Roadmap to Hyper-connected Manufacturing

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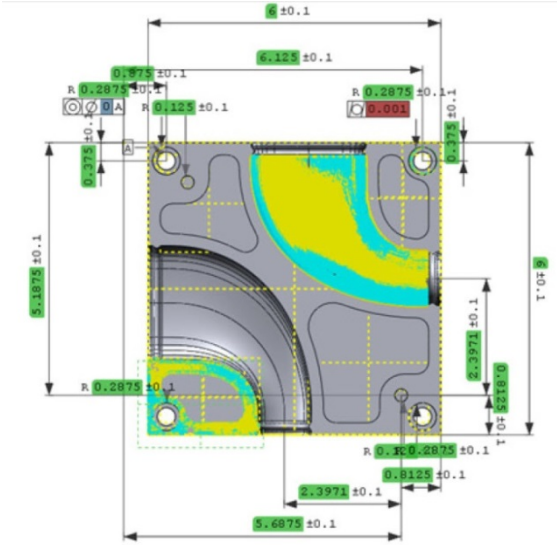
Introduction

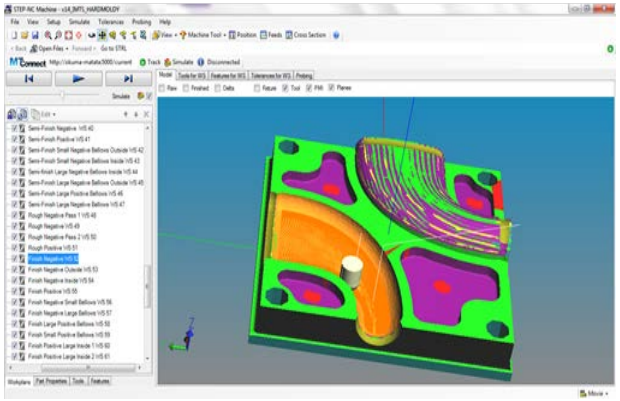
Hyper-connected manufacturing is
STEP + Digital Manufacturing + Smart Manufacturing

- Today manufacturing machines are controlled using codes
  - Detailed instructions unique to each machine
- This roadmap describes a path to intelligently connecting millions of machines using digital models
  - Models described by the STEP standard
  - Customized for processes by the STEP-NC standard
  - Linked using protocols as described in this map

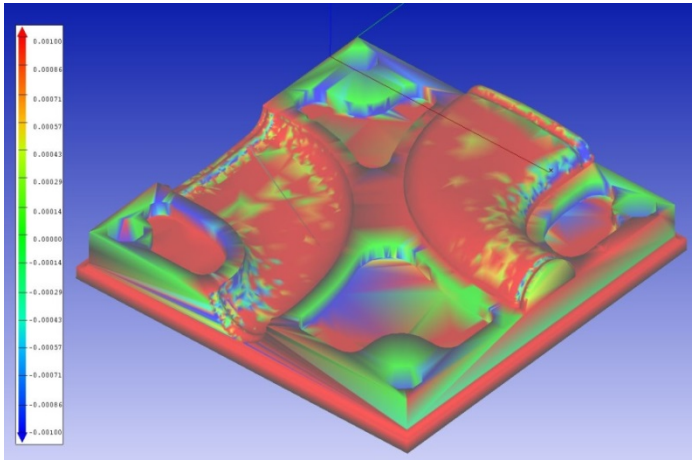
Transparent (visible and open) Machining and Measurement



Part with GD&T



On-machine mesh generation



Real time virtual metrology

Actual metrology

Roadmap

to hyper-connected manufacturing

2016 Smart Phone Visualization

2017 Automated Metrology

2018 CAM Exchange

2019 Model Based Integration

2020 Shared Spaces

Transparent Machining

1 => New software stack enables remote visualization of processes on smart phones and tablets

Transparent Inspected Machining

2 => Detailed simulation enables virtual measurement of process results using virtual CMM

Optimized Machining

3 => CAM data exchange enables optimization by third parties

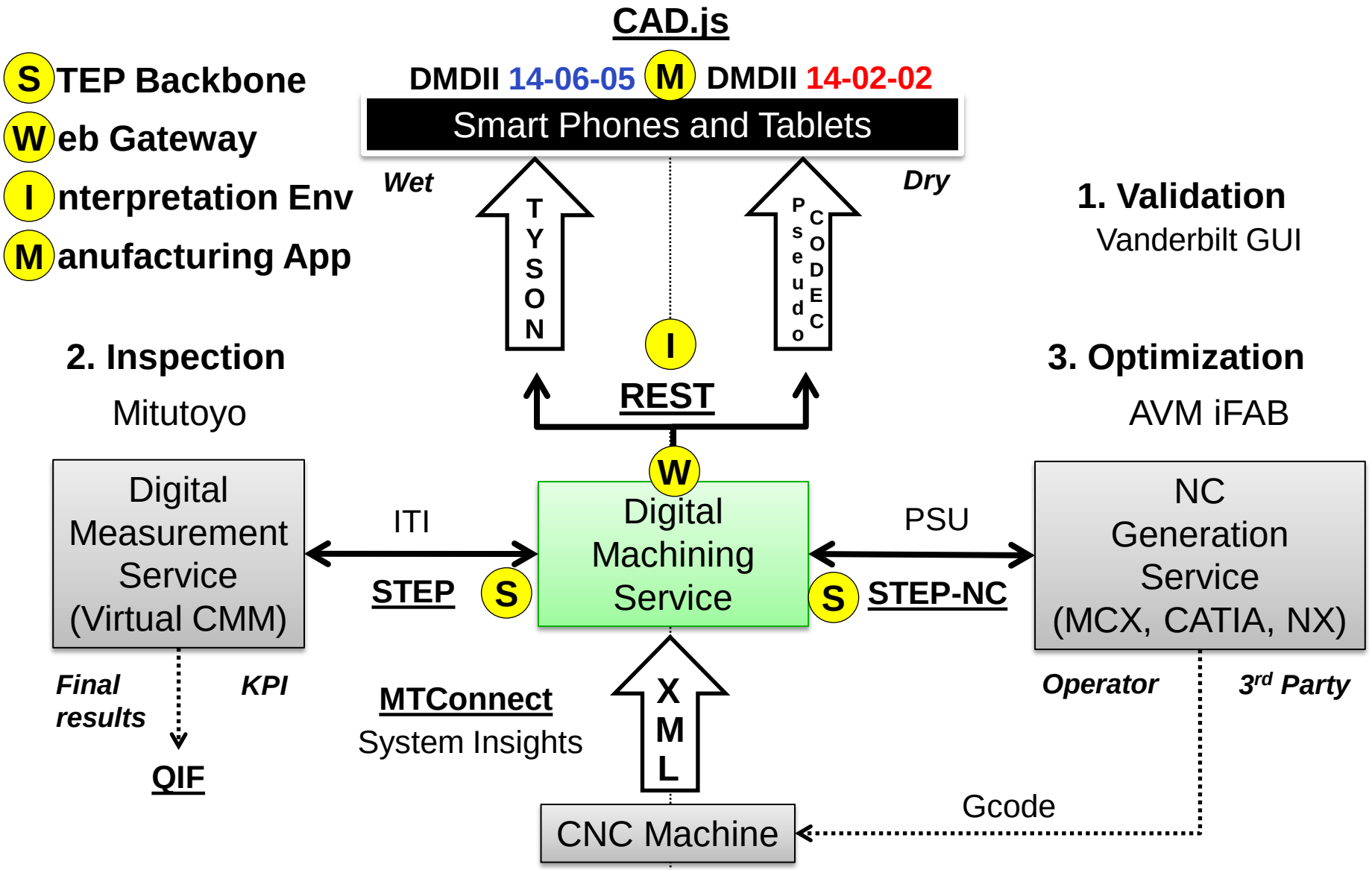
Closed Loop Machining

4 => Intelligent Apps on the CNC detect discrepancies and compensate

Connected Machining

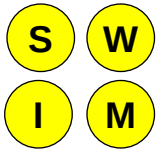
5 => Results integration for millions of machines

Phases 1 and 2 (in progress)



Phase 3 (in planning) Optimized Machining

- Goals
  - CAM to CAM data exchange
  - Read/Write web services
    - Tooling assembly
    - Workpiece fixture and placement
    - Machine tool kinematic definition
  - Real time stream management
    - Wet and Dry look-ahead
    - Integration of force and Sound
- Means
  - CAM data exchange
    - Boeing => CATIA
    - PSU => MCX
  - Read / Write apps
    - STEP Tools =>
    - Vanderbilt =>
    - Vendors (Sandvik, Iscar, Okuma, DMG, Makino, ..)
  - Streaming experiments
    - Machining with sound, etc.



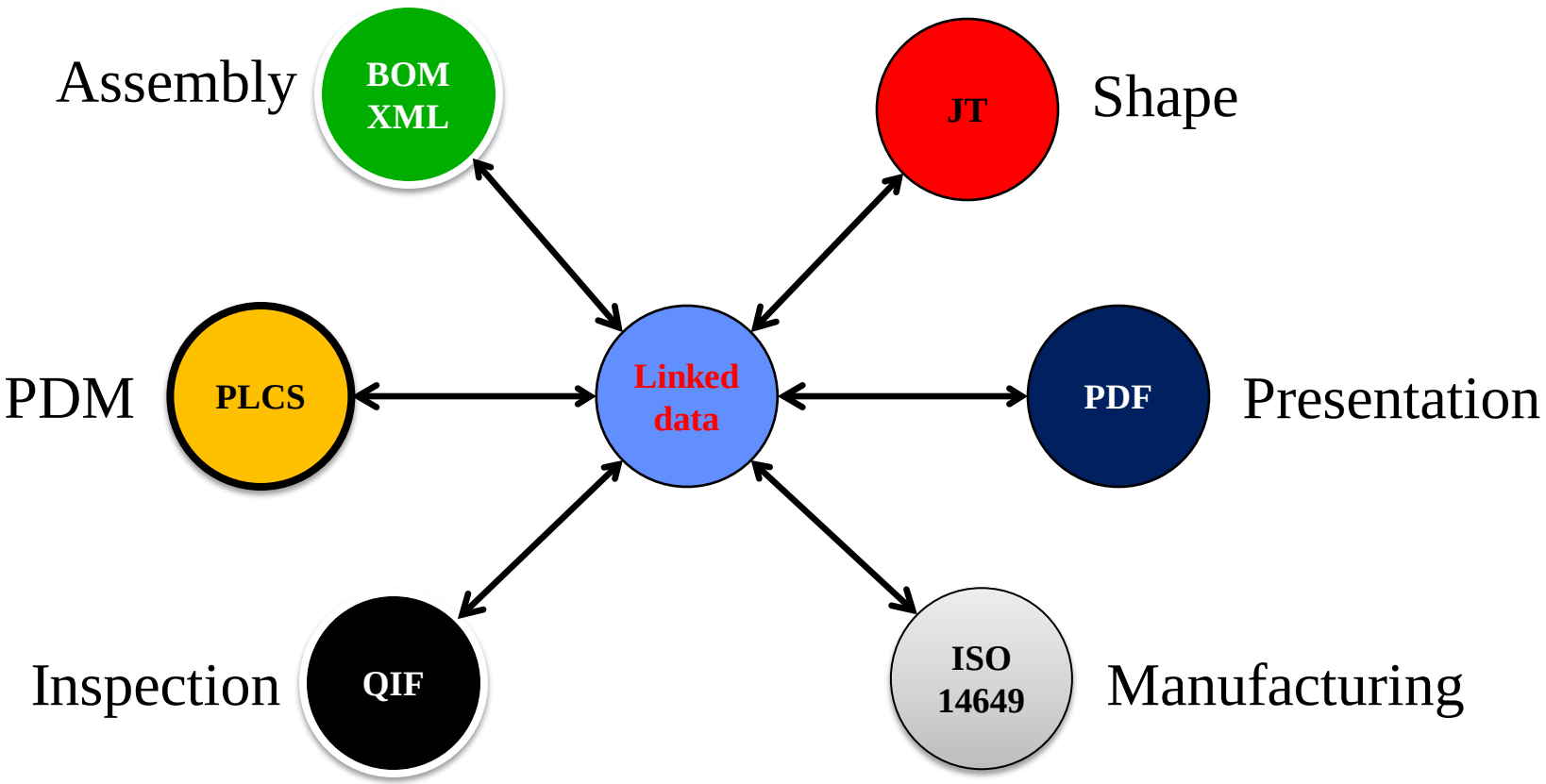
Path finding for Phase 4 Closed Loop Machining

- Research
  - Accuracy issues
    - Setup validation
    - MTConnect sampling rate
    - Tool bending
  - Measurement issues
    - Tolerance definition
    - Problem detection
    - Problem correction
- Standards development
  - Recommended Practices
    - Machine tool kinematics
    - 3D cutter assembly
    - 3D fixture assembly
  - AP238 Edition 2
    - Edition 1 modularization
    - Corrections from testing
    - AS9102 & APQP quality assurance
    - 4D geometry
    - Model optimization

SWIM documentation

- **S** STEP Backbone (Information Models)
  - EXPRESS definitions of STEP and STEP-NC
  - http://www.steptools.com/support/stdev_docs/stpman/html/index.html
- **W** Web Gateway (Protocols, Hyperlinks, UUIDs)
  - Example of gateway functionality
  - http://www.steptools.com/support/stepnc_docs/stepncdll/
- **I** Interpretation Environment (P21e3 supported schema definitions)
  - Distributed manufacturing objects in JSON, XML etc
  - http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=63141
- **M** Manufacturing App (open source)
  - Example App - machining process viewer
  - https://github.com/ghemingway/cad.js/tree/master

Alternate Approach - Linked data



Concluding remarks

- The SW system is like the router of hyper-connected manufacturing
  - New-build systems like STEP-NC Machine
  - Re-purposed systems like CAD/CAM's
  - Requirement is to implement the protocols starting with P21 e3
- First three gates
  - Summer 2016: First TIM system is operational
  - Fall 2016: Protocols for Read/Write SWIM published
  - Spring 2017: Funding for Phase 3 development and Phase 4 research
- Understood benefits
  - 15% better machining by enabling 3rd party optimization
  - Reduced scrappage due to real-time measurement
  - Deployment of less expensive, less rigid machines like robots
  - Faster to market because of direct machine to machine connection