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Characterizing Dimensional Form, Surface Texture and Feature Resolution in Additive Manufacturing

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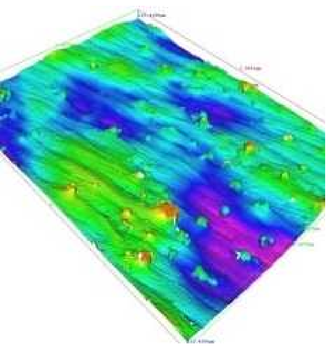

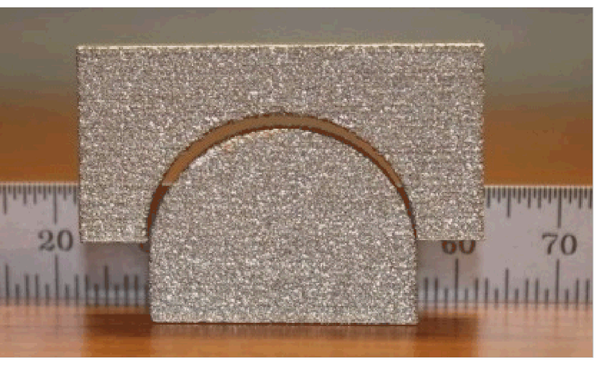

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New Challenges from Additive

- Motivated by design freedom
- Challenges for parts, processes & equipment
  - geometry depends on material, process, machine, orientation, supports, post-processing…
  - equipment accuracy generally exceeds process
- Metrology challenges
  - metrology may be "harder" than fabrication
  - complex geometries and/or internal features
  - inferior surface quality
  - form deviations included in uncertainty analyses
  - GD&T applies, but less "traditional" surfaces
  - now worried about material, not just geometry

Dimensional Metrology Work

- Scope
  - address dimensional accuracy, surface form error, surface texture, minimum feature resolution
- Artifact based characterization
  - seek simple parts w/simple measurements

Polyhedron

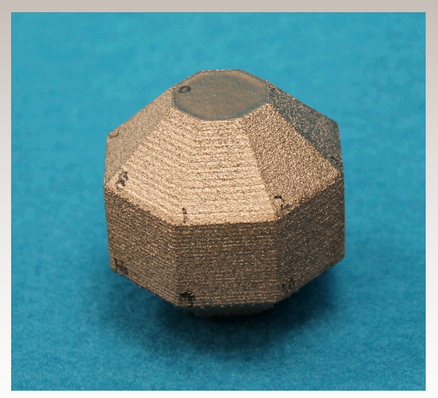
- Investigates form, texture, orientation, anisotropies
  - Polyhedron: 26-sides, 45° increments, 43 mm width
  - adjustable size, # of angles, internal structure
  - dimensional accuracy
    - plane intersections compared to nominal
    - vector deviation plot identifies global part shrinkage
  - form accuracy
    - polyhedron faces measured as planes
    - form degrades w/downward angle
    - compensation is desired, but non-trivial
  - surface texture
    - measure polyhedron faces
    - roughness degrade w/increasing down-facing angle
    - kurtosis, S_{ku} – rounded surfaces on top & sides
    - skewness, S_{sk} – more peaks on angled surfaces than top or sides
    - isotropy, S_{tr} – strong anisotropy (i.e. lay or structure) on all sides except top, suggestive of laser scanning

3D Siemens Sta

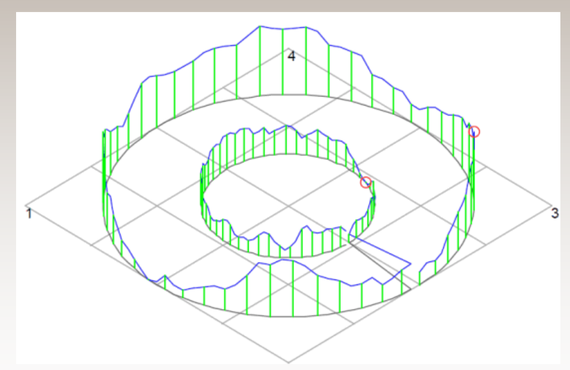
- Derived from 2D analog for optical systems & printers
  - exact STL representation, eliminating part representation biases
  - minimum feature size
  - calculating modulation transfer function (MTF) provides means for evaluation & comparing AM equipment, processes, materials and metrology limits

Acknowledgements

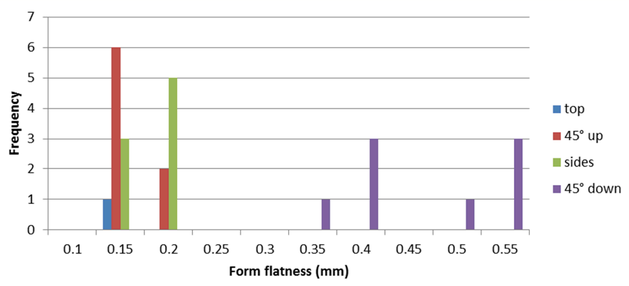
- SNL – Tyrell Lorenzo (Zeiss UPMC)
- KCNSC – Chris Boucher (EOS), Joe Dinardo (Aream)



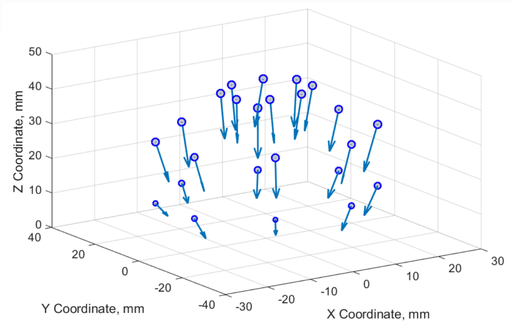
Ti6Al4V 26-sided polyhedron produced by electron beam melting



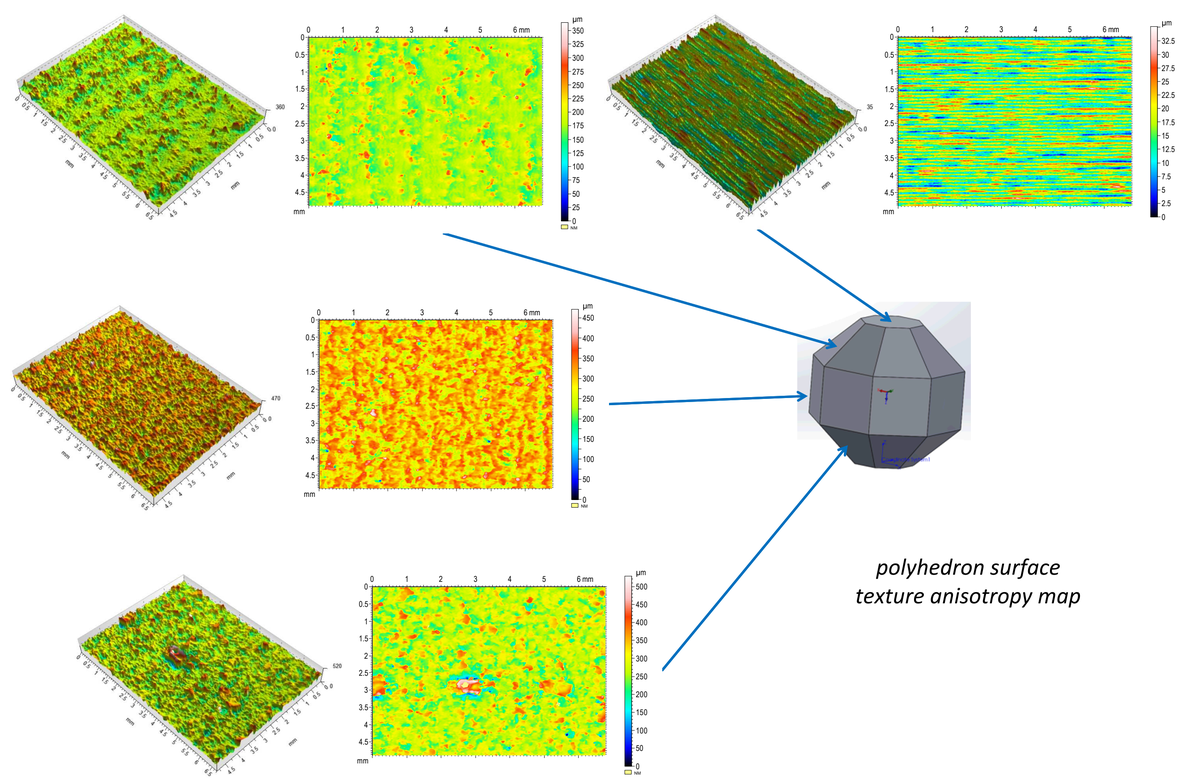
polyhedron top surface form error via CMM



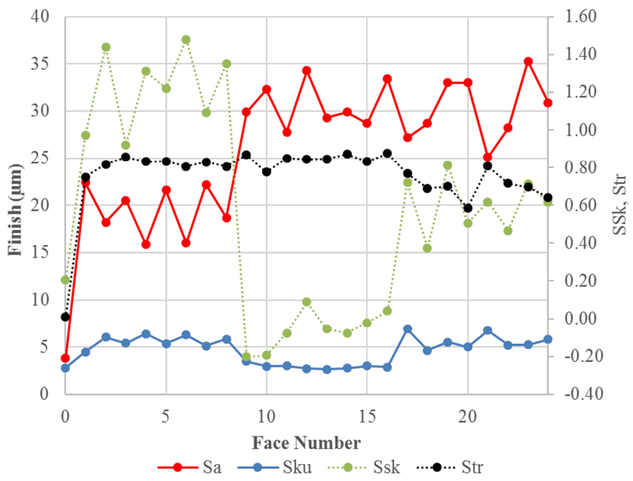
polyhedron form error distribution



polyhedron deviation vector plot



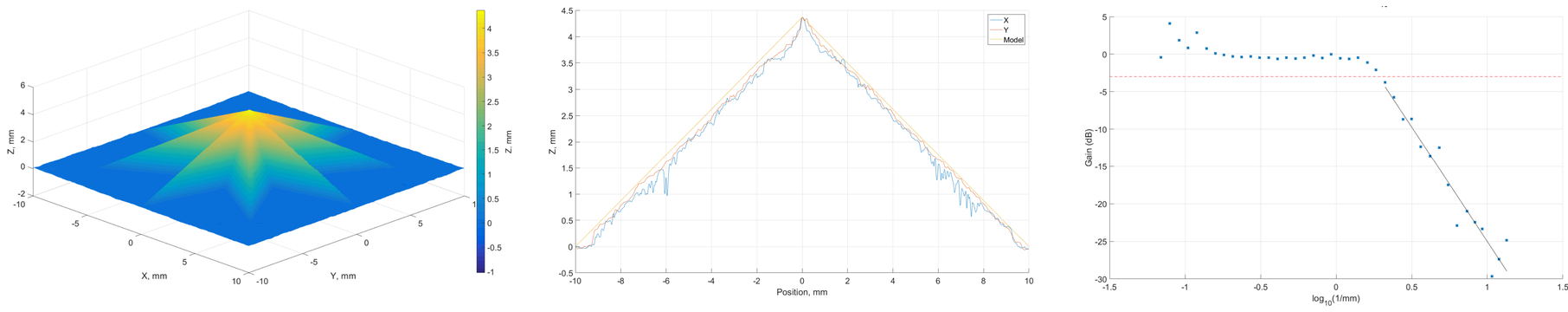
polyhedron surface texture anisotropy map



polyhedron surface finish trends

2D Siemens star, Wikipedia

PH17-4 Siemens star produced by laser powder bed fusion



17-4PH Siemens star form error (left), tip profile (middle) and modulation transfer function (right)

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