & Microstructure of Laser ALM Ti6Al4V
NGMP.RP.00029.DP.S.ASTR	ALM for Propulsion Systems Burst Test Report
NGMP.PLN.00019.DP.S.ASTR	ALM Evaluation & Development Plan for Propulsion Systems

Roadmap



Modular Propulsion System

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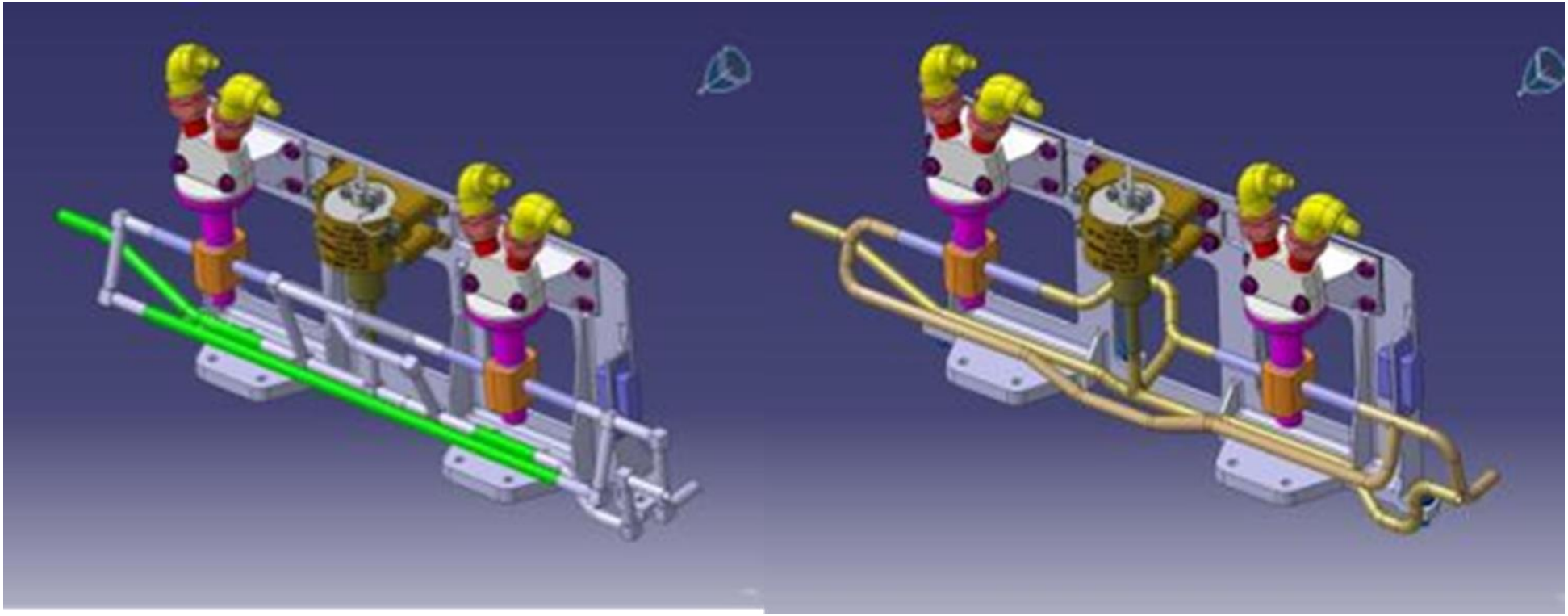
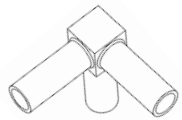


Conventional Pipe work

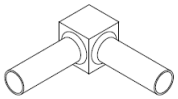
Proposed ALM Pipe work

Hardware Produced:

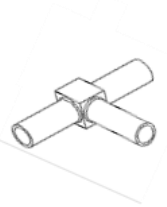
Conventionaly Machined Components



3 way Elbow

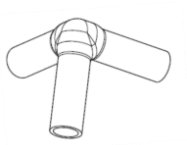


Elbow



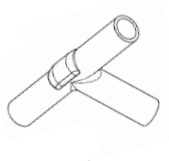
Tee Piece

Components re-designed for ALM



3 way Elbow

Elbow



Tee Piece

Actual components produced by ALM

3 way Elbow

Elbow

Tee Piece

Tasks:

- Redesigned for ALM manufacture and produce component and test samples
- HIP (Hot Isostatic Pressing) and external finishing
- Machine internal bores on samples
- Weld test samples welded
- Perform burst tests

Hardware Produced:

Sample components (Produced from the same drawings as conventionally machine components).

Hardware Produced:

Simple and Organic Manifolds

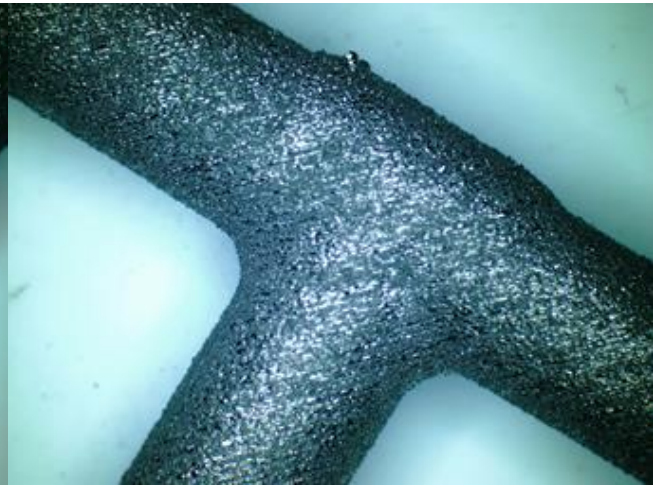
Note: Samples only, as currently a robust method of finishing the bores to the required standard for surface finish and cleanliness has not been established

Surface Finishing (External):

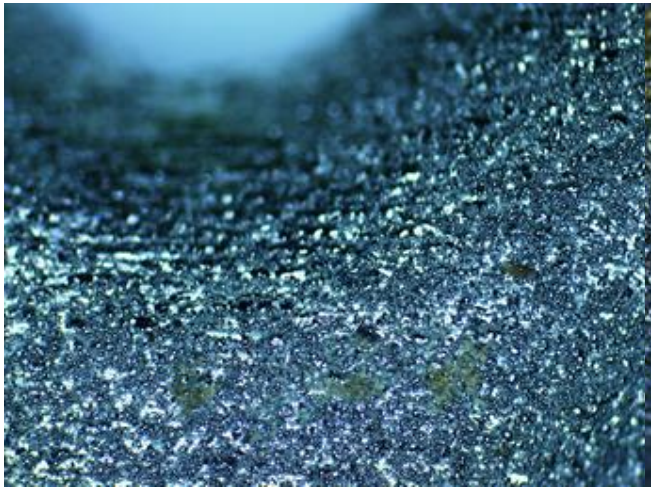
"As Produced" x 7 magnification

3 way Elbow

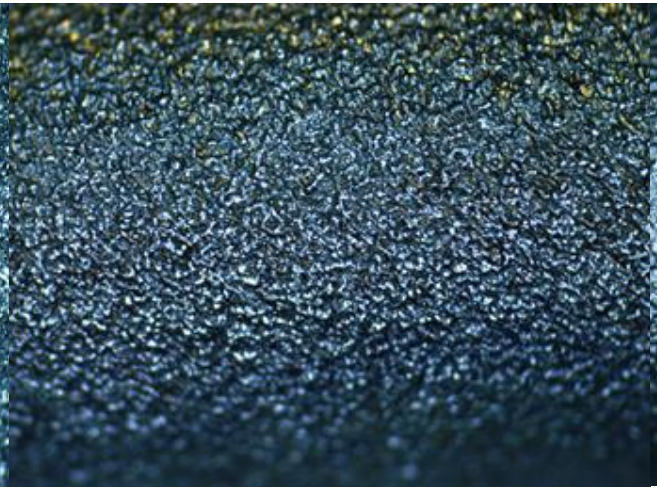
Elbow



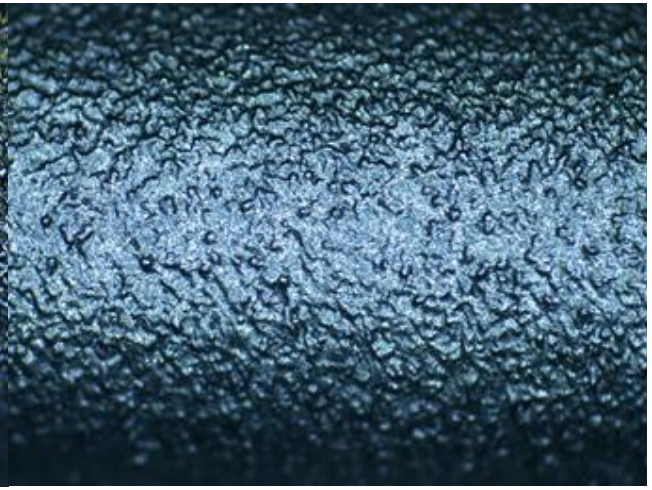
Tee Piece



As produced



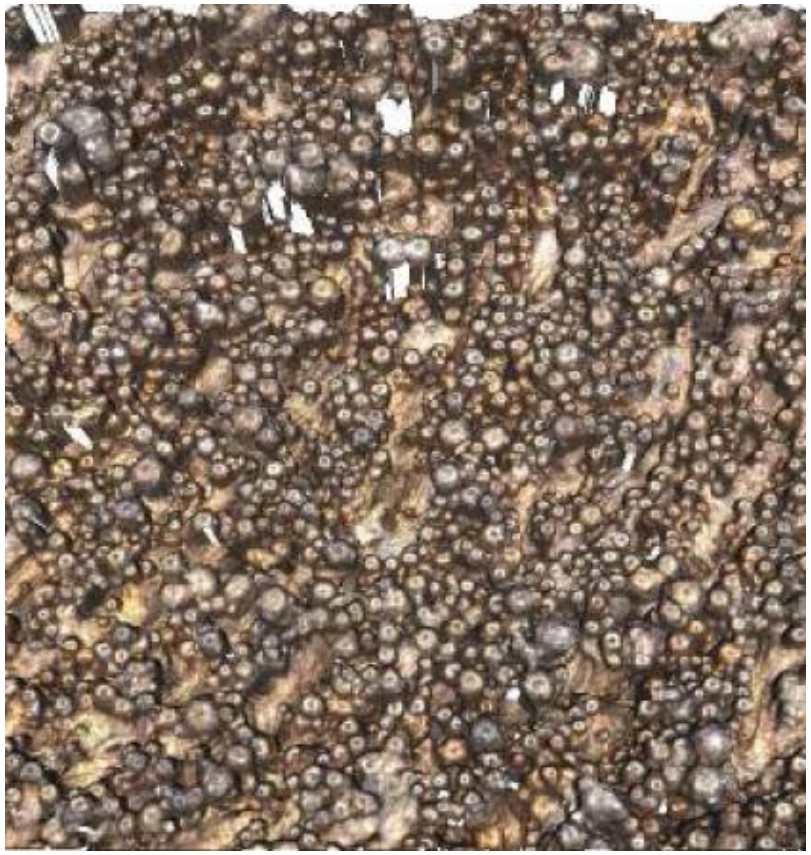
Bead Blast (Glass bead)



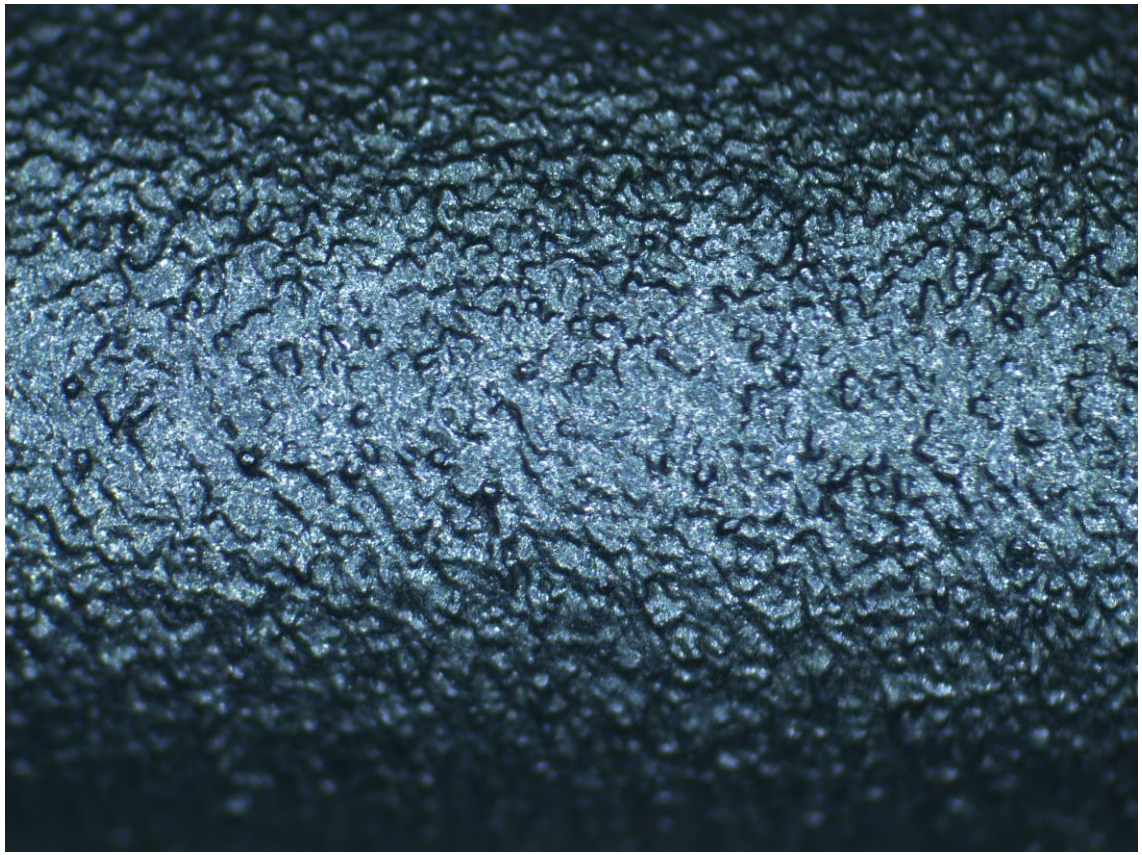
Grit Blast (Al oxide)

25 x magnification

Surface Finishing (External):



20 x magnification “as produced”



25 x magnification after Grit blast with Al oxide

Surface Finishing (External):

Polished 3 way Elbow

Polished Tee Piece

Method:

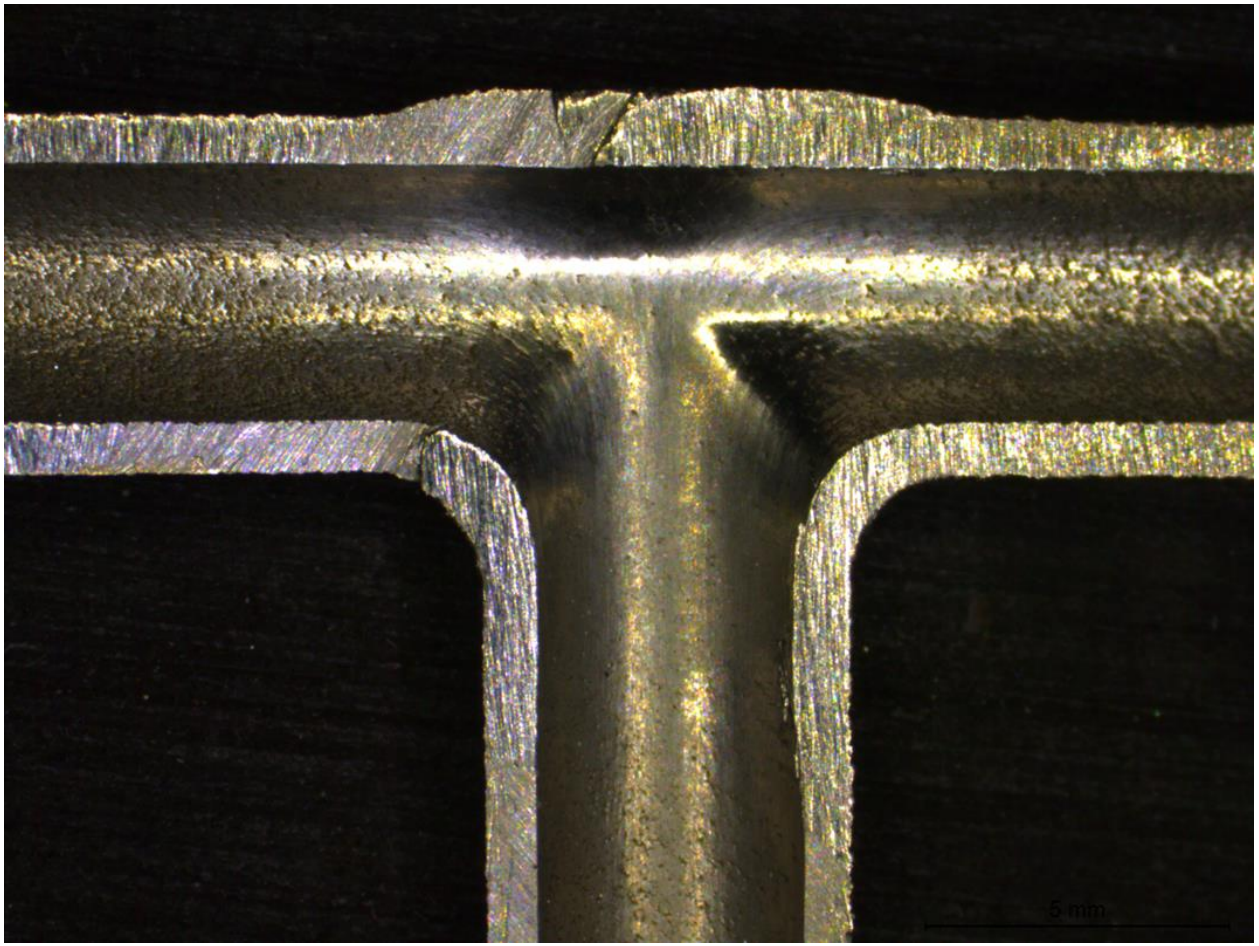
- Parts placed in a vibrating bowl with ceramic particles for 12 hours
- Abrasive media changed for plastic particles for 1 hour
- Finally media changed again to porcelain for final polishing for 1 hour

(hundreds of parts can be placed in the vibratory bowl at any one time).

Surface Finishing (internal)

Abrasive Flow Deburring and Surface Finishing.

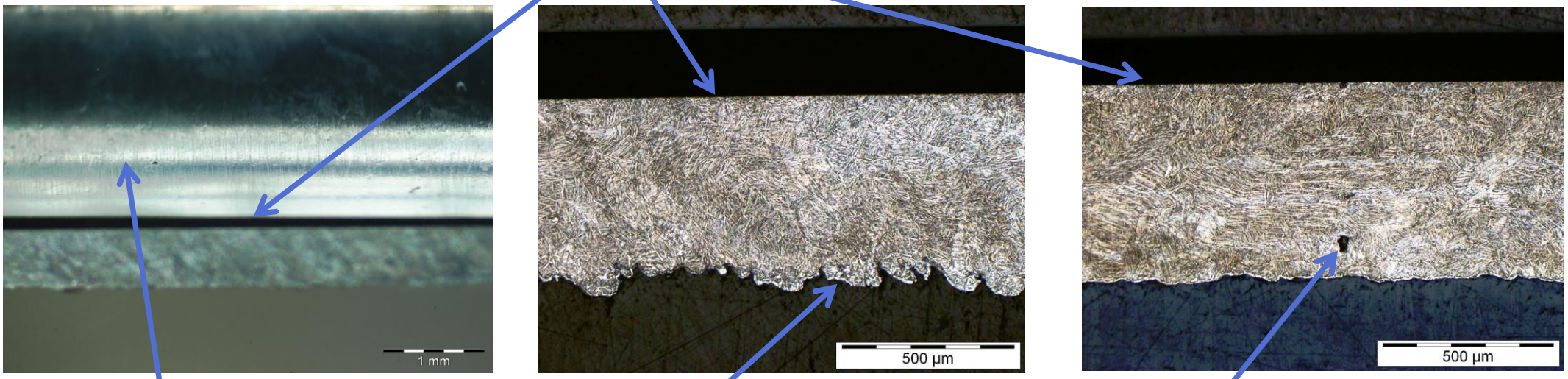
- This method uses an abrasive media in the form of a viscous slurry, which is pumped through the component at high pressure. The slurry abrades the internal surfaces and removes any internal burrs and smooth's the peaks of a rough surface, as shown in the photo attached.



Surface Finishing (internal)

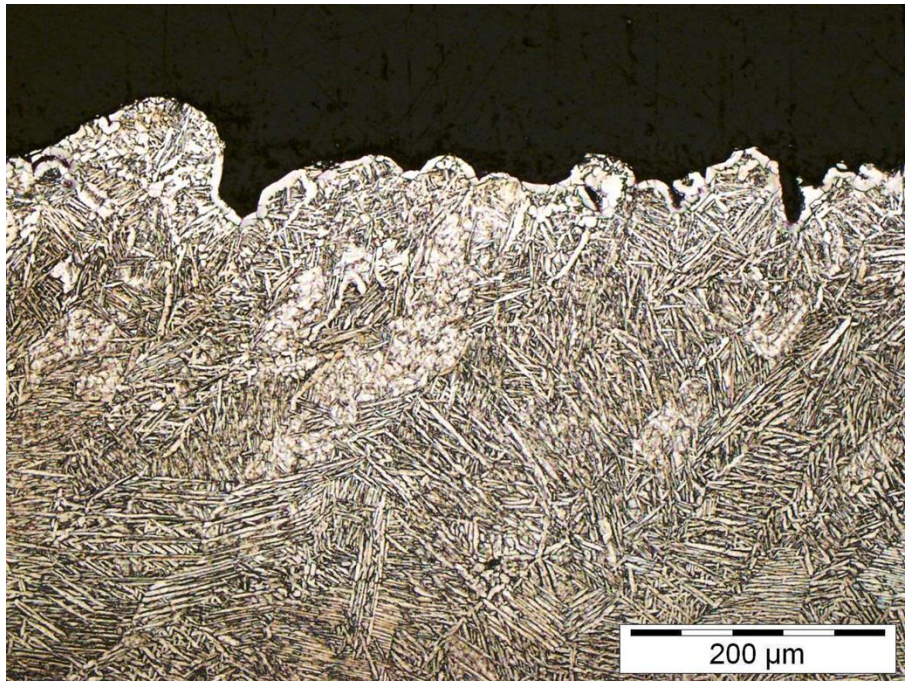
Honing.

- This is a machining process where an adjustable honing tool is inserted into the bore. As the tool rotates hydraulic pressure is applied which expands the tool in the bore. A cutting fluid floods through the centre of the tool and a carbide blade scrapes against the side of the bore removing small amounts of material until the correct diameter is achieved. This is checked frequently during the process with a bore gauge.

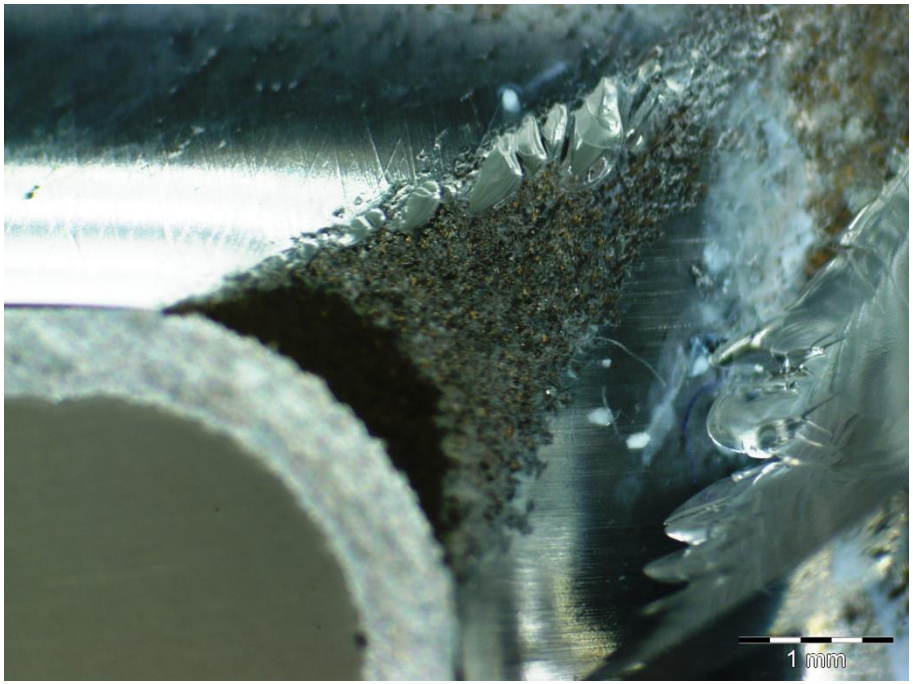


Surface Finishing (internal)

Honing Cont'd



Widmanstätten structure α + β
(Basket weave)



With current geometry the inside corners haven't cleaned up

Note: At this point in time, honing provides a cost affective means of finishing the bores to an acceptable standard.

Conclusion

- The ALM method of manufacturing Propulsion components is shown to be very cost effective when compared to conventional methods of manufacture, however additional finishing techniques are needed to achieve the mechanical properties and the required surface finish both externally and more importantly internally where contamination could be an issue. These are:
  - Hot Isostatic Pressing (HIP) to remove any porosity and improve the mechanical properties
  - Grit Blasting of the external surfaces to remove feedstock particles from surface crevices
  - Honing to finish the bores

- Additional things to consider:
  - Material to be added to allow for HIP'ing
  - The blast media to suit different materials. (Ti6Al4V, Al Oxide media proved to be more efficient)
  - Material to be added to allow for polishing the external surfaces including producing the legs over length to be able to machine back to create sharp corners for welding
  - Material added to the bores to allow for honing
  - Internal corners to be left sharp for machining to clean up
  - The initial design has to take into account not only the ALM process but also the subsequent finishing techniques

On the basis of this and the previous studies, Airbus Defence and Space are buying an ALM machine, to be installed in the first quarter of the new year