Engineering Laboratory

Proposed Standardized Test Artifact for Additive Manufacturing

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NIST
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NIST Projects in Additive Manufacturing

Powder

Process

Part

Purpose—Test Artifact

- Two primary methodologies of performance characterization of a machine or process
  - Series of direct measurements of machine or process characteristics
  - Measurement on manufactured test pieces
- Direct measurement of AM machines difficult
  - Lack of access and control over positioning axes
  - Sensors interfere with process or safety interlocks
- Test pieces play a larger role in AM than in traditional manufacturing

Potential Uses

- Can demonstrate capabilities and limitations of machine or process
- Can be used as point of comparison
  - Between machines or processes
  - Before and after implementation of improvements
- Can be used as method of performance verification between machine user and vendor

Suite of Standards

Fundamental AM Standards

- Terminology
- Certification
- Test Artifacts
- Test Methods for Raw Materials
- Test Methods for System Performance
- Data Formats
- Qualification
- Procurement Requirements for AM Parts
- etc.

Candidate Top-Level Standards

- General concepts
- Common requirements

Raw Materials

- Metal Powders—Part 1: Size, Part 2: Morphology, Part 3: viscosity, etc.
  - Spherical Powders
  - Disk-Shaped Powders
  - etc.
- Polymer Powders—Part 1, Part2, etc.
- Photopolymer Resin—Part 1, Part 2, etc.
- etc.

Process / Equipment

- Process-Specific Performance Test Methods
  - Process Category
- Process-Specific Test Artifacts
  - Process Category
- System Component Test Methods
  - System Components by Process Category
- etc.

Finished Parts

- Material Test Methods—Part 1: Tension Testing, Part 2: Porosity Testing, Part 3: Fracture Toughness, etc.
  - Metals
  - Polymers
  - Others
- Material Specifications—Part 1: Powder Bed Fusion, Part 2: Photopolymer Vat, Part 3: Binder Jetting, etc.
  - Specific Materials by Process Category
- etc.

Specialized AM Standards

- Specific to process or technology

Suite of Standards

- 1 top level Test Method, 7 process level standard practices (1 for each process category)
- Test Method generally describes
  - potential uses of test artifact
  - test artifact geometry
  - measurements to be taken on the test artifact
  - reporting of results
- Standard Practices provide
  - links to download specific test artifact geometries (different processes may use different size scales)
  - guidance in preparing a build (not a process prescription)
  - specific process parameters to be reported.

Prior Work

- Reviewed more than 40 test artifacts previously described in literature.
- Four categories of test artifacts
  - Comparing different processes
  - Evaluating individual processes
  - Evaluating metal-based processes
  - Other uses
- NISTIR 7858, “A Review of Test Artifacts for Additive Manufacturing,” May 2012.

Prior Work → Design Criteria

- The intent of most test artifacts falls into one of two main categories
  - Intended to demonstrate the capabilities of the machine or process
  - Intended to highlight specific machine defects to allow iterative process improvement
- We seek to design a test artifact that will accomplish both.

Design Criteria

- Test part should demonstrate machine's or process's ability to build features with proper form, orientation, size and location
  - Straight features (paraxial and askew)
  - Parallel and perpendicular features
  - Round features
  - Concentric circles or arcs
  - Fine features
- Holes and bosses
- Features in planes orthogonal to build plane

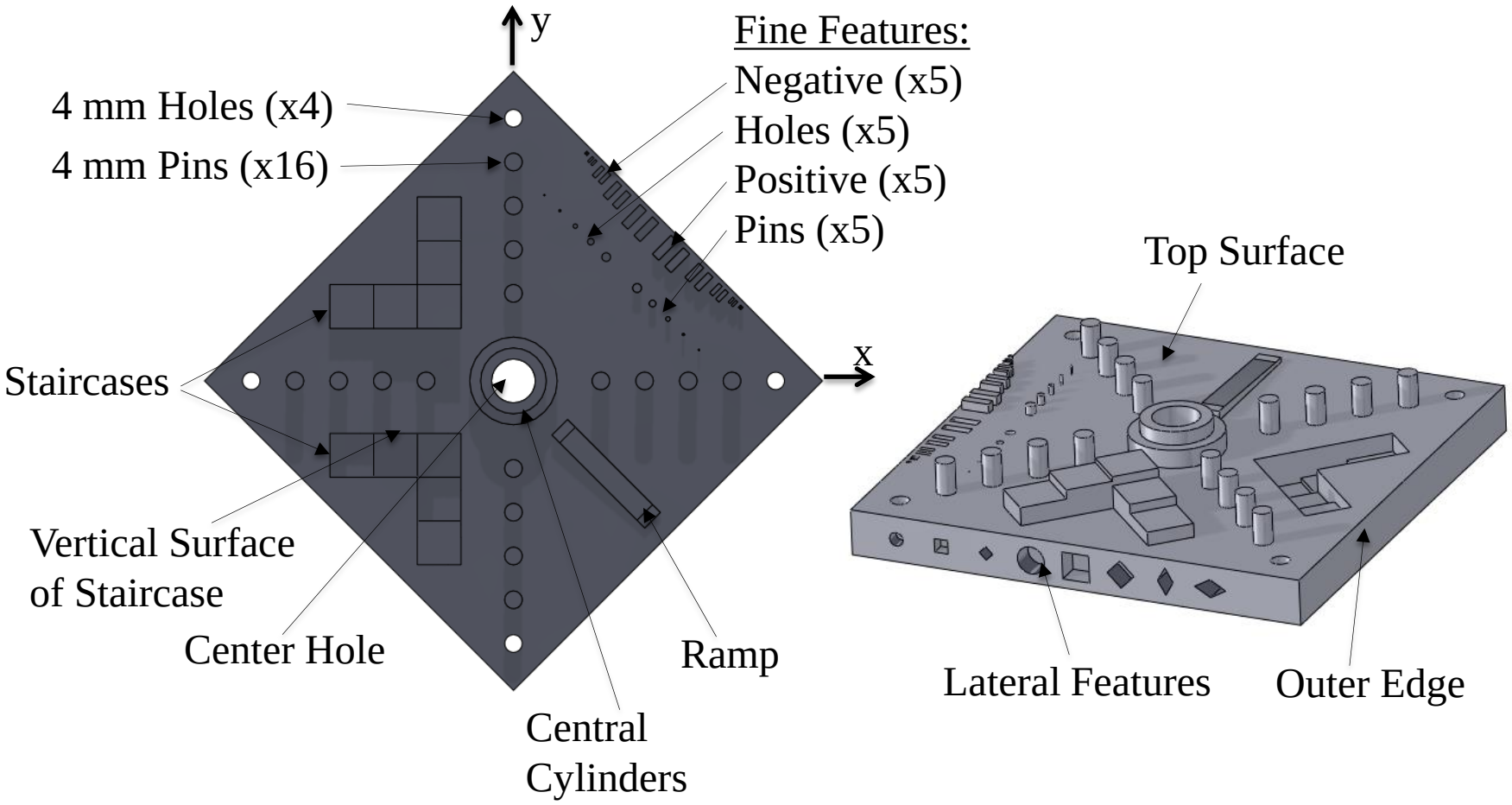
Design Criteria

- Design should link specific part defects to specific machine or process errors
  - Geometric errors of beam positioning axes
  - Geometric errors of build platform (z-axis)
  - Alignment errors between axes
  - Beam size

Design Criteria

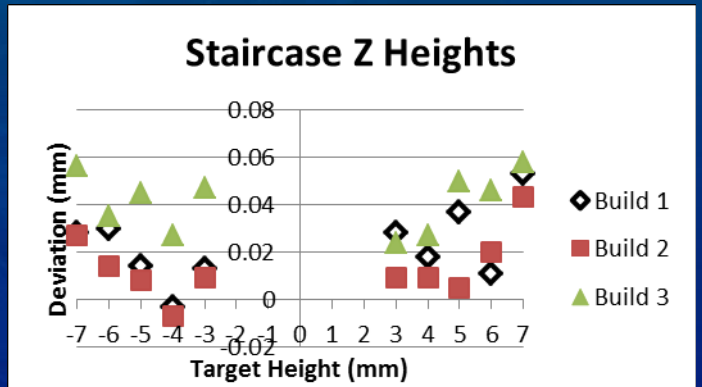
- General Considerations
  - Easily measurable with low measurement uncertainty
  - Trade off between testing full work volume and the time and material cost. We try to find balance, but side with faster, smaller builds
  - Minimize other variables
    - Support structures
    - Post processing
  - Minimize impact on recoating arm
  - Allow testing of surface roughness along with mechanical and physical properties

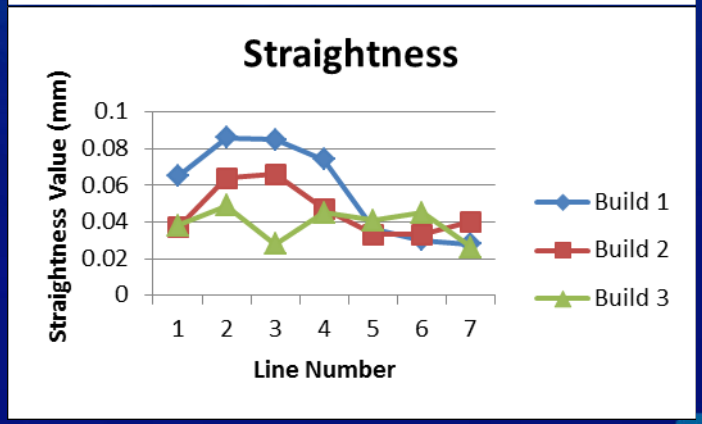
Description of Proposed Artifact



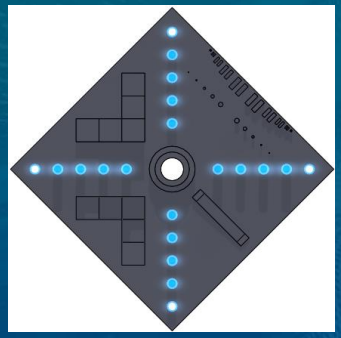
Results—Repeatability

- Multiple builds by DMLS in stainless steel show average repeatability of approximately 30 μm (2x average standard deviation using several feature measurements)
  - Pin and hole diameters
  - Pin and hole positions
  - Z-heights on staircases
  - Straightness measurements
  - Roundness measurements
  - Flatness measurements

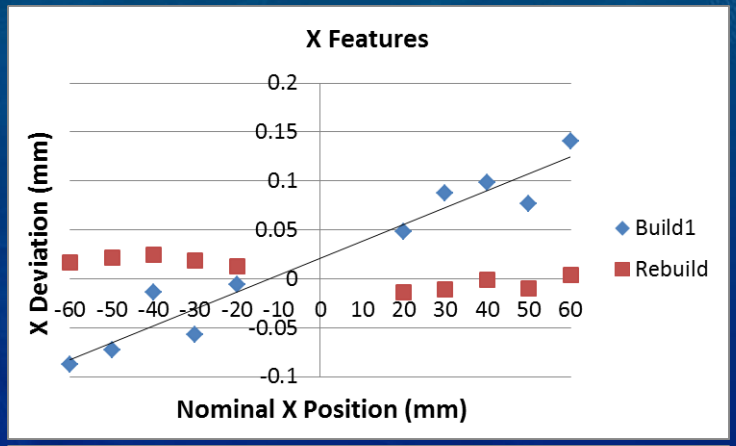


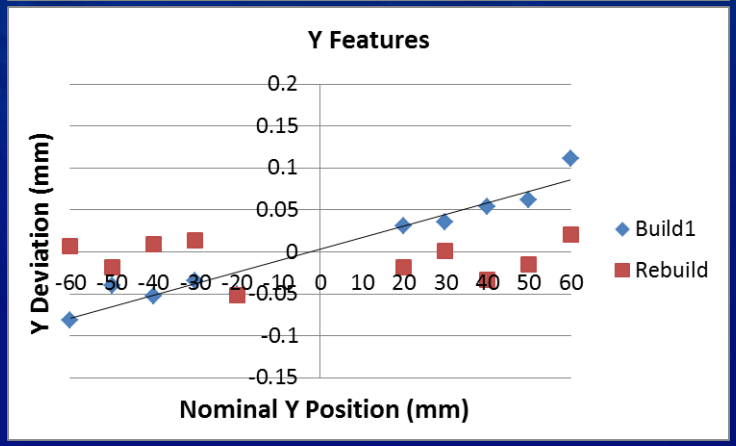


Process Improvement

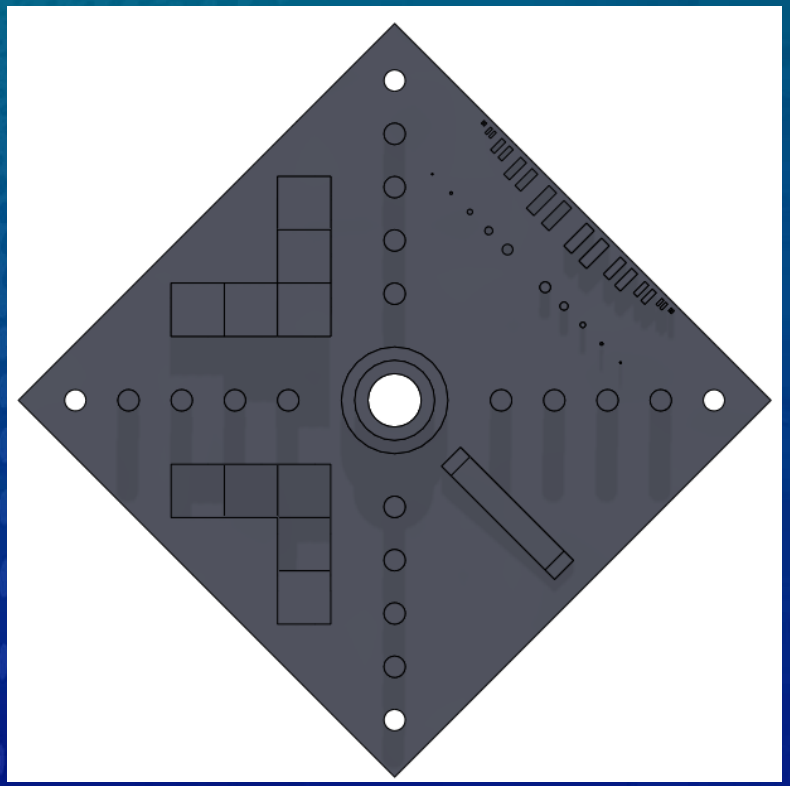


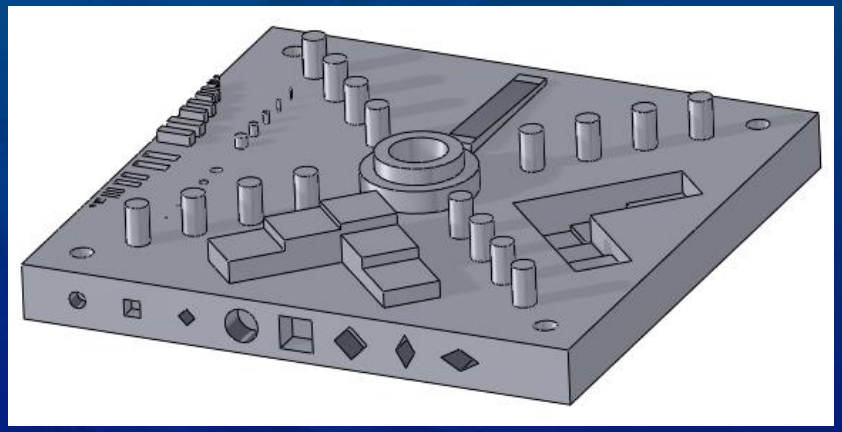
- Use measured deviations of build 1 to calculate improved beam offset and x- and y-scaling
  - Pins and holes were too close to center; scaling was too small
  - Scaling = slope of best fit line to position deviation of pins and holes (represented as %)
  - Rebuild with adjusted scaling produced pins and holes with position deviations no greater than 52 µm (8 of 10 better than 25 µm)





Questions???





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