

CU 36: Coordinating the AM Process (Pilot)

TOPIC 4: Controlling design data

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FOR SAM PILOT ATTENDEES AND TRAINERS ONLY

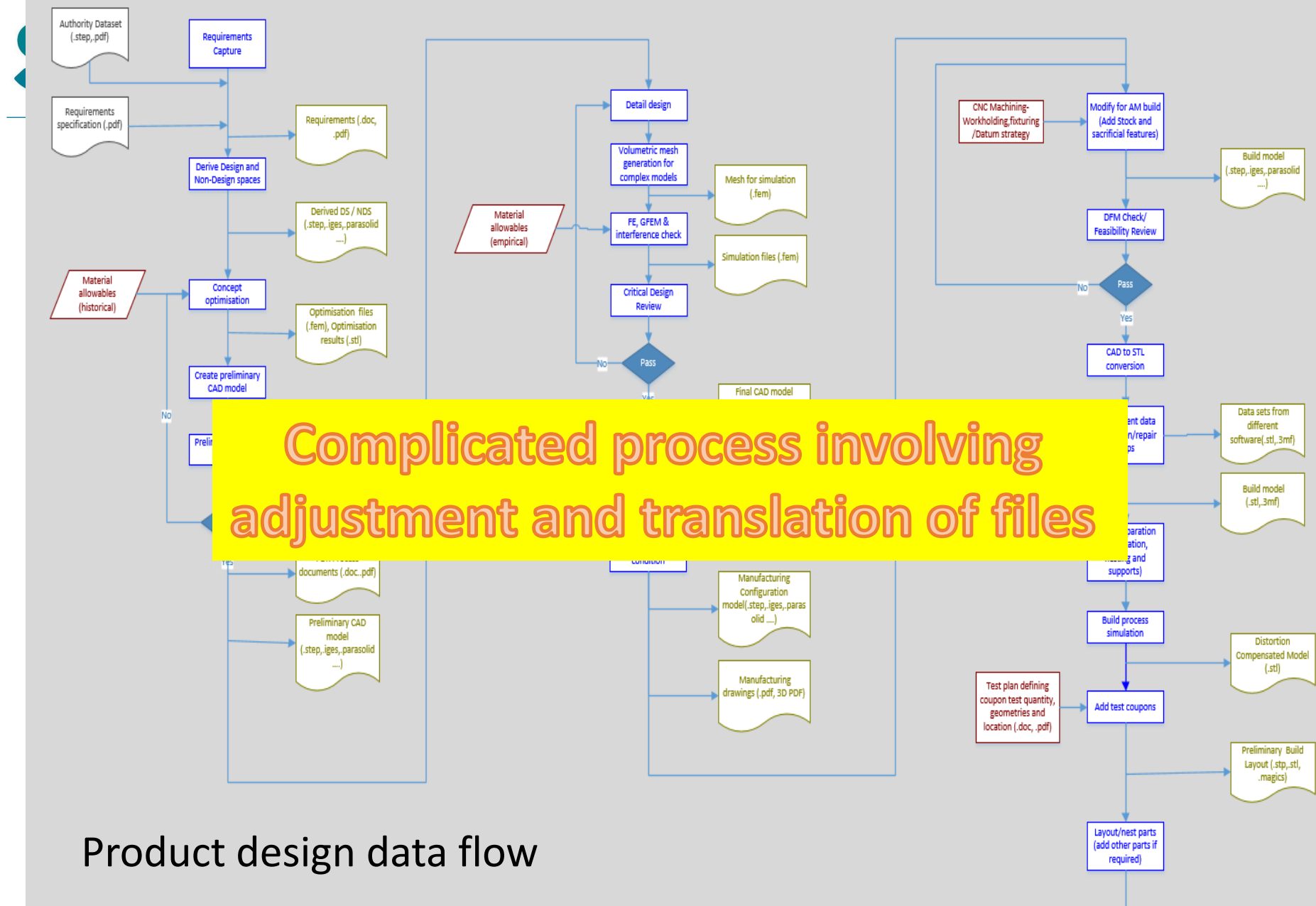
Topics covered include....

- Why design data control is critical
- Challenges for AM data management
- File formats and tolerancing
- Beyond design data – the digital tread
- Role of PLM/MES
- Data security and export control

Why Design Data Control is critical?

- Each of the data processing steps (CAD design, tessellation, build orientation, support design, build layout, slicing, building, post processing) contribute to the finished part quality.
- Data traceability is required for reproducibility, quality assurance, qualification & certification procedures
- Large amounts of data are generated, exchanged which need to be efficiently and securely managed.

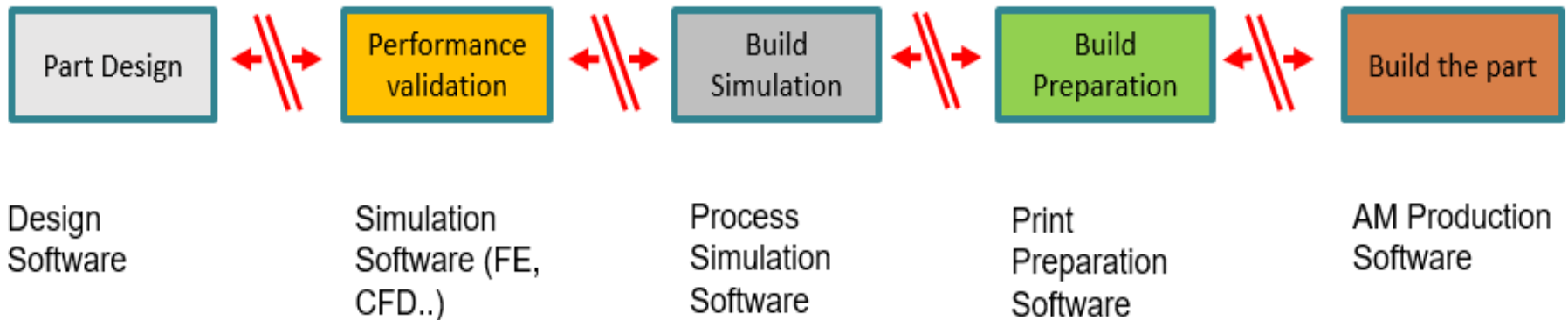
“Bad” data can lead to failed builds and scrap parts
Losing design data can lead to legal action...fines



Product design data flow

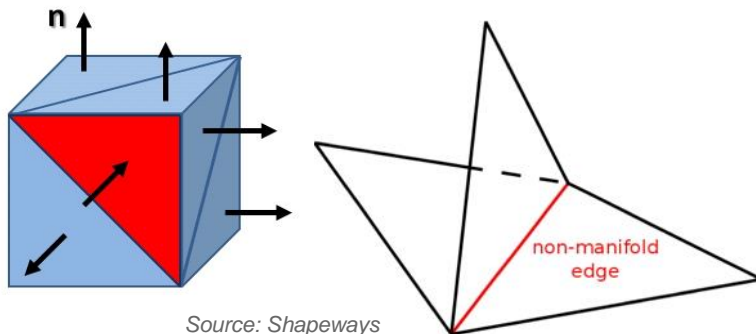
Some of the Challenges with AM Data Management include;

- Different data input formats (STL etc..or IGES,STEP or Native CAD)
- Wide variety of disconnected software packages required
- Multiple file conversions
- Lack of “standardised” data manipulation setting leads to part geometry errors



Standard Tessellation Language (STL) Files

- Original AM file format
- Large file sizes
- Only mesh data
 - No scaling information
 - No colour information
 - No material information
 - No meta data of any kind



- Mesh errors are common
 - Inverted “flipped” normals
 - Intersecting/overlapping triangles
 - Holes in the mesh
 - “Bad” Non-manifold edges
 - Noise shells

<https://amfg.ai/2018/04/19/top-5-stl-file-errors-you-should-know>

- Can lead to build failures and bad parts
- Errors may require manual repair but software provides automated repair



[missing triangles in STL file - Bing images](#)

Some alternative File Formats

Additive Manufacturing File (AMF) Format

- Contains five elements:
 - Object
 - Material
 - Texture
 - Constellation
 - Metadata
- Constellations copy bodies rather than the mesh
- It allows curved triangles
- Graded materials, sub-structures, microstructures, porous, and stochastic materials are possible.



3MF

- “3D payload” contains all additional part data
- Creates instances of copied bodies rather than duplicating the mesh
- Reduced file size by 2-3x
 - Efficient storage of beam lattices
- Support structures attached to part data
- Human readable



Direct Slice

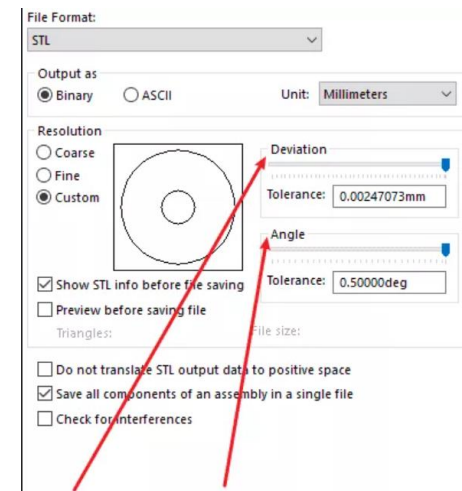
- Removes meshing format
- Greater model accuracy
- Checking and repairing routines elimination
- Pre-processing time reduction
- File size reduction
- Limited adoption in CAD packages
- Slicing time can take longer

Meshing tolerances

- Converting CAD model to STL, AMF or 3MF formats risks data “degradation”
- Tolerance setting;

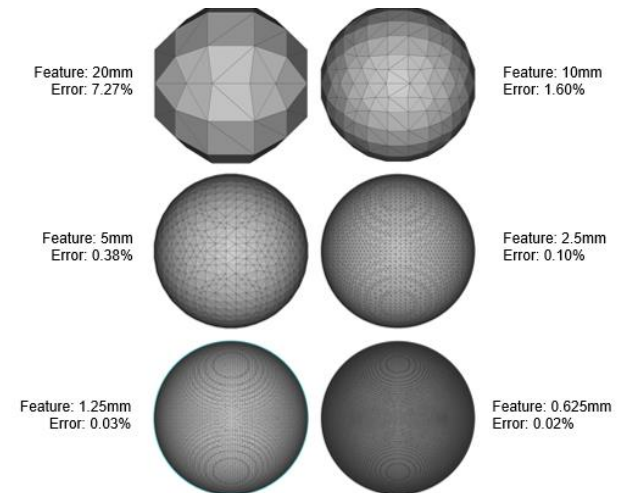
Angle Control – maximum angular deviation between adjacent triangles

Chordal Tolerance/Deviation – the maximum distance between the surface of the original design and the tessellated surface of the STL model.



<https://www.solidprint3d.co.uk/a-guide-to-stl-exports-for-3d-printing/>

- Recommended to set the tolerance x 5 better than resolution of AM process
- For STL file Chord height setting of 0.01 mm to 0.02 mm recommended for most PBF processes



File versioning

To avoid confusion it is recommended to use a standard approach to file naming and version control

Design Space
As Provided by Customer.

Optimisation
Optimised output – different attempts with different version numbers.

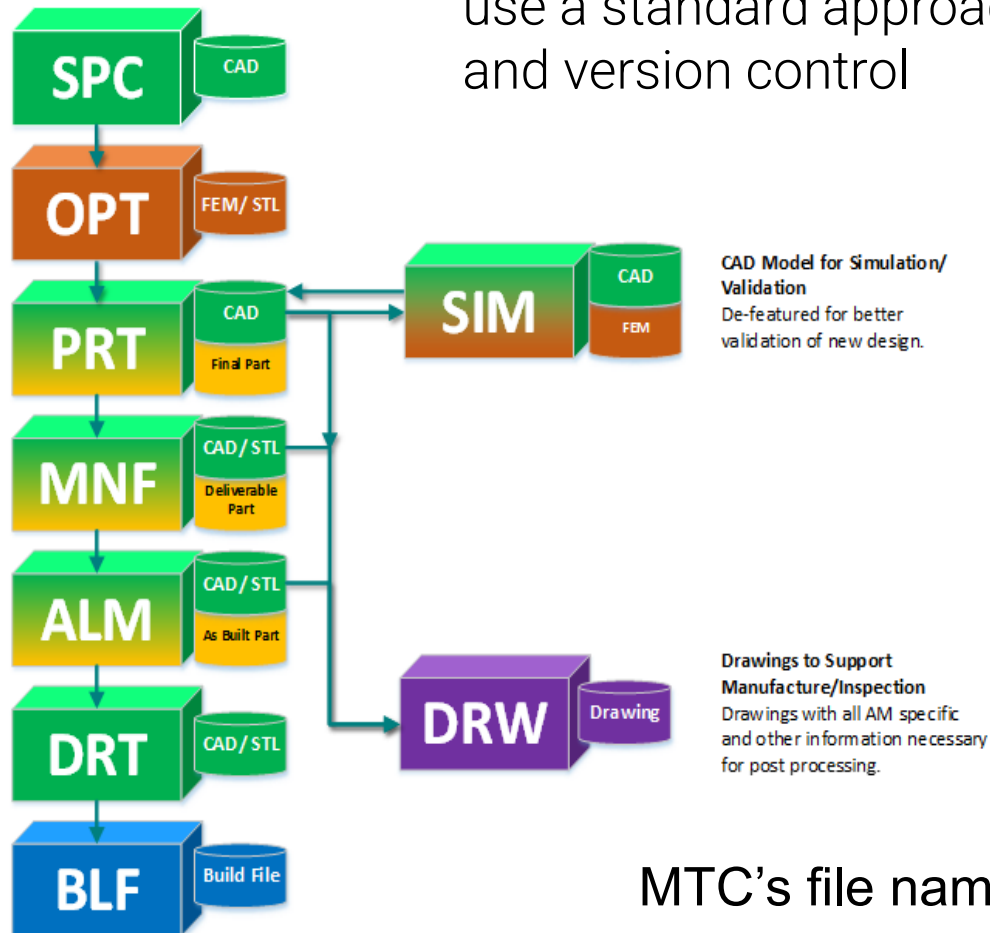
Final Part Geometry
Model require for end us by customer.

Part To Delivery To Customer
Model to be delivered to customer (e.g. has pilot holes).

Part To Be Manufactured in AM
Part that should come out of the AM machine as built. Machine stock added, holes filled, etc.

Model Required to Build Intended Part
Scaling and Distortion applied.

Model with Build Considerations
Orientation, supports, chamber packing, slicing.



MTC's file naming convention

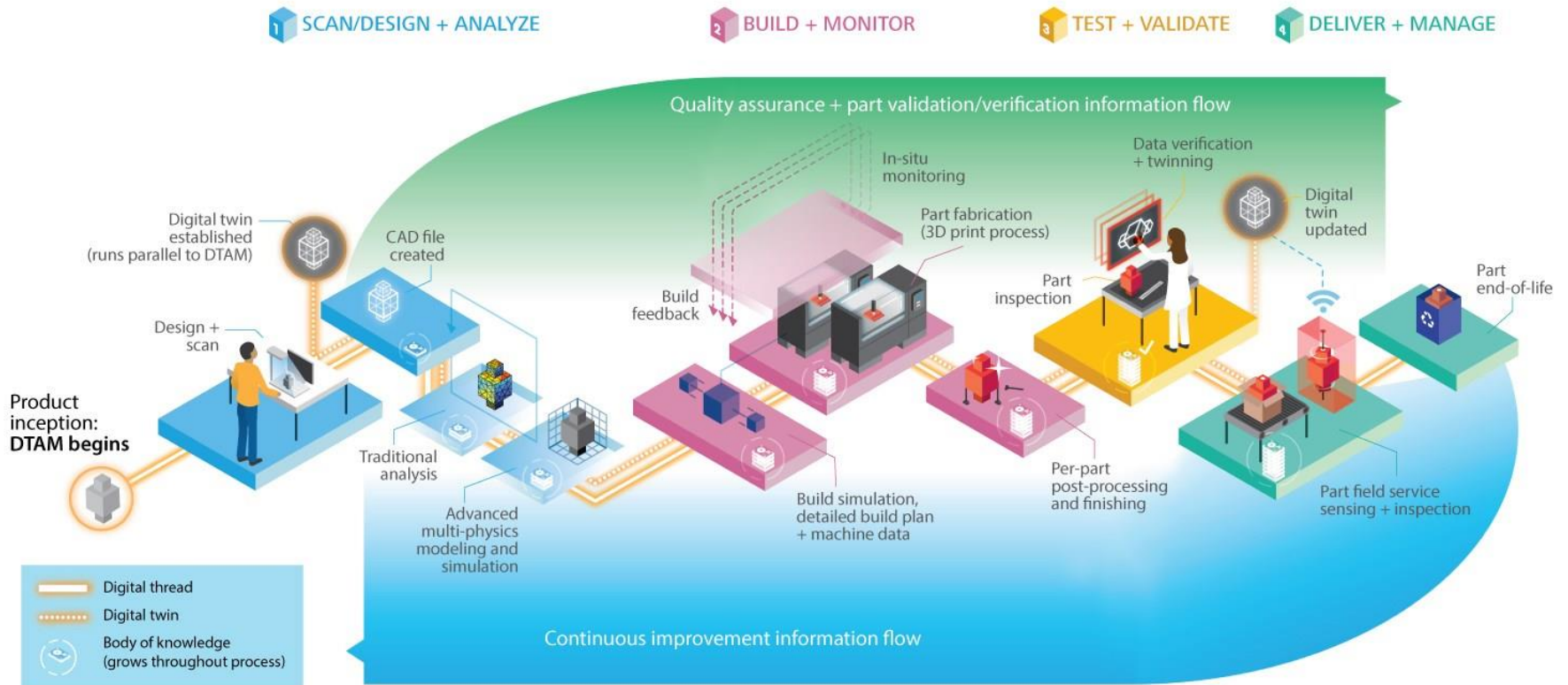
- Large quantity of data generated for AM part makes it very difficult to track and trace the files manually using model register
- PLM/PDM system is potential solution
- Important to know who “owns” each type of data in AM process

who	date	filename including extension	geometry type	component / feature	based on (parent)	setup summary	material version	comment
Layout files								
RB	15/04/17	Scenario 1-design space constraint v7.scdoc	LS CAD	8pt design (2LCs)	Accituri Issue 4 spec	2 LCs	Ti64 - B	Definition of tabs position
RB	24/04/17	Scenario 1-design space constraint v7.1.scdoc	LS CAD	8pt design (2LCs)	Scenario 1-design space constraint v7.scdoc	2 LCs	Ti64 - B	Removed simulation results
RB	17/04/17	ewira 7.1.x_t	Parasolid	8pt design (2LCs)	Scenario 1-design space constraint v7.1 LS CAD	2 LCs	Ti64 - B	sent to AT & Nick G for FEM
RB	04/04/17	Scenario 1-design space constraint v7.1.scdoc.3dm	Rhino file	8pt design (2LCs)	Scenario 1-design space constraint v7.1 LS CAD Modified to adapt to the tabs	2LCs	N/A	
RB	19/05/17	11201-PRT-204	PRT/STP	8pt design (2LCs)	renamed ewira 7.1.x_t	2LCs	Ti64 - B	This is the thickened strut output from the model Rob set up
RB	19/05/17	11201-PRT-205	PRT/STP	8pt design (2LCs)	11201-PRT-204	-	N/A	bracing struts across the skin support tabs removed. This is the geometry sent to Paco for checking
AH	16/05/17	EWIRA_8PointStrut_Spring_Reactions.inp	fem					
AH	16/05/17	11201-SIM-205-v1.0.inp	fem		Renamed EWIRA_8PointStrut_Spring_Reactions.inp			Spring deflections and reaction forces in other output folder. Sent to Paco as EWIRA_8PointStrut_Spring_Reactions.inp
MF	17/05/17	11201-ag-208.scdoc	LS CAD	8pt design (16LCs)	Renamed "Scenario 1-design space constraint v8_mig.scdoc"	16 LCs	Ti64 - B	
Tom LS	18/05/17	11201-ag-208_LSMODd.scdoc	LS CAD	8pt design (16LCs)	Scenario 1-design space constraint v8_mig LS CAD	16 LCs		sent to AT & F
MF	24/05/17	11201-PRT-208-V1.scdoc	LS CAD	8pt design (16LCs)	renamed "11201-ag-208"	16 LCs	Ti64 - B	sent to LS to check
MF	24/05/17	11201-PRT-206-v7.1.3dm	Rhino file	8pt strut design (2LCs)	Scenario 1-design space constraint v7.1.scdoc.3dm	2LCs	N/A	Removed vertical struts between tabs of secondary loads to comply with the geometry of 11201-PRT-205
MF	16/04/18	11201-PRT-206-v8- With thinner Struts.3dm	Rhino file	8pt strut design (2LCs)	11201-PRT-206-v7.1.3dm		N/A	Added thinner struts between various points of lugs. Created only for renders showing the workflow
MF	24/05/17	11201-PRT-207-v0.1.x_t	Parasolid	8pt design (2LCs)	11201-PRT-206-v7.1.3dm	2LCs	N/A	Merged struts to reduce blend points
MF	24/05/17	11201-PRT-207-v0.2.x_t	Parasolid	8pt design (2LCs)	11201-PRT-207-v0.1.x_t	2LCs	N/A	Improved symmetry between upper and bottom
MF	31/05/17	11201-PRT-207-v0.4.x_t	Parasolid	8pt design (2LCs) blended	11201-PRT-207-v0.2.x_t	2LCs blending auto	N/A	Inb&Outb Tabs adapted to Build volume, sec. loads tabs rounded. Blending auto from Tspines
MF	30/05/17	11201-PRT-207-v0.4.2.stl	Stl file	8pt design (2LCs) blended	11201-PRT-207-v0.4.x_t	2LCs blending auto	N/A	Eyes blending added sculpting
MF	30/05/17	11201-PRT-207-v0.4.dxf	dxf file	8pt design (2LCs)	11201-PRT-207-v0.4.3dm (Scratch folder)	2LCs	N/A	Half wireframe of struts distribution for Sandeep FEA
MF	02/06/17	11201-PRT-207-v1.0.stl	Stl file	8pt design (2LCs) blended	11201-PRT-207-v0.5.3dm (Scratch folder)		N/A	Mesh smoothing. Sent to EBM build
MF	02/06/17	11201-PRT-207-v1.0.x_t	Parasolid	8pt design (2LCs) blended	11201-PRT-207-v0.5.3dm		N/A	PDR model. Used for meeting with CT and AT
MF	05/06/17	11201-PRT-207-v1.1.stl	Stl file	8pt design (2LCs) blended	11201-PRT-207-v1.0.stl		N/A	Anchor nuts satellite holes added. Sent to polymer print
MF	06/06/17	11201-PRT-207-v1.2.stl	Stl file	8pt design (2LCs) blended	11201-PRT-207-v0.5.1.3dm		N/A	0.5mm offset (struts 4mm). Satellite holes added. For polymer and eBM print. (05/05/2018)Sent for GOM validation
AH	07/06/17	11201-PRT-207-v0.4.4-boolean	NX Prt and stp	8pt design (2LCs) blended	11201-PRT-207-v0.4.3.x_t		N/A	Used for preliminary beam stress checks
MF	08/06/17	11201-PRT-400-v3- issue3Hinge.stl	Stl file	Hinge Issue 3			N/A	Sent to polymer print
MF	09/06/17	11201-PRT-207-v1.3-axisNpoints.stp	Step file	8pt design (2LCs) blended tapered	11201-PRT-207-v1.0.x_t	Tapered version	N/A	Tapered, thickened according to AH struts stress checks. Sent to

Model Register used to track the file versioning and exchange in one of the internal projects (Source: MTC)

Digital Thread in AM

Digital data management goes beyond design data and AM build files

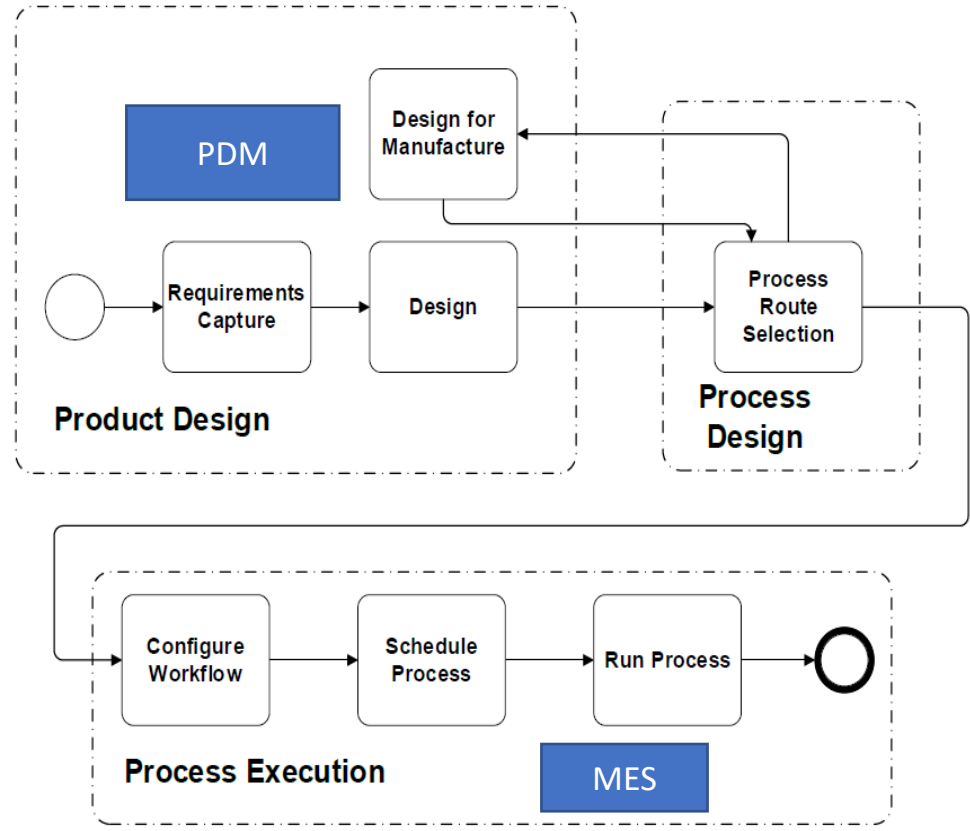


Source: <https://www2.deloitte.com/insights/us/en/focus/3d-opportunity/3d-printing-digital-thread-in-manufacturing.html>

PDM/PLM and MES systems

Generic Product Data Management (PDM) and **Product Life cycle Management (PLM)** systems might not consider all aspects of AM workflow

Manufacturing Execution Systems (MES) track and document components/assemblies through the manufacturing process. Enable scheduling of resources (people/machines), provide traceability, can feed into stock management, and can update people not involved in the manufacture of the status of the part.



PDM/PLM and MES systems for AM

PDM/PLM Systems (not exhaustive)



- MES Systems (not exhaustive)



Data Security

- Product data is commercially sensitive
- Customer may stipulate secure platforms /software for data transfer
- Penalties for breach as well as loss of reputation
- In some cases information is commercially sensitive and also has national security implications too!

National Security

You may expect this if you are dealing with..

- Armed forces
- Police
- Security services
- Defence companies



<https://military.com>



<https://www.hampshire.police.uk/>



<https://www.neweurope.eu>



UK National Security

Be wary if you receive an email or other communication marked
OFFICIAL , SECRET, TOP SECRET

OFFICIAL

The majority of information that is created or processed by the public sector. This includes routine business operations and services, some of which could have damaging consequences if lost, stolen or published in the media, but are not subject to a heightened threat profile.

SECRET

Very sensitive information that justifies heightened protective measures to defend against determined and highly capable threat actors. For example, where compromise could seriously damage military capabilities, international relations or the investigation of serious organised crime.

TOP SECRET

HMG's most sensitive information requiring the highest levels of protection from the most serious threats. For example, where compromise could cause widespread loss of life or else threaten the security or economic wellbeing of the country or friendly nations.

Government Security Classifications May 2018 Version 1.1 – May 2018

If you don't hold the appropriate level of security clearance do not open

Export Control – What is it for ?

- Export control regulations are in place to prevent exchange of dangerous data, materials, or goods. Reasons include:
 - National and global security
 - Non proliferation and terrorism
 - International legal obligations
 - Human rights and internal repression

Export Control - Legislation

- EU:
 - EC Regulation 428/2009
- UK:
 - UK Export Control Act 2002
 - UK Export Control Order 2008
- USA
 - International Traffic in Arms Regulations (ITAR)
 - Export Administration Regulations (EAR)

**NOTE: ITAR regulations
apply to companies outside
of the USA !!**

Export Control – Penalties for breaking

- For the individual:
 - Prosecution of company employees and directors
 - Up to 10 years in prison
 - Dismissal from employment
- For the company
 - Program delays and additional costs
 - Business trading restrictions and sanctions
 - Fines of up to \$1m per violation
 - Reputational damage



<https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.ppic.org>

Export Control – what is covered

- Affects the ‘export’ of any tangible (physical) or intangible (electronic) goods
- Relates to hardware, technical information, drawings, CAD files, source code, software, or technical ‘know how’.
- Exporting controlled items including data usually requires an export licence
- Some countries are also subject to sanctions or additional controls

Export control focuses on two categories of controlled items:

- Military Use - Specifically designed or modified for military use
- Dual Use - both military and civilian applications but not adapted for military use.

Dual use categories (US/EU)

Category 0: Nuclear materials, facilities and equipment

Category 1: Special materials and related equipment

Category 2: Materials processing

Category 3: Electronics

Category 4: Computers

Category 5: Telecommunications (Part 1) and Information security (Part 2)

Category 6: Sensors and lasers

Category 7: Navigation and avionics

Category 8: Marine

Category 9: Aerospace and propulsion

What Must A Company Do To Comply With Export Control Laws?

Export Control Terms & Conditions in Contracts

Ensure clauses included in contracts and agreements to identify and mitigate commercial and legal export control risks

Screening & Embargo Checks

Trading Parties / Staff screening against individual, business entity and country specific lists

Establishing Intended End Use

Providing / obtaining necessary End User Certificates

Export Licences & Authorisations

Obtaining all necessary UK, US, EU & other export and re-transfer authorisations and meeting all licence conditions

Segregating & Labelling

Marking & control of export controlled hardware & technical data

Maintaining Records

Retention of company, transactional, project & functional records for Government & / or Client formal audits

Physical & IT Access Controls

Access controls on site and to applications, data systems and servers

Internal Compliance checks

Internal Compliance Checks Regular assessment of the company export compliance & adherence to policy & process

Training & Awareness

Provision of training & guidance materials to employees within Induction, regular Refresher, Project & Function

Legislation Updates & Management of Impacts

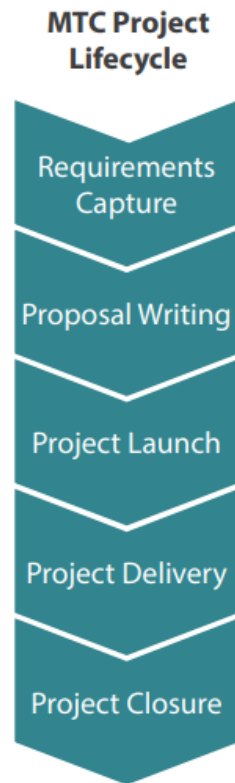
Keeping abreast of changes in laws, embargoes/sanctions & licensing

Classification

Hardware, Software, Source Code, Technical Information & sometimes technical know is classified in Control Lists:

- External companies must advise MTC of the classification rating of its supplies
- MTC is responsible for classifying anything that is intended for export.

Export Control could impact all aspects of our business. Special attention should be paid when working within a Project Lifecycle involving the following activities:



Travel overseas

- Permits required if carrying company IT equipment overseas even if personal travel
- Licences needed if export controlled data being held on equipment or being accessed or shared whilst overseas
- Some destinations/ technical data may require licence processing of several months

Technical document creation

- Need to mark document if export controlled & control distribution & access during & after creation
- Need to know if using export controlled data – contact Export Control immediately if USA ITAR/ EAR or for classification guidance

Material in, access & use

- Identify export controlled materials received typically via Supplier Dispatch note/ PO) or document cover notes
- Liaise with Export Control to manage appropriate physical segregation, labelling, access control & tracking
- If ITAR/ EAR items, restrictions or approvals may apply on access by specific nationalities or exhibition/ display

Contracts

- Need to ensure that MTC includes export control clauses in Sales & Purchase Orders & Agreements
- Request export control classification from providers of hardware, technology, etc
- Lookout for export control terms or references within external contracts/ documentation & notify Export Control immediately

Shipping overseas

- All tangible exports, even those being hand-carried, require completion of Dispatch Note via Shipping function
- Specific information, certifications, licences required potentially taking weeks to process

Technical data access & exchange

- Control on transfer/exchange via email, phone/ video call or shared data systems
- Documents containing export controlled data must be classified, marked, tagged & tracked
- External export controlled data should be pre-advised as such prior to upload to MTC servers
- Access to ITAR/ EAR data requires strict company specific and nationality control
- Export Control approval required before exporting any technical data & strict record keeping required

Useful further reading

- ISO/ASTM 52915:2016(E) Standard Specification for Additive Manufacturing File Format (AMF)
- ISOASTM52911-1-AM-Design-Part1_Laser-based powder bed fusion of metals
- Tolerancing from STL data: A Legacy Challenge
- <https://www.sciencedirect.com/science/article/pii/S221282712030946X>
- Digital Thread for Additive Manufacturing (DTAM)
- <https://www2.deloitte.com/us/en/pages/public-sector/articles/digital-thread.html>
- Building a digital twin for additive manufacturing through the exploitation of blockchain: A case analysis of the aircraft industry
<https://www.sciencedirect.com/science/article/pii/S0166361518308741>
- Government Security Classifications May 2018 Version 1.1 – May 2018

<https://www.gov.uk/guidance/uk-strategic-export-control-lists-the-consolidated-list-of-strategic-military-and-dual-use-items>



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www.skills4am.eu



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