# Usability of Manufacturing Data for Analytics

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# LOCKHEED MARTIN: PEOPLE

**114,000+**
Employees

**57,000**
Scientists and Engineers

**375+**
Facilities Worldwide

Operating in over
**54** Countries

With **7,500+**
Employees

# LOCKHEED MARTIN: BUSINESS STRUCTURE

## Aeronautics





## Missiles and Fire Control

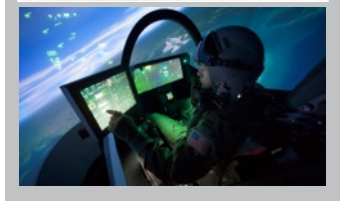




## Rotary and Mission Systems







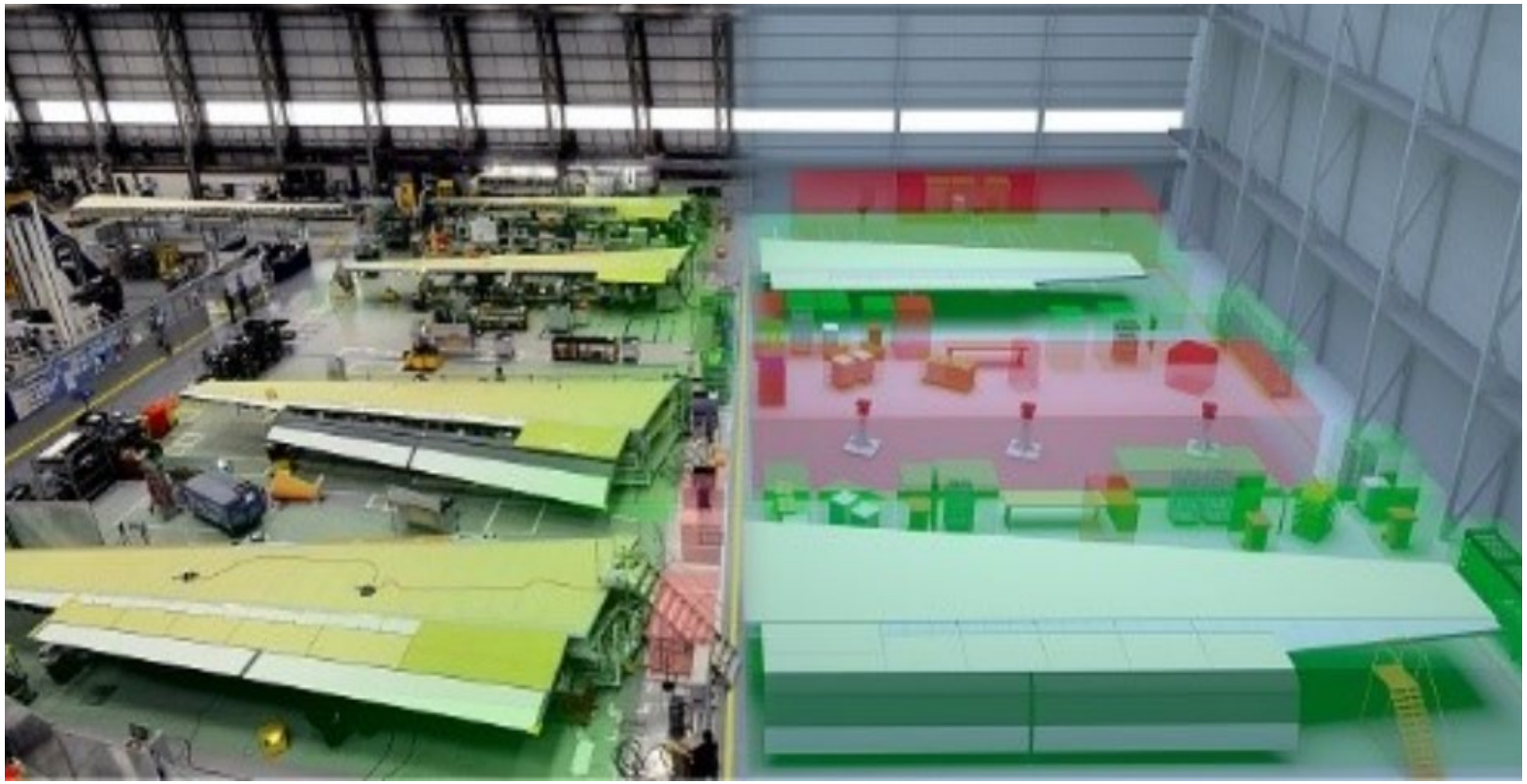
## Space





# Agenda.

- Problem statement: manufacturing data is “hard to use” for generalized AI applications
- Areas to look for solutions
- Recap



Images: https://pixabay.com/, unless otherwise noted

# Problem Statement.

**Some ontological questions are proving very hard to answer through analytics tools.**

- What is the best way to process a part?
- What is the best team to perform a specific assembly operation?
- There is a mishap. Why did this happen?
- Why did a feature fail inspection (next slide)?

**Today:** answers require human intervention.

**Future:** cognitive systems to significantly help with these tasks (if not perform).

**Fact:** today, manufacturing produces a lot of data.

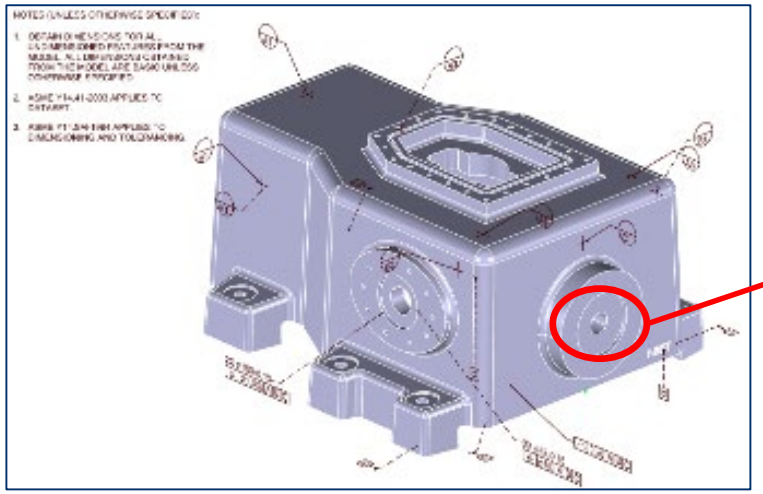
**We have the data! HOWEVER….**

There is no connection back to model based engineering requirements (no digital thread)

The 5 year fighter jet

# Missing digital thread

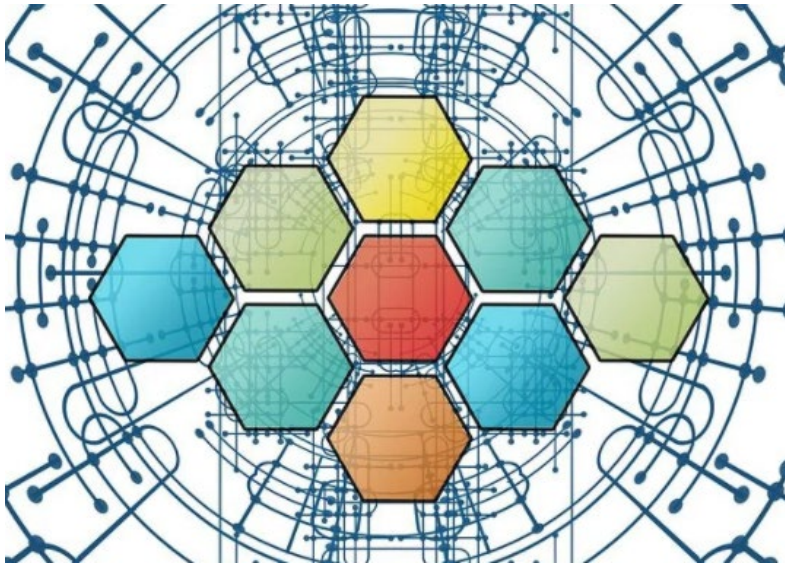
- **Part Numbers**: No Part Numbers (much less of an issue today)
  C130 program: first flight 1957
- **Serial Numbers**: Inconsistent Serialization
  Many times it is ad-hoc and not well orchestrated
- **Feature level tracking**: no tracking to model based requirements.
  Example below.



**Inconsistent Feature ID's throughout the processes.**

- CAD assigned feature ID: extr_14
- CAM assigned feature ID for Roughing: rough_bore_20
  Extremely hard to output using G-code no_reference
- Inspection assigned feature ID for Roughing: hole_678
- CAM assigned feature ID for Finishing: bore_67
  Extremely hard to output using G-code no_reference
- Inspection assigned feature ID for Finishing: front_bore

# Other challenges



**Unclear Record of Authority**

- **Internal:** Multiple CAD/PLM/ERP eco-systems
  *Even within 1 company*
- **External:** suppliers do not share customer's CAD/PLM/ERP eco-system
- "STEP" is treated as an **"annoyance",** even though it is all suppliers get

**Not a culture of delivering data artifacts with manufactured items**

- Example: Digital inspection/test results.
  ***"binary":*** *part is good/no good*
  If "good", ship it. Maybe a paper printout is also delivered.
  *Data gets lost or destroyed*.
- Material certs and other requirements are typically delivered in paper form (to be scanned to pdf).
- External suppliers hesitant to deliver artifacts into their customer's eco-system.

**Lack of manufacturing semantics and ontologies**

- Every OEM provides the same data item with a different identifiers.
- General lack of manufacturing ontologies: it is hard to compare manufacturing processes at an ontological level.

# What is required going forward?

## For all downstream model-based consumption, we need a clear and consistent vendor-neutral record of authority

- JT (ISO 14306:2017)
- STEP AP 242 (ISO 10303-242:2020)
- Can not be an “afterthought” or “annoyance”
  *It has to be the Record of Authority for MBE*.


## “Deliberate” part serialization for all part numbers

- Need clear instructions: Does the part need to be serialized?
- YES: clear serialization of physical part carried over into the digital representations.
- NO: physical part not serialized; no link to the digital artifacts.
- Cost trade-offs

## Ontology development (interoperability)

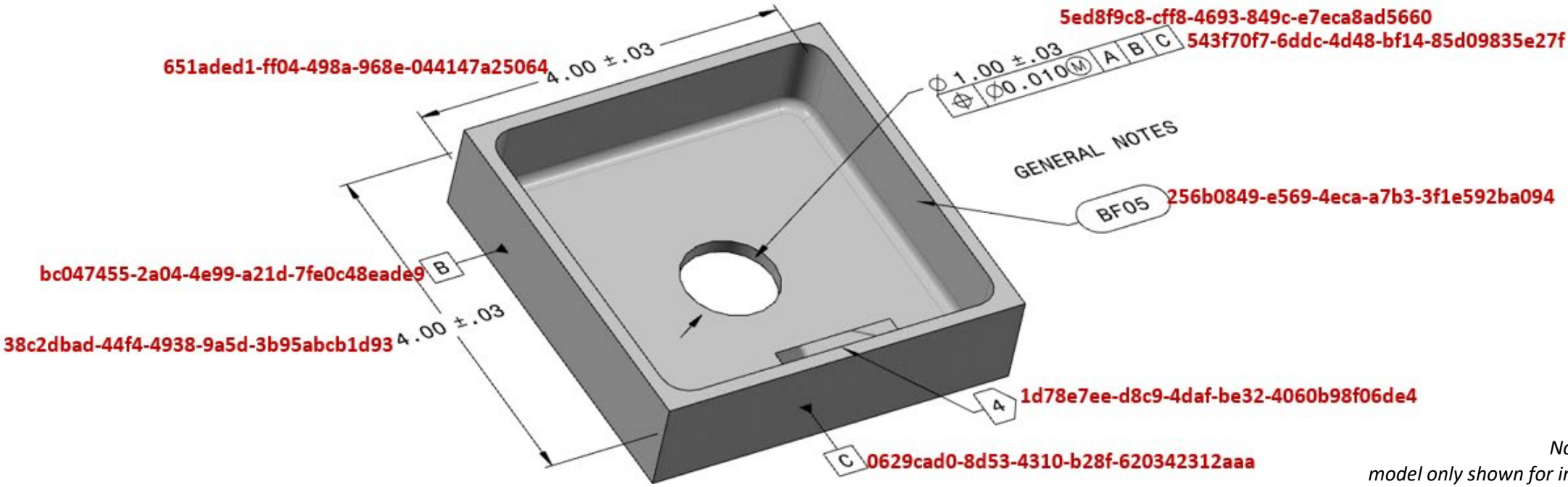
- Connected to high level ontologies (Basic Formal Ontology, Common Core Ontology, Industrial Ontology Foundry, etc)
- https://www.youtube.com/watch?v=MynCGvI1QSg

## AI/ML driven analytics linking data to MBE requirements

- Infer links between data and MBPC’s.
- NIST efforts (Bill Bernstein, Laetitia Monnier)

# Workable digital thread needed: ISO 10303 AP242 Edition 2

- A **single, unique, permanent** identifier, on every model based engineering requirement (geometry and Product Manufacturing Information (PMI)), that can be **persisted** through the life cycle of the part or assembly (Persistent ID's).
- Model Based Product Characteristic (MBPC)
- Ought to be assigned at time of product "authoring" (model generation)
- **ONLY** when the requirement changes, is there a new UUID assigned. Must be maintained regardless of CAD system used.




*Not an LM part number;*
*model only shown for informational purposes*

# What are UUID's?

**ISO/IEC 9834-8:2014 Standard**

- *Information technology -- Procedures for the operation of object identifier registration authorities – Part 8: Generation of universally unique identifiers (UUID's) and their use in object identifiers*
  - Reference https://www.iso.org/standard/62795.html
  - Reference: https://en.wikipedia.org/wiki/Universally_unique_identifier

**UUID's**

- Alphanumeric (combination of letters & numbers)
  36 fields (32 data fields, plus 4 dashes)
  5ed8f9c8-cff8-4693-849c-e7eca8ad5660
- Widely adopted (see "gift cards")
- Unique: Chance of randomly generating two identical UUID's is exceedingly low (one chance in about $10^{38}$)

  Reference: a person consists of roughly $10^{28}$ atoms, earth $10^{50}$ atoms, the observable universe: $10^{80}$ atoms.
- Do not require central registration or coordination
- Are easy to generate: API's for generating UUID's conforming to the standard are widely available in many computer languages



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# Example: QIF report.

**Serial Number**

**Part Number**

| ASME Y14.45 Single Part Data Report Example | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Part Name: Boxy** | **Part QPId** | **Part Serial #: 1** | **3D CAD Model ID: DMDII_test2_20170708** | | | | | | **Report # QA-12345** |
| **QPIds** | f2d3ae2b-25da-4524-8694-32ece8d142d2 | | 3D CAD Model QPId: 9637e2e8-9be4-4cc3-8cb8-dc53ca07b6fa | | | | | | Report QPId: 985eee8e-27c2-4ad0-8fd3-c3c05a1333de |
| **Characteristic Name_#** | **Characteristic QPId** | **Specification** | **Min Spec** | **Max Spec** | **Measured Value** | **Accept?** | **Tooling/Equipment** | **Non-Conformance #** | Comments |
| FLATNESS_1 | e04c20a3-4ed7-4ff9-909c-7ec645137ac2 | ASME Y14.5-2009 | 0.000 | 0.100 | 0.001 | PASS | CMM | | |
| FLATNESS_2 | e2cec972-a31c-44d7-bd25-bc77c7205b12 | ASME Y14.5-2009 | 0.000 | 0.200 | 0.001 | PASS | CMM | | |
| FLATNESS_3 | 302fbe11-508d-411d-ac9b-fa3798297569 | ASME Y14.5-2009 | 0.000 | 0.100 | 0.001 | PASS | CMM | | |
| FLATNESS_4 | 67b1647f-bfaf-417c-8de0-7e9b251ee5b4 | ASME Y14.5-2009 | 0.000 | 0.100 | 0.001 | PASS | CMM | | |
| FLATNESS_5 | b90ed429-2402-4556-872a-387034f57f2b | ASME Y14.5-2009 | 0.000 | 0.100 | 0.001 | PASS | CMM | | |
| PERPENDICULARITY_1 | c0115e2c-6796-4db4-bb3d-7b6566980aa4 | ASME Y14.5-2009 | 0.000 | 0.025 | 0.017 | PASS | CMM | | |
| PERPENDICULARITY_2 | 6007370c-e612-499c-983e-461c04e88bd7 | ASME Y14.5-2009 | 0.000 | 0.025 | 0.015 | PASS | CMM | | |
| PERPENDICULARITY_3 | 0d5bd430-5428-49b2-b730-9eb82ae93dc3 | ASME Y14.5-2009 | 0.000 | 0.025 | 0.010 | PASS | CMM | | |
| PERPENDICULARITY_4 | cab7bbc5-34d1-47b5-bc8b-ff94f0b1ff2a | ASME Y14.5-2009 | 0.000 | 0.025 | 0.010 | PASS | CMM | | |
| DISTANCEBTW_1 | 8c5cad4e-5050-4d92-872e-ab688d320fd1 | ASME Y14.5-2009 | 59.700 | 60.300 | 59.953 | PASS | CMM | | |
| DISTANCEBTW_2 | 310172d2-2d66-4efd-839f-6a47665d7b74 | ASME Y14.5-2009 | 59.700 | 60.300 | 59.964 | PASS | CMM | | |
| DIAMETER_1 | 3c8cc944-a925-40fb-ba66-59f2f6f04a96 | ASME Y14.5-2009 | 15.200 | 16.800 | 17.705 | FAIL | CMM | NCR# 12345 | |
| DIAMETER_2 | 641970ca-0394-4e84-9f32-efda80c048bc | ASME Y14.5-2009 | 15.200 | 16.800 | 18.002 | FAIL | CMM | NCR# 12345 | |

**Model Based Product Characteristics**

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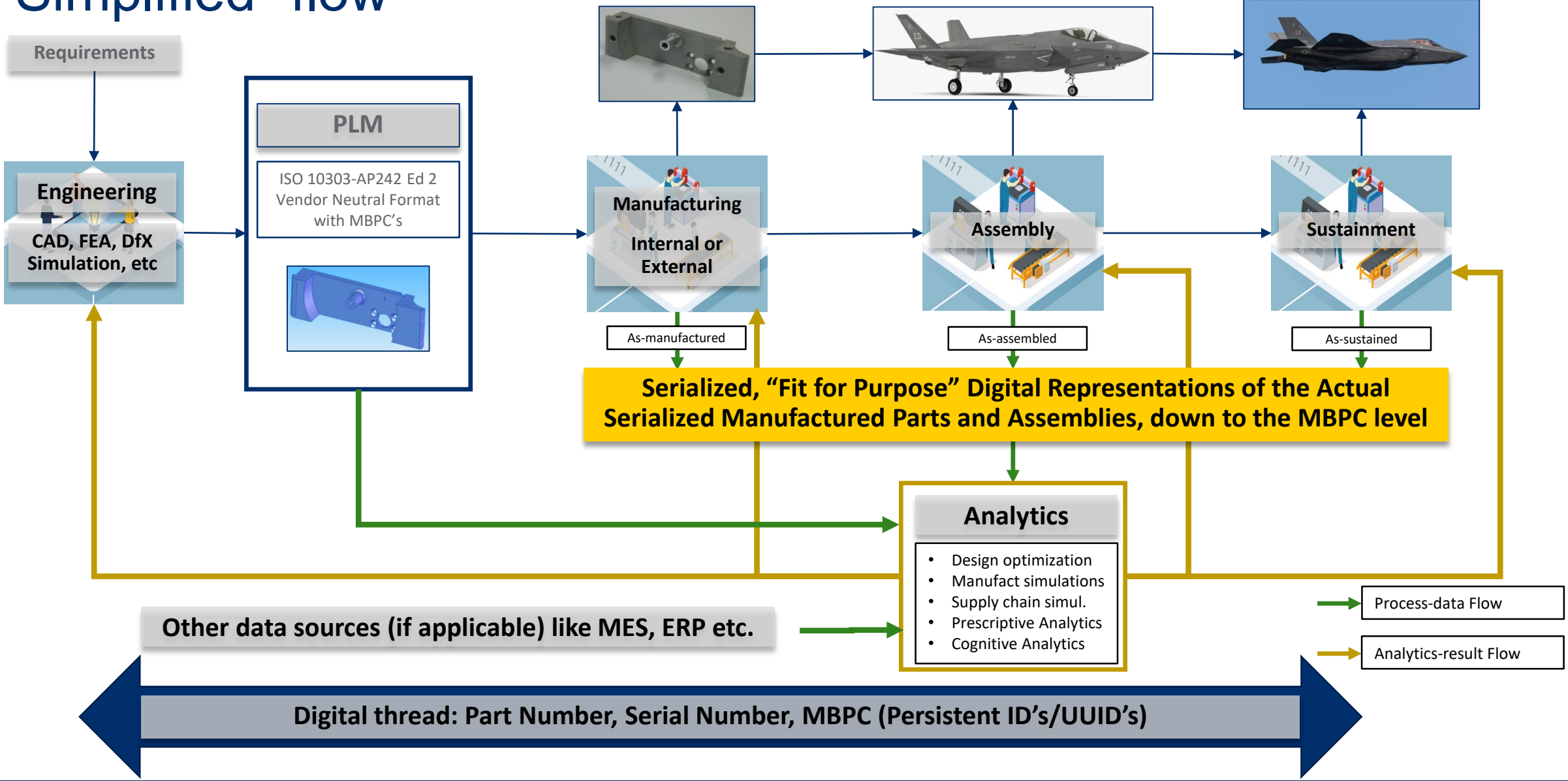
# Simplified “flow”



# Additional comments

- **Not having Serial Number and MBPC-level traceability does not mean you can't do useful analytics (same for ontologies and semantics)**
  - Limits the scope of the analytics. Having Serial Numbers and MBPC's will allow higher order of analytics (Prescriptive and Cognitive).
  - Takes much more effort on the part of the data analytics people to come up with insights ("data-janitors").
  - Insights will likely not lead to generalizations.
- **Standardized data artifacts will become required deliverables for suppliers (internal and external)**
  - Need to work out infrastructure for artifact delivery and quality control.
- **Standards are going to be critical**
  - (ISO 10303) STEP-AP242 Ed 2 (model data)
  - (ISO 10303) STEP-AP238 Ed 2 (process data)
  - (ISO 23952) QIF (inspection and test results data)
  - (ANSI) MTC1.4-2018 (MTConnect for process results data)
  - LOTAR (long term archival and retrieval)
  - IPC series of standards for electronics assembly (IPC2581/IPC 2591)
  - Ontological standards such as Industrial Ontology Foundry and Common Core Ontology, linked to Basic Formal Ontology
  - ASME Y14 set of standards

# Recap

## Manufacturing data needs to enable higher order analytics

- Need consistent digital thread for manufacturing data
  Part number, Serial number, Model Based Product Characteristics
- Data architectures based on strong ontological and semantic frameworks
- Successfully enable digital twin use cases
- Data artifacts will become required deliverables with physical parts
- Standards will become increasingly important

# Thank you for your attention!

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