



Quality Assurance of high performance metallic ALM components

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20th April 2012, Research & Technology Track,
Materialise World Conference, Leuven, Belgium

Today's talk

1. Introduction to Materials Solutions. 10%
2. Quality Assurance at MS. 60%
3. Example ALM specific QA challenge. 30%

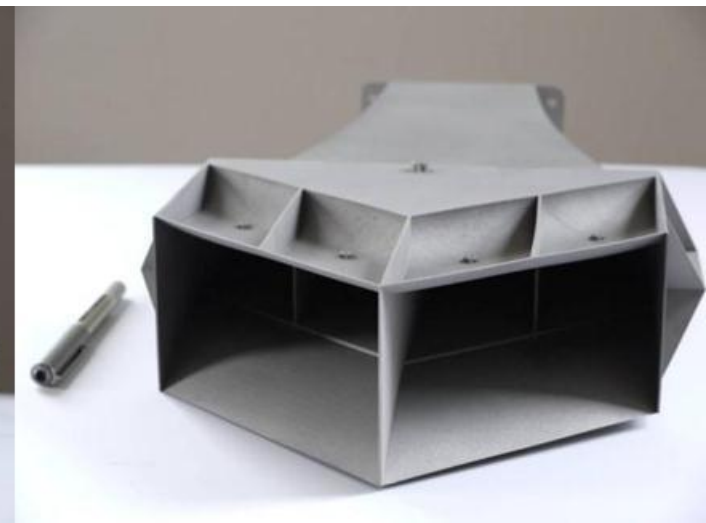
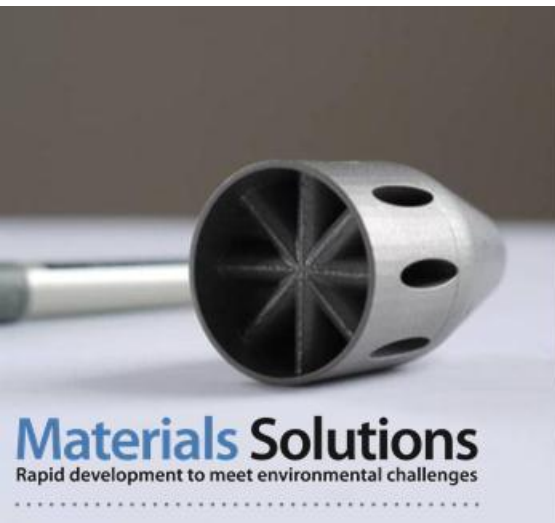
Materials Solutions

- Materials Solutions is an AS9100 RevC registered ALM parts supplier and consultancy specialising in nickel superalloys and high temperature applications...
... developing ALM processes **towards production use.**



Materials Solutions

- Markets: **aerospace, F1**, automotive, medical devices, designer goods and others
- ISO 9001:2008 and **AS9100 RevC** Multiple customer approvals.
- Experienced quality manager with aerospace background.
- Currently operate **5 EOS M270 DMLS** machines plus a wide range of production, inspection and analytical equipment.



Materials Solutions

- Situated in a purpose-designed factory in Worcester, UK (previously Birmingham)



Materials Solutions: a 'development factory'

Customer Requirements (drawing, CAD model, SoW etc.) + PO (£,\$,€ etc.)



ALM parts
and/or reports





Lift the lid ...





Quality

Strive to meet all
customer requirements

Electronic QMS
(Quality Management System)

QMS Accreditations
Customer approvals

Electronic
Production
Management system

Conventional Aerospace/
'Precision Engineering' supply partners

Materials Expertise

Extensive inspection capability



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Customer Requirements

- Fundamentally we require CAD models to enable the machines to operate ...
- However, we make-to-print i.e. customers typically provide an engineering drawing detailing the requirements which we strive to achieve.
- Communication is key. If there is uncertainty over meeting a requirement we inform the customer...

Accreditations and Approvals

- Documented procedures (QMS) and audited practice conforms to key quality standards:
- ISO9001:2008 – general quality
- AS9100 Rev C – aerospace specific
- We expect the same of our suppliers
- Customer approvals based on ISO/AS registration and further audits:
 - Rolls Royce (UK, Canada, Nuclear ...), ITP, Major motorsport engine manufacturer...



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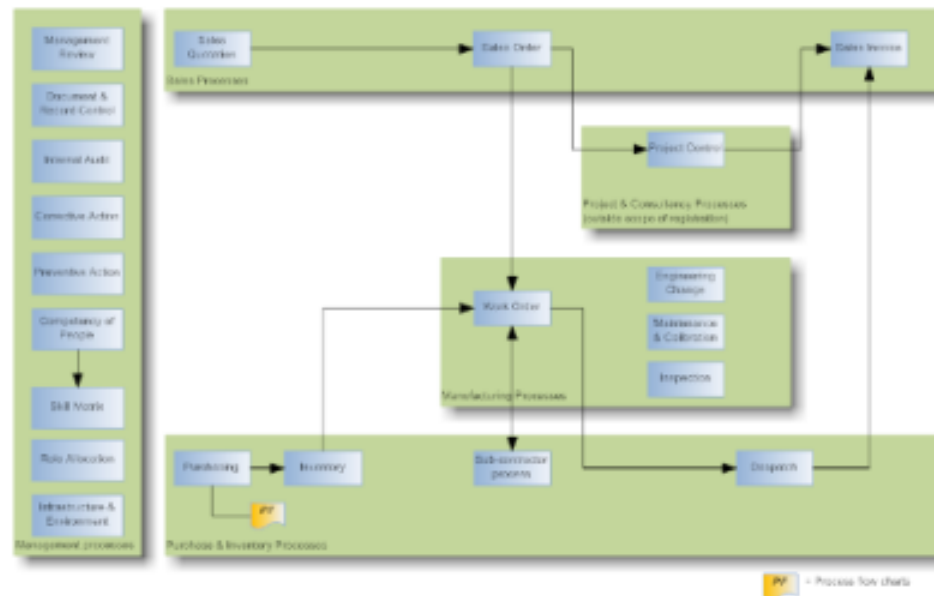
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QMS process map

Top level process map



Revision	Changes	Date	Initial
A	Initial revision.	23/06/07	QQ
B	Process map updated.	15/06/10	NH
C	Process map updated.	29/07/10	NH

- Electronic Quality Management System
 - Effectively our formal procedures, written to reflect the requirements of AS9100 RevC
 - Microsoft Sharepoint intranet site.

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Production Management

- Production management via 123Insight ERP/MRP/CRM software.
 - Controls: Parts/stock, Work Orders, Sales Orders, Shop floor data collection, Contract Review...
 - Monitor: Status of WIP, Quality metrics e.g. delivery performance...

Contract review

- A detailed contract review, performed on all customer projects, is key to what we do...
- Stand out aspects:
- Drawing review. All requirements identified and reviewed using software tool.
 - *Ensure requirements do not slip through the net*
- Risk Identification and Assessment:
 - *Ensure mistakes are not repeated ... Linked to past NCRS (non conformance reports).*
 - *Identify possible new risks*

Manufacturing control: work orders

123Insight - Hadi Zarringhalam, Materials Solutions (MatSol) [Licence expires in 34 days] - [Works Order Enquiry]

Home | Reports | Commercial | Stock | Production | Quality | Tools | Help | Accounts | Settings | Accounts | Reports | Tools

123Insight | Planning | Production | Quality | Tools | Help | Accounts | Settings | Accounts | Reports | Tools

Work Order Enquiry

Work Order Number: WO-2375/A | Material Type: Manufacture | Version: 0002

Part Number: 54788 | Part Description: [REDACTED]

Item: 02 | Project/Job: [REDACTED]

Customer Code: M20 | Customer Name: [REDACTED] | Sales Order: SO-1002 | Job: 2

Stations (1 of 2)

Station	Job	Serial Number Range	Station Name/Status	Completion	On Hold	Work Order	Show
1	1	10112000000	01 In Progress	26 Apr 2012			

Planned vs. Actual: ☐ This Order: 1000

Cost Data (GBP)

Cost Breakdown	Planned	Actual	Variance (%)
Start Date: 09 Apr 2012			
Received Qty: 1			
Component Cost: 5,000.00			
Subcontract Cost: 10,000.00			
Set Cost: 5,000.00			
Run Cost: 5,000.00			
Total: 25,000.00			
Date Set: 21 Nov 2011 10:11 AM			

Stuffs Components (1 of 2)

Sequence	Part No.	Desc	Status	Qty Outstanding	Qty Returned
1	54630	Powder, 101118	PLN	0	0
2	53984	Blk plate, 101118	PLN	0	0

Stuffs Operations (6 of 16)

Op No	Operation	Desc	Material	Unit	Planned Set/Hours	Planned Run/Hours	Actual Set/Hours	Actual Run/Hours
10	CAD	Design & data preparation	101118	ea	0	0	0	0.1
20	M270 S1681	M270 job setup	101118	ea	0	0	0	1.5
30	M270 S1681	M270 job setup	101118	ea	0	0	0	0
40	INVT	101118 operation	101118	ea	0	0	0	0
50	INVT	101118 operation	101118	ea	0	0	0	0
60	INVT	101118 operation	101118	ea	0	0	0	0
70	INVT	101118 operation	101118	ea	0	0	0	0
80	INVT	101118 operation	101118	ea	0	0	0	0
90	INVT	101118 operation	101118	ea	0	0	0	0
100	INVT	101118 operation	101118	ea	0	0	0	0
110	INVT	101118 operation	101118	ea	0	0	0	0
120	INVT	101118 operation	101118	ea	0	0	0	0
130	INVT	101118 operation	101118	ea	0	0	0	0
140	INVT	101118 operation	101118	ea	0	0	0	0
150	INVT	101118 operation	101118	ea	0	0	0	0
160	INVT	101118 operation	101118	ea	0	0	0	0

123Insight Notes | Production Notes | Commercial Notes

B1385
In 718 #4

Materials Solutions

Work Order WO-2375/A (Re-Print)



MS Part No. 54788
Description [REDACTED]
Serial Number [REDACTED]
Customer [REDACTED]

Due Date 26/04/2012
Start Date 30/03/2012
MS Issue 02
Qty 1
Sales Ref SO-1311.002

Drawing Issue 018

Production Note: WO Split Note: Commercial Note:

B1385
In 718 #4

Seq No	Component	Description	Qty	Unit	Actual	Issued Qty	Initial
10	54630	Powder, 101118	5	ea	5		
20	53984	Blk plate, 101118	1	ea	1		

Op.	Resource	Op. Description	Set Time (Hours)	Run Time (Hours)	Qty	Comp	Scrap	Initial
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10 CAD CAD data conversion, etc.

0 0

20 M270 S1681 M270 job setup

0 0

30 M270 S1681 ALM- parts to be built according to files:

Ref	File
1	54788_01_A.psl
2	54788_01_A_ext_0m.sl

[REDACTED]

[REDACTED]

Parameters:

Ref	Scaling (X,Y)	Offset	Parameters
1	-0.03, -0.03	0	DirectPart
2	-	-	ExternalSupport

[REDACTED]

[REDACTED]

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Materials Expertise

Extensive inspection capability

Subcon

- **Approved** specialist suppliers
 - Machining
 - EDM, milling, turning, grinding etc.
 - Welding
 - TIG, laser etc
 - Vacuum HT (in-house soon)
 - NDT
 - Dye pen, X-ray, Visual, pressure etc
 - Surface finishing
 - Hand finishing, MMP
 - Coating



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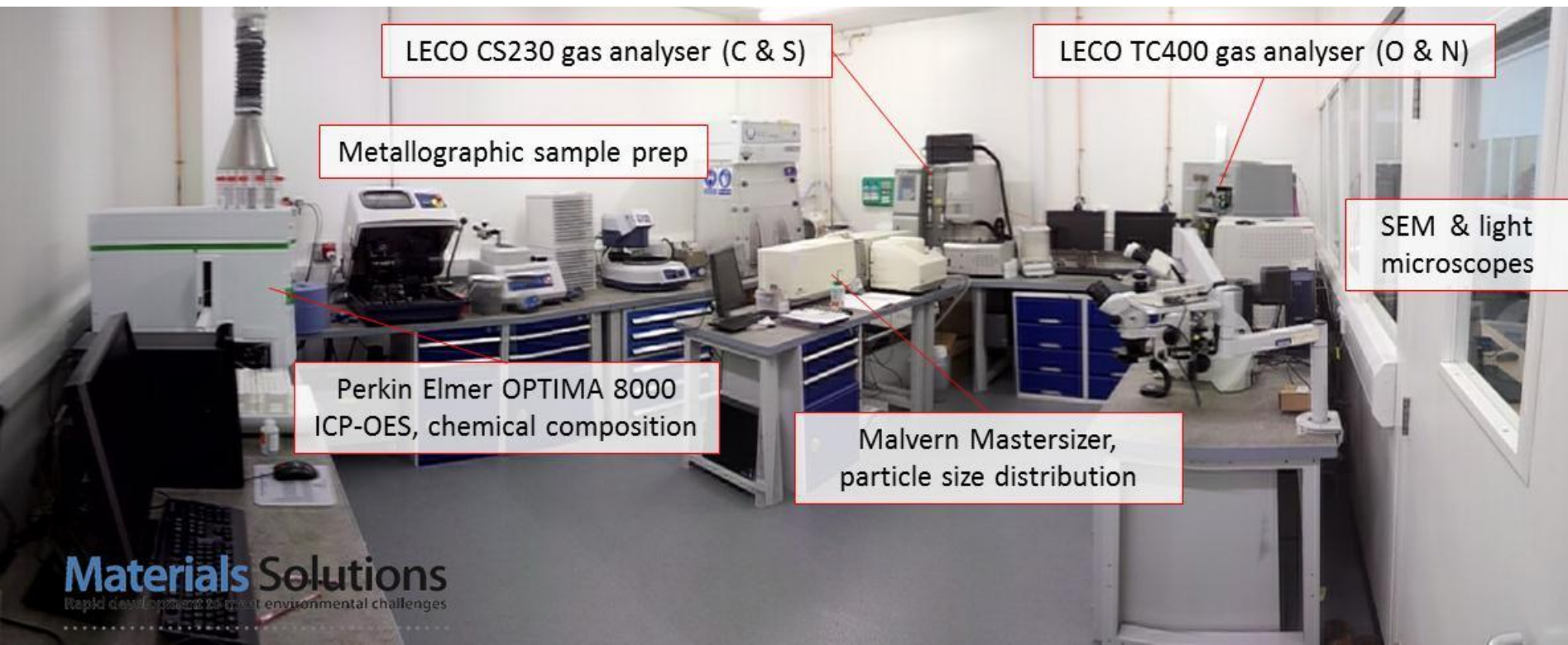
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Materials development

- Process development
- Validation of properties
- Specification development
- Routine property testing



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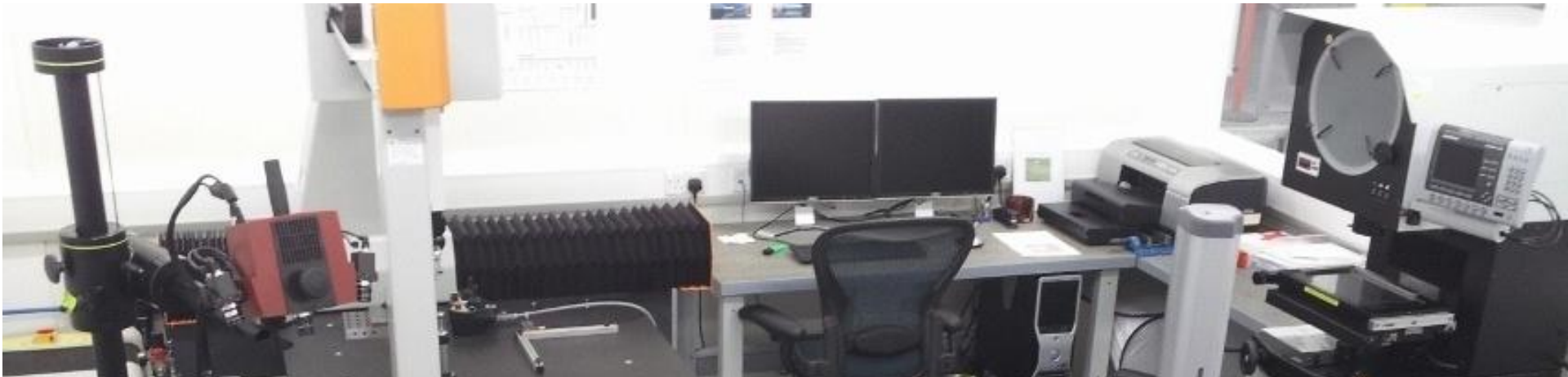
Materials Expertise

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Inspection

- Comprehensive in-house inspection capability ... Very little that cannot be inspected .. not just “built to CAD”.
- Our main work horse is a Nikon-Metrology ceramic-construction CNC CMM
- Offline programming to avoid inspection bottle necks

Inspection



- Supported by various tools: GOM ATOS optical 3D scanner, Baty Vertical Profile Projector, TESA digital height gauge, Mitutoyo Surface Roughness tester, wide range of callipers, mics, gauges etc.
- UKAS traceability maintained on equipment via ext. labs
- Air conditioned inspection room

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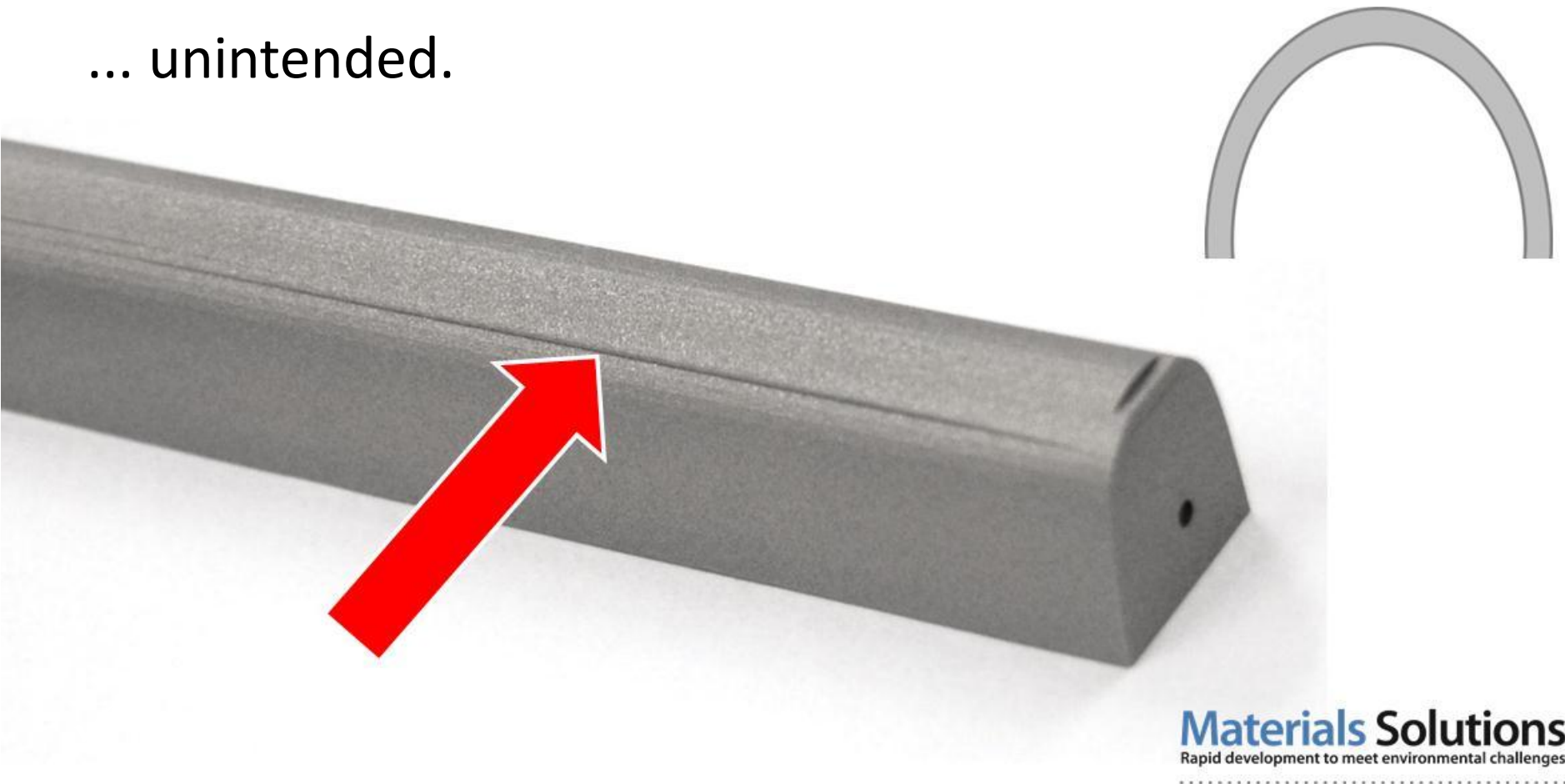
ALM specific quality challenges

There are many! One example:

- Distortion coinciding with rapid cross-section change.

Cross section change distortion

- Peripheral 'steps' or 'witness marks' in parts, parallel to the XY plane
... unintended.



Background: massive tensile stresses are generated and act in-build

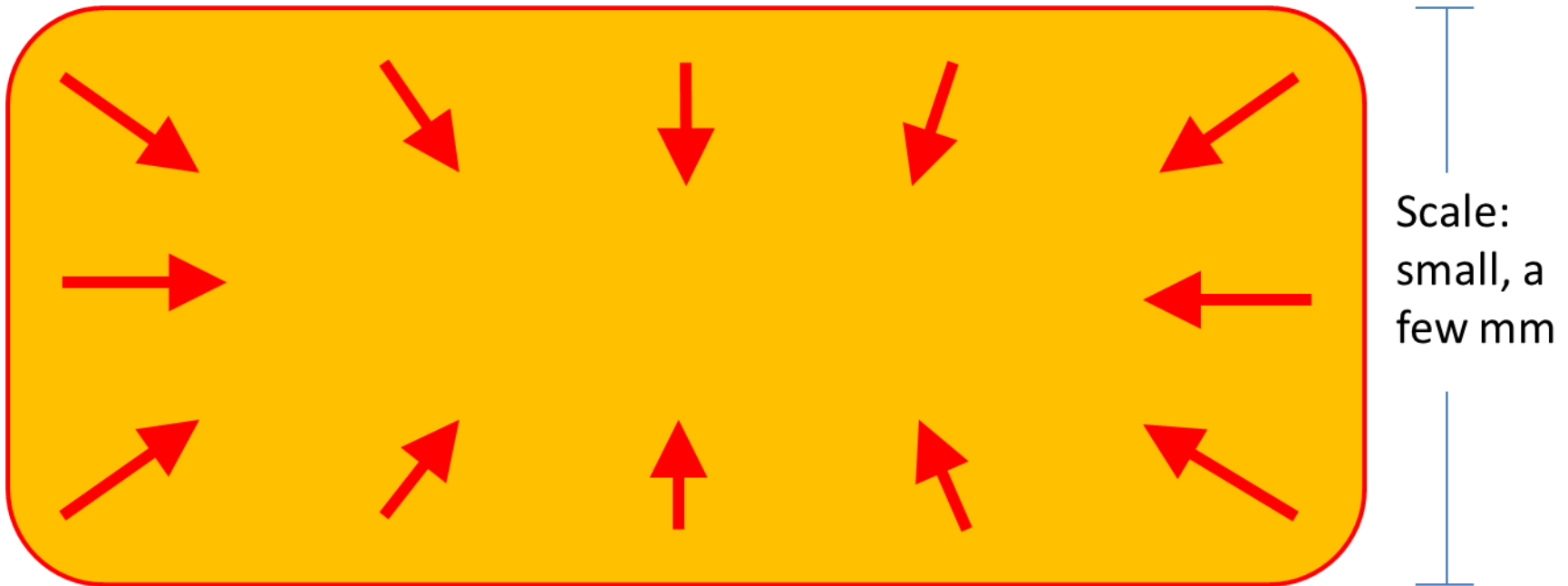


...standard practice is to heat treat parts which causes these stresses to dissipate. The test geometry below demonstrates the effect of cutting a part in the as-built condition with no HT.



Cross section change distortion

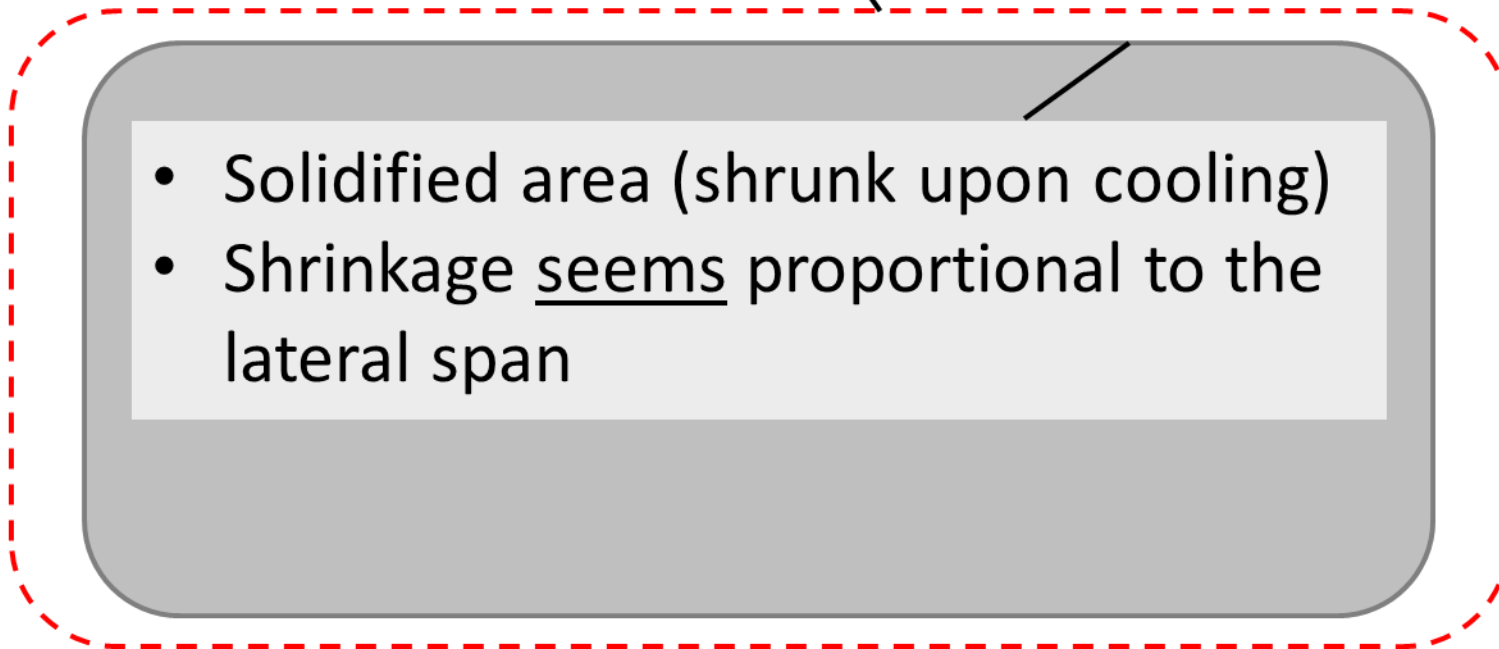
- During build, each molten portion shrinks inwards



(Top-down view the laser's point of view)

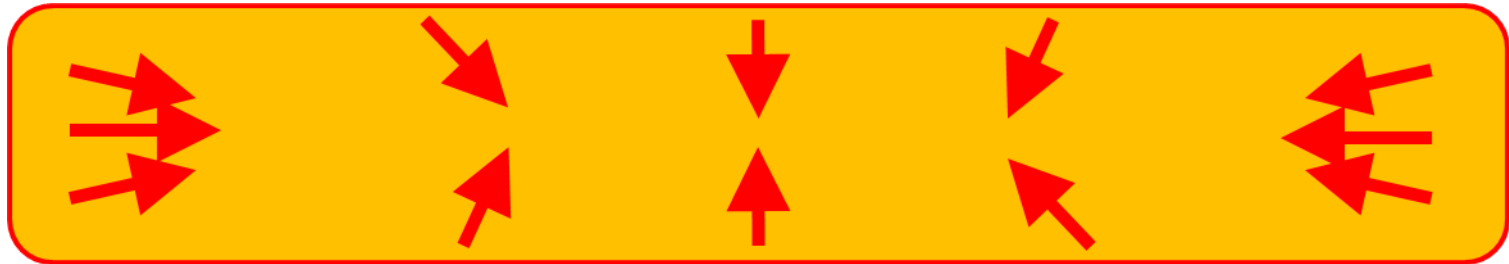
Cross section change distortion

- Original scanned/melted area

- 
- The diagram illustrates the concept of cross-section change distortion. It features a large, light gray rounded rectangle with a dashed red border. Inside this rectangle is a smaller, darker gray rounded rectangle. A line points from the text 'Original scanned/melted area' to the top edge of the darker gray rectangle. Another line points from the top edge of the darker gray rectangle to a smaller, light gray rounded rectangle inside it. This smaller rectangle contains a list of two items: 'Solidified area (shrunk upon cooling)' and 'Shrinkage seems proportional to the lateral span'.
- Solidified area (shrunk upon cooling)
 - Shrinkage seems proportional to the lateral span

Cross section change distortion

- Alternative geometry
...scanning, melting, shrinking ...



Cross section change distortion

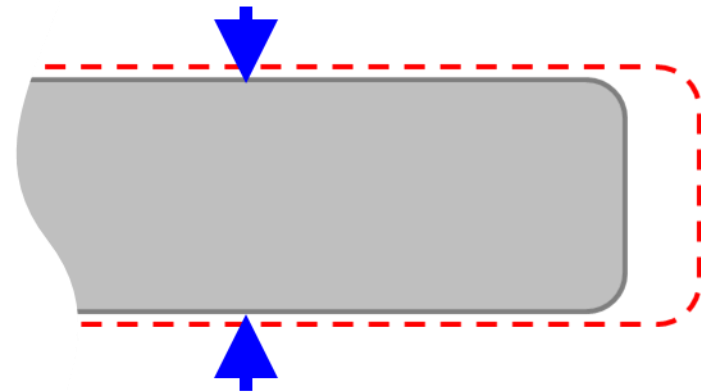
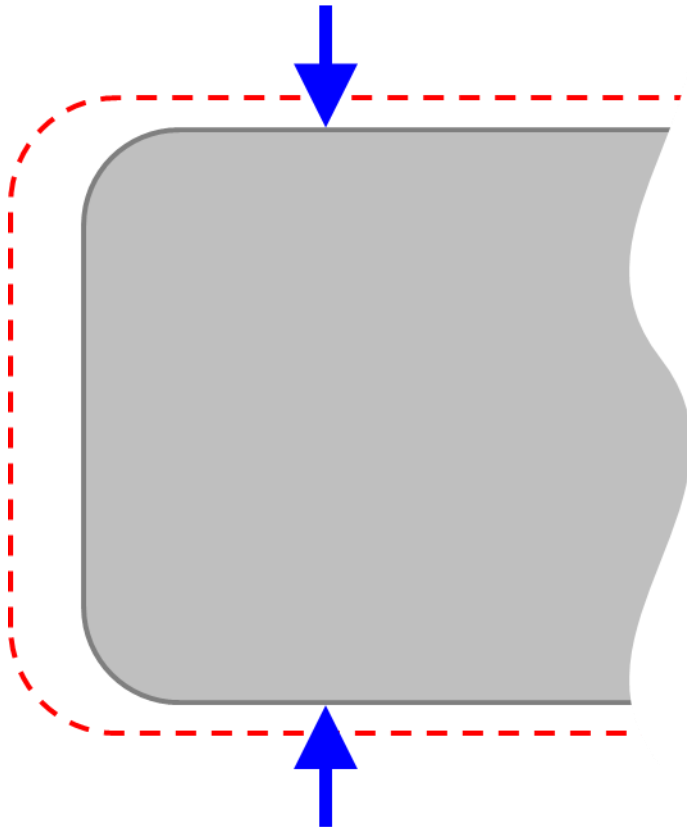
- Alternative geometry
...shrunk.



Cross section change distortion

- Geometries compared

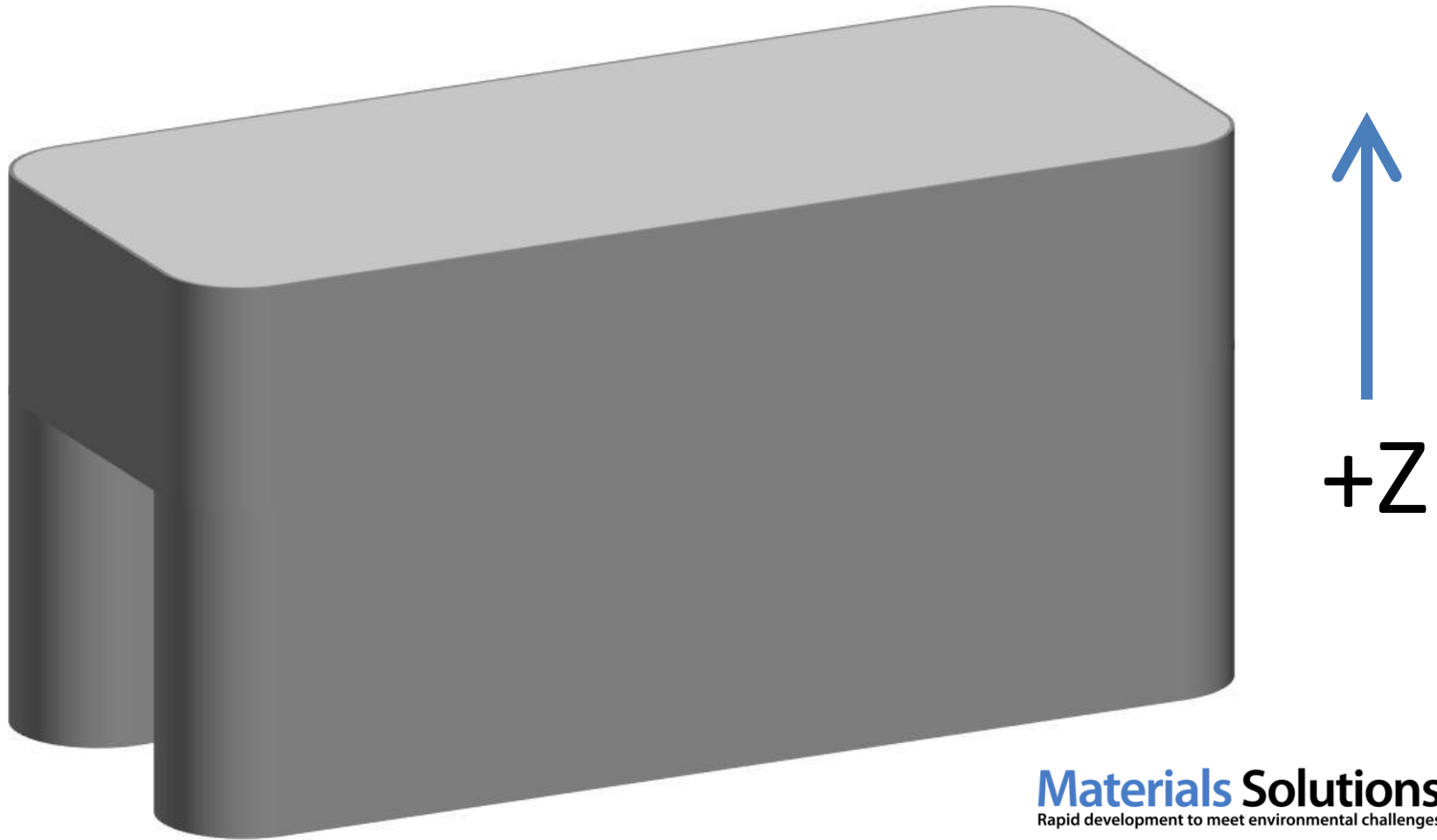
Greater shrinkage here...



...than here.

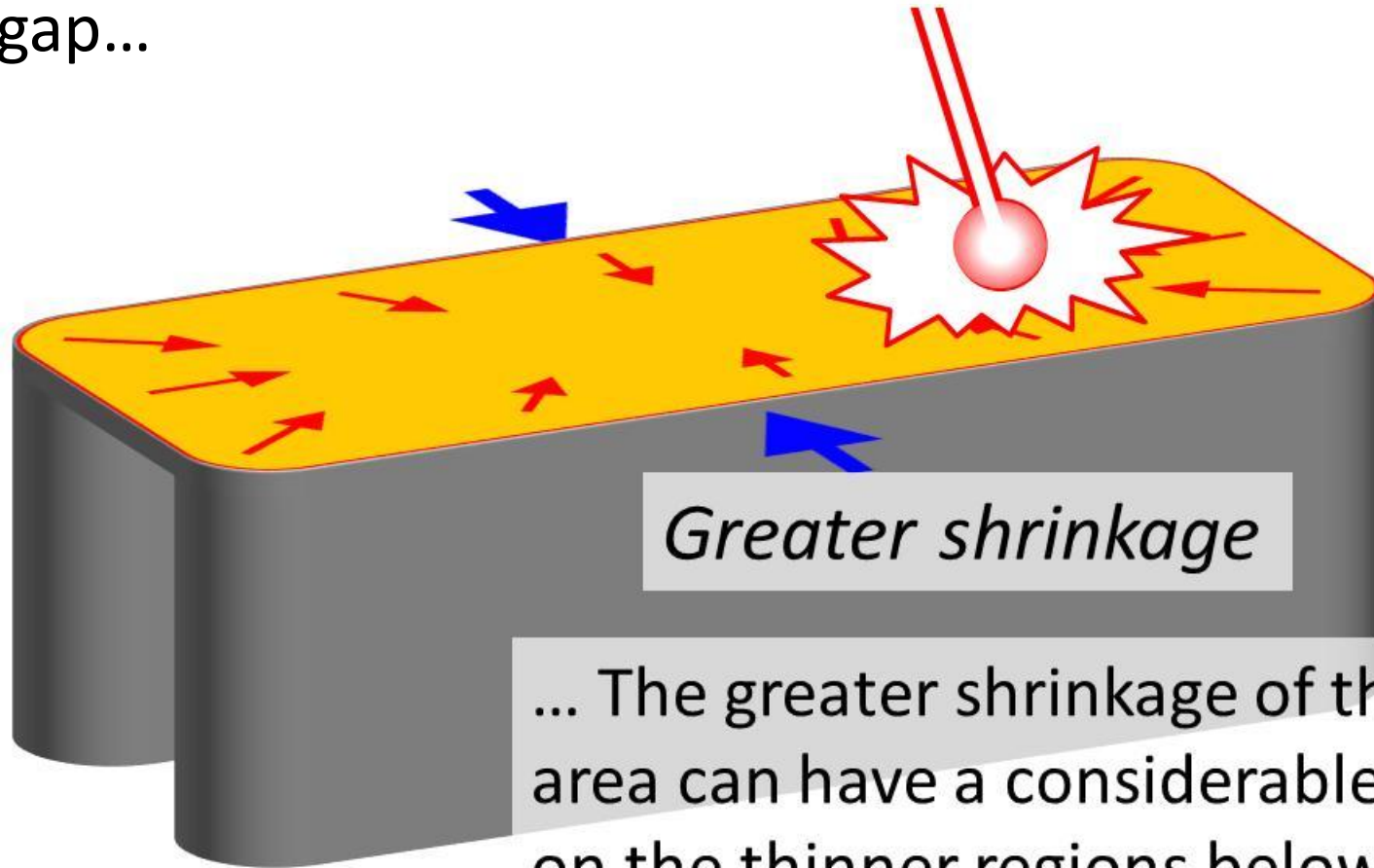
Cross section change distortion

- Consider the two geometries combined



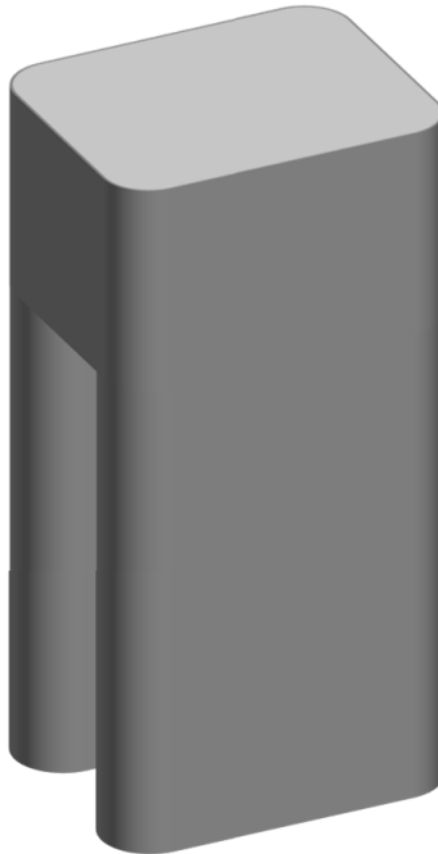
Cross section change distortion

- Mid-build. As the larger cross section is built, it bridges the gap...



Cross section change distortion

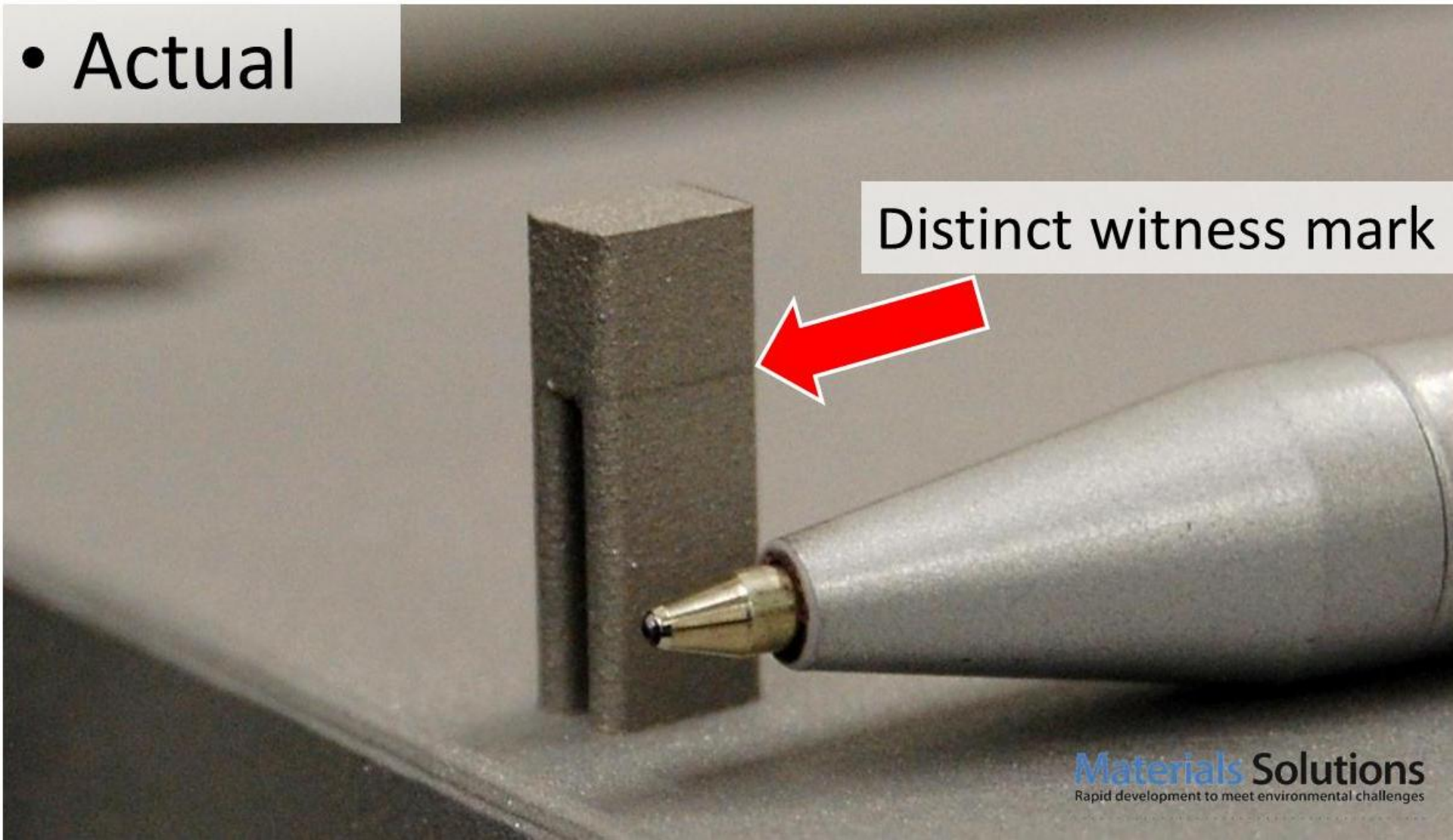
- A similar geometry: Nominal



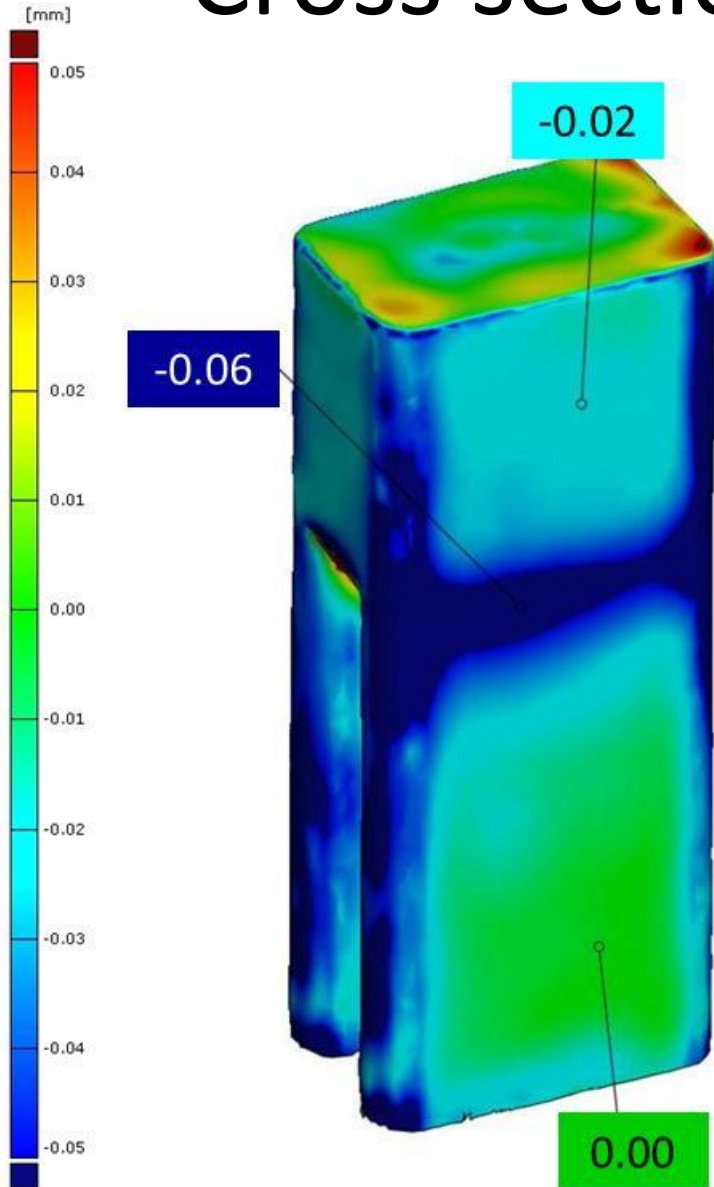
Cross section change distortion

- Actual

Distinct witness mark

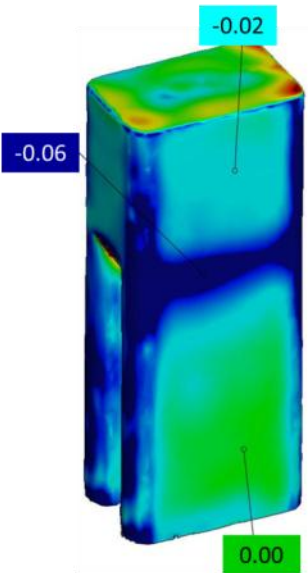


Cross section change distortion



GOM structured-light scan.
Aligned to front face.
60 micron deep
step/distortion.

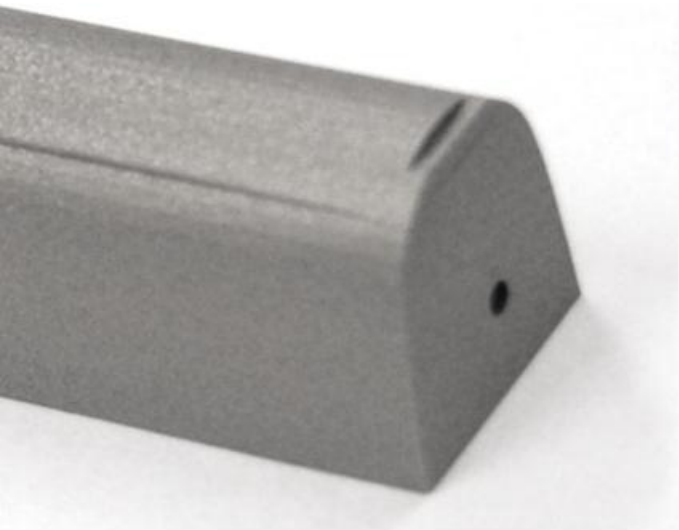
Cross section change distortion



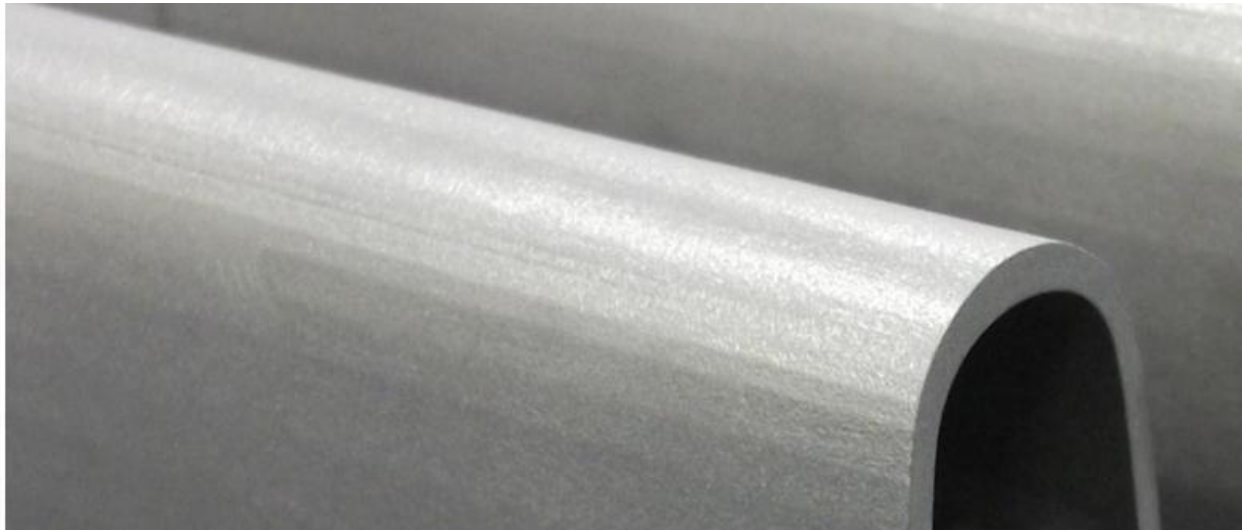
- This is a characteristic of metals ALM *... and similar to those seen with established metal-melting processes such as investment casting.*
- Awareness of such behaviour is key

Cross section change distortion

- With careful planning, negative consequences can be eliminated or satisfactorily mitigated.



Trial part,
severe distortion



Final part, distortion greatly reduced

The end is nigh: Conclusions

- Production of ALM metallic parts faces many challenges ...as with all other manufacturing processes.
- For some applications (e.g. aero engines), a lot is demanded ... especially considering the relative immaturity of the process.

Conclusions

- To meet exacting requirements, carefully implemented rigorous QA practice is essential.
- It is not easy, but done right, the outcome is impressive and the customer is happy.

Thank you

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