



Data Article

Uncertainty quantification in dimensions dataset of additive manufactured NIST standard test artifact



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ABSTRACT

The printed features on an additive manufactured part will often deviate from the nominal values of the 3D model's features due to the factors such as printer resolution, printing parameters, printing technology, and the measurement method. The National Institute of Standards and Technology (NIST) standard test artifact contains a collection of various features that can be used to characterize a 3D printer's performance and has been used to benchmark metal printers. There is limited documentation on how well different additive manufacturing processes can fabricate the NIST artifact. This dataset records the dimensional uncertainty of selective printed features of the NIST artifact manufactured with polymer and resin printing processes. It contains the post-processing dimensional measurements of geometric features on the printed test artifacts. In order to generate the data, a total of 16 samples of the test artifact were printed with fused deposition modelling (FDM) and stereolithography (SLA) additive manufacturing methods. The percentage error between the measurement of features in the printed samples and their nominal computer aided design (CAD) values are calculated. For future reusability of this data, the same NIST test artifact CAD model can be printed, and the

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features' measurements can be compared with the dataset presented in this article.

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Specifications Table

Subject	Mechanical Engineering
Specific subject area	Additive Manufacturing
Type of data	Table Figure Equation
How data were acquired	SolidWorks 2020 Ultimaker Cura Ultimaker 3 Anycubic Mega X Stratasys Dimension Elite GrabCAD Print Stratasys Mojo Vernier calipers
Data format	Raw Analyzed
Parameters for data collection	The geometric dimensions of the printed National Institute of Standards and Technology (NIST) test artifacts were considered for data collection. Geometric tolerance conditions like surface flatness, roundness, and concentricity were not considered for analysis in the data collection.
Description of data collection	The NIST test artifact was first independently modelled by each participant based upon the standard's specifications, and then models were printed on various FDM and SLA printers that used polymer and resin materials. A vernier caliper is used to measure the dimensions of the printed features and listed in a table format.
Data source location	Institution: New York University Tandon School of Engineering City/Town/Region: Brooklyn, NY Country: USA Latitude and longitude (and GPS coordinates, if possible) for collected samples/data: 40.69429305994625, -73.98657900223606
Data accessibility	With the article

Value of the Data

- This dataset helps to quantify discrepancies between the engineering specifications for an additively manufactured part compared to the final production model.
- Researchers and engineers who are working in the additive manufacturing/3D printing industry.
- The same standard test artifact specimen can be printed on other 3D printers and the collected data can be used to highlight the dimensional accuracy of different machines. Three possible experiments, among others: (1) quantify the linear displacement errors of 3D printers, (2) compare a given print performance with a known dataset, and (3) measure implementation errors introduced throughout the manufacturing process.

1. Data Description

The tables listed in this section show the feature measurements taken from the 3D printed samples. The figures in this section show the feature and dimension from the computer aided

design (CAD) model of the National Institute of Standards and Technology (NIST) additive manufacturing standardized test artifact. A total of 16 specimen models (CAD files) were designed from the same specifications as the reference model, and then each was printed and measured independently. Each row of the tables lists the measurement of each samples' features. The percent error between the measured dimensions of the printed samples are calculated using Eq. (1), and the reference NIST model are determined and listed in each table. The average and standard deviation of the physical measurements of each sample are also calculated and listed in the table. The unmodified raw data is available as a supplementary file of this article.

$$\left| \frac{\text{Measured Dimension} - \text{CAD Dimension}}{\text{CAD Dimension}} \right| \times 100\% \quad (1)$$

Table 1 shows the measurement of the length of the outer edge of the printed specimen and the percent of error from the dimension of the NIST specification. Fig. 1 shows the dimension of the length of the outer edge of the reference NIST CAD model. The reference length of the outer edge is 100 mm, and the average measured value of the length is 99.77 mm from the collection of 16 printed samples.

Table 1

Measured dimension of outer edge.

	Distance from side H to opposite side [mm]	Error [%]
Sample 1	99.39	0.61
Sample 2	99.83	0.17
Sample 3	100.02	0.02
Sample 4	99.56	0.44
Sample 5	99.72	0.28
Sample 6	99.94	0.06
Sample 7	99.7	0.3
Sample 8	99.74	0.26
Sample 9	99.4	0.6
Sample 10	99.71	0.29
Sample 11	99.5	0.5
Sample 12	99.4	0.6
Sample 13	99.7	0.3
Sample 14	100.24	0.24
Sample 15	99.94	0.06
Sample 16	100.5	0.5
Avg	99.77	
SD	0.31	

Tables 2 and 3 shows the measurement of the lateral features of the printed specimens. The lateral features such as the circular hole and square were printed on the sides of the specimen. The lateral features and dimensions of the reference NIST CAD model are shown in Fig. 2. The NIST model has two lateral circular features of diameter 3 mm and 6 mm. The measurements of these two circular holes are shown in Table 2. The smaller circular hole feature had an average measurement of 2.93 mm and the larger circular hole had an average measurement of 5.81 mm.

There are also two lateral square cutouts in the referenced NIST model, with widths of 3 mm and 6 mm. The measurements of the width and height of these square features are shown in Table 3. The average measurements of the width and height from the printed samples were 2.93 mm and 2.98 mm, respectively, with the nominal value 3 mm from the reference model. The average measurements of the larger square were 5.94 mm and 5.88 mm for the width and height, respectively. In Table 3, no measurements are shown for Sample 2 because the square feature failed to print correctly and therefore, its measurements are omitted.

The NIST standard specifies two staircase features on planar surface A as shown by the reference model in Fig. 3. Each step on this staircase feature has a different height measured with respect to surface A. In Fig. 3, the staircase feature shown on the left is created with cut features

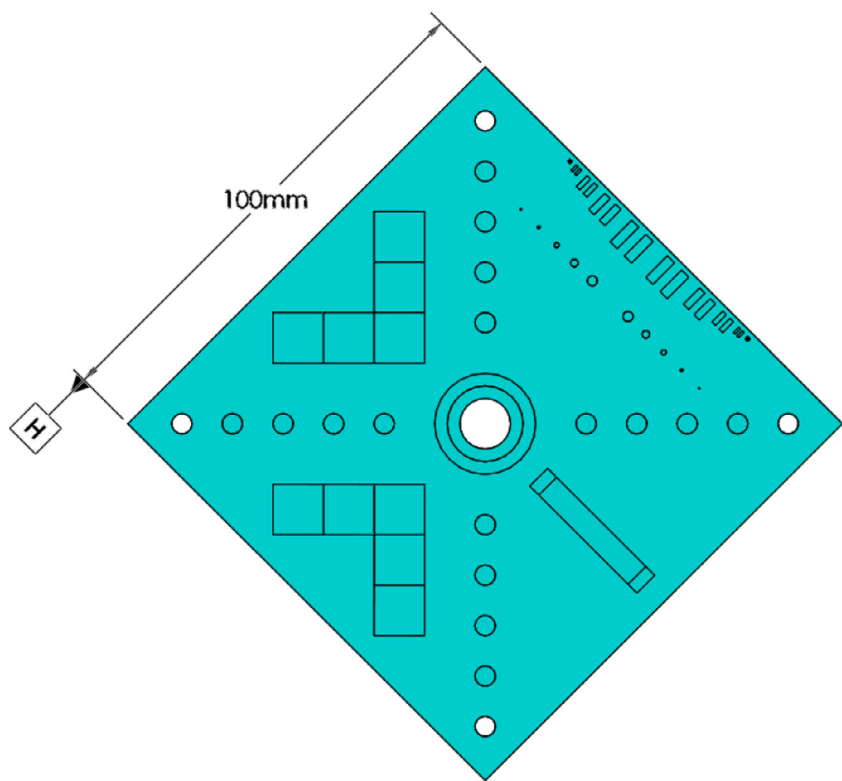


Fig. 1. Actual dimension of outer edge from H to the opposite side.

Table 2
Measured dimensions of the two holes of the lateral features.

	Hole1 Diameter [mm]	Error [%]	Hole2 Diameter [mm]	Error [%]
Sample 1	3.05	1.67	5.94	1
Sample 2	4	33.33	5.79	3.5
Sample 3	2.93	2.33	5.87	2.17
Sample 4	2.34	22	5.532	7.8
Sample 5	2.73	9	5.47	8.83
Sample 6	2.82	6	5.91	1.5
Sample 7	2.78	7.33	5.69	5.17
Sample 8	2.87	4.33	5.73	4.5
Sample 9	3	0	6	0
Sample 10	3.02	0.67	5.83	2.83
Sample 11	2.5	16.67	5.5	8.33
Sample 12	2.8	6.67	5.8	3.33
Sample 13	3	0	6	0
Sample 14	2.98	0.67	5.92	1.33
Sample 15	2.95	1.67	5.84	2.67
Sample 16	3.06	2	6.06	1
Avg	2.93		5.81	
SD	0.35		0.18	

Table 3

Measured dimensions of the squares of the lateral features.

	Square1 Width [mm]	Error [%]	Square2 Width [mm]	Error [%]	Square1 Height [mm]	Error [%]	Square2 Height [mm]	Error [%]
Sample 1	3.24	8	6.03	0.5	2.86	4.67	5.64	6
Sample 2	-	-	-	-	-	-	-	-
Sample 3	3.05	1.67	5.97	0.5	3	0	5.96	0.67
Sample 4	2.562	14.6	5.61	6.5	2.728	9.07	5.582	6.97
Sample 5	2.81	6.33	5.85	2.5	2.74	8.67	5.65	5.83
Sample 6	3.12	4	6.08	1.33	2.79	7	5.77	3.83
Sample 7	2.75	8.33	6.44	7.33	3.6	20	6.87	14.5
Sample 8	2.95	1.67	5.76	4	2.91	3	5.78	3.67
Sample 9	2.66	11.33	5.6	6.67	3	0	6	0
Sample 10	3.02	0.67	5.86	2.33	3.01	0.33	5.68	5.33
Sample 11	3	0	6	0	3	0	6	0
Sample 12	2.6	13.33	5.7	5	2.7	10	5.5	8.33
Sample 13	3.1	3.33	6	0	3.1	3.33	6	0
Sample 14	3.07	2.33	6.03	0.5	3.06	2	6.23	3.83
Sample 15	2.91	3	6.01	0.17	3.01	0.33	5.59	6.83
Sample 16	3.15	5	6.18	3	3.18	6	5.96	0.67
Avg	2.93		5.94		2.98		5.88	
SD	0.21		0.22		0.22		0.34	

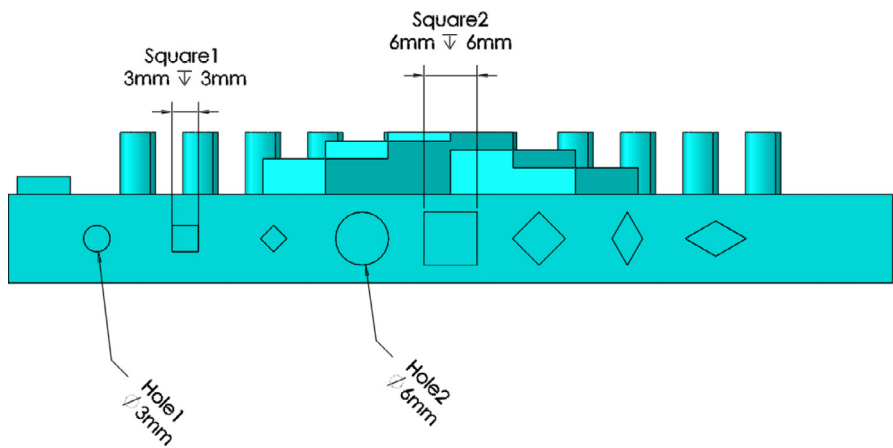


Fig. 2. Actual dimensions of the two holes and squares of the lateral features.

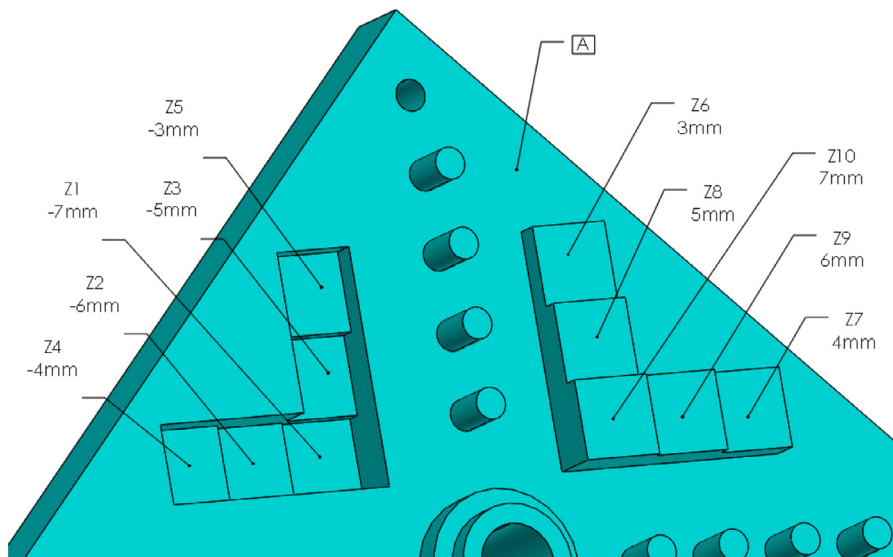


Fig. 3. Actual dimensions of staircase heights with respect to planar surface A.

and the staircase feature on the right is created with extruded platforms. The positive direction of datum A is taken to be in the direction of the extruded platforms and the negative direction would be in the direction of the cut staircase features.

Table 4 lists all the measured heights of each step from the cut staircase feature. The values are negative because each step is below surface A. The average values and the percent error from the nominal heights' dimensions are shown in Table 4. For example, the deepest step has a nominal value of -7 mm and the measured average value is -6.96 mm from all the printed samples. Similarly, Table 5 shows all the measured values of each step of the extruded staircase feature.

Table 4

Measured dimensions of the staircase heights in the negative direction with respect to datum A.

	Z1 Position [mm]	Error [%]	Z2 Position [mm]	Error [%]	Z3 Position [mm]	Error [%]	Z4 Position [mm]	Error [%]	Z5 Position [mm]	Error [%]
Sample 1	−6.99	0.14	−5.96	0.67	−4.85	3	−4.04	1	−2.74	8.67
Sample 2	−7	0	−6.08	1.33	−5.08	1.6	−4.08	2	−3.09	3
Sample 3	−6.64	5.14	−6.09	1.5	−5.21	4.2	−4.98	24.5	−3.02	0.67
Sample 4	−6.884	1.66	−6.131	2.18	−4.971	0.58	−3.892	2.7	−2.96	1.33
Sample 5	−6.83	2.43	−6.08	1.33	−4.93	1.4	−4.09	2.25	−3.11	3.67
Sample 6	−7.05	0.71	−5.97	0.5	−4.98	0.4	−3.89	2.75	−2.92	2.67
Sample 7	−7.09	1.29	−5.98	0.33	−5.08	1.6	−4.03	0.75	−3.06	2
Sample 8	−7.01	0.14	−6	0	−4.99	0.2	−4	0	−2.99	0.33
Sample 9	−7	0	−6	0	−4.8	4	−4	0	−2.8	6.67
Sample 10	−6.94	0.86	−5.83	2.83	−4.77	4.6	−3.91	2.25	−2.82	6
Sample 11	−7	0	−6	0	−5	0	−4	0	−3	0
Sample 12	−7	0	−6.1	1.67	−5.2	4	−4.06	1.5	−3	0
Sample 13	−7.1	1.43	−6	0	−5	0	−3.95	1.25	−2.9	3.33
Sample 14	−6.93	1	−6.12	2	−5.05	1	−3.97	0.75	−3.07	2.33
Sample 15	−7.06	0.86	−6.01	0.17	−5	0	−4.03	0.75	−3.02	0.67
Sample 16	−6.77	3.29	−5.72	4.67	−4.79	4.2	−3.82	4.5	−3.18	6
Avg	−6.96		−6		−4.98		−4.05		−2.98	
SD	0.12		0.11		0.13		0.26		0.12	

Table 5
Measured dimensions of the staircase heights in the positive direction with respect to datum A.

	Z6 Position [mm]	Error [%]	Z7 Position [mm]	Error [%]	Z8 Position [mm]	Error [%]	Z9 Position [mm]	Error [%]	Z10 Position [mm]	Error [%]
Sample 1	2.98	0.67	3.96	1	4.86	2.8	5.89	1.83	6.99	0.14
Sample 2	3	0	4	0	5	0	6	0	7	0
Sample 3	2.99	0.33	3.99	0.25	4.96	0.8	6.07	1.17	6.98	0.29
Sample 4	2.692	10.27	3.855	3.63	5.684	13.68	5.697	5.05	6.615	5.5
Sample 5	3.06	2	4.12	3	5.02	0.4	6.48	8	7.34	4.86
Sample 6	3.04	1.33	4.04	1	5.07	1.4	6.11	1.83	7.29	4.14
Sample 7	2.54	15.33	3.45	13.75	4.24	15.2	5.16	14	6.05	13.57
Sample 8	3.01	0.33	3.97	0.75	4.98	0.4	6.04	0.67	6.97	0.43
Sample 9	3	0	4	0	5	0	5.8	3.33	6.6	5.71
Sample 10	3.04	1.33	3.9	2.5	4.84	3.2	5.81	3.17	6.71	4.14
Sample 11	3	0	4	0	5	0	6	0	7	0
Sample 12	2.9	3.33	4.1	2.5	5	0	6.1	1.67	7.1	1.43
Sample 13	3	0	4	0	5.1	2	6.1	1.67	7.1	1.43
Sample 14	3.05	1.67	4.18	4.5	5.04	0.8	6.05	0.83	7.24	3.43
Sample 15	3.02	0.67	4.05	1.25	5.03	0.6	6.02	0.33	7	0
Sample 16	3.27	9	4.09	2.25	5.21	4.2	5.9	1.67	7.1	1.43
Avg	2.97		3.98		5		5.95		6.94	
SD	0.16		0.16		0.28		0.27		0.32	

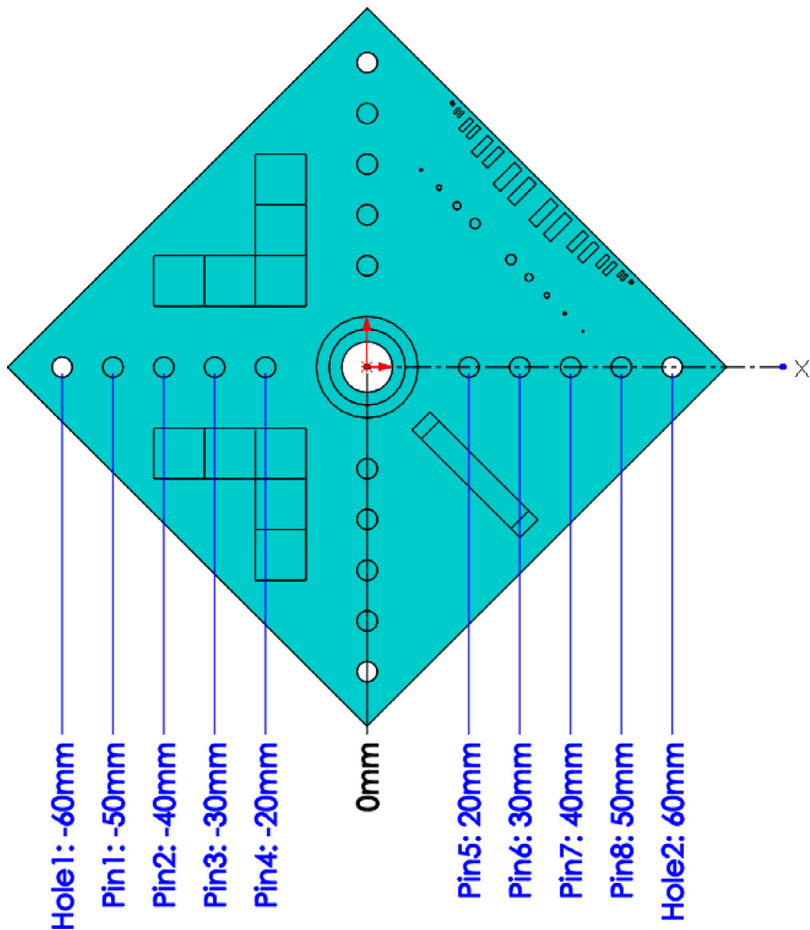


Fig. 4. Actual dimension of location of pins and holes along x-axis with respect to the origin.

Fig. 4 shows the top view of the NIST reference model with the holes and pins features on the horizontal axis. The origin is located at the center of the model and the horizontal x-axis locations are shown for each feature with respect to the origin. The location dimensions are from the center of each feature to the origin. Table 6 shows all the measurements of the features that lie to the left of the origin in the printed part. The average and standard deviation of all 16 measurements from each sample is calculated. The percent of error from the measured location value to the nominal value from the reference model is also calculated. Similarly, Table 7 shows the measurements and calculations for the pin and hole features that are located to the right of the origin. The measurements of Sample 10 are omitted due to the lack of instrument needed to accurately measure the locations of the pin and hole features.

Fig. 5 shows the top view of the NIST reference model with the holes and pins features on the vertical axis. The origin is located at the center of the model and the vertical y-axis locations are shown for each feature with respect to the origin. The location dimensions are from the center of each feature to the origin. Table 8 shows all the measurements of the

Table 6
Measured center position of pins and hole in the negative x-axis with respect to the origin.

	Hole1 X Position [mm]	Error [%]	Pin1 X Position [mm]	Error [%]	Pin2 X Position [mm]	Error [%]	Pin3 X Position [mm]	Error [%]	Pin4 X Position [mm]	Error [%]
Sample 1	−58.2	3	−50.2	0.4	−40.1	0.25	−29.9	0.33	−19.3	3.5
Sample 2	−60	0	−50	0	−40	0	−30	0	−20	0
Sample 3	−60	0	−50	0	−40	0	−30	0	−20	0
Sample 4	−61.12	1.87	−50.91	1.82	−40.576	1.44	−30.221	0.74	−20.002	0.01
Sample 5	−60.99	1.65	−50.55	1.1	−39.09	2.27	−29.28	2.4	−19.7	1.5
Sample 6	−59.87	0.22	−50.03	0.06	−40.02	0.05	−30.07	0.23	−20.07	0.35
Sample 7	−60.09	0.15	−49.13	1.74	−39.6	1	−29.05	3.17	−20.1	0.5
Sample 8	−60.3	0.5	−50.24	0.48	−40.54	1.35	−30.52	1.73	−20.15	0.75
Sample 9	−60	0	−50	0	−40	0	−30.5	1.67	−22	10
Sample 10	-	-	-	-	-	-	-	-	-	-
Sample 11	−60	0	−50	0	−40	0	−30	0	−20	0
Sample 12	−60.85	1.42	−49.9	0.2	−39.9	0.25	−29.9	0.33	−19.9	0.5
Sample 13	−60.1	0.17	−50.2	0.4	−40.3	0.75	−30.5	1.67	−20.4	2
Sample 14	−60	0	−49.83	0.34	−40.48	1.2	−29.68	1.07	−20.28	1.4
Sample 15	−59.94	0.1	−49.94	0.12	−40.03	0.08	−30.08	0.27	−20.02	0.1
Sample 16	−60.11	0.18	−49.76	0.48	−39.41	1.48	−29.92	0.27	−20.01	0.05
Avg	−60.1		−50.05		−40		−29.97		−20.13	
SD	0.66		0.39		0.41		0.41		0.57	

Table 7

Measured center position of pins and hole in the positive x-axis with respect to the origin.

	Pin5 X Position		Pin6 X Position		Pin7 X Position		Pin8 X Position		Hole2 X Position	
	[mm]	Error [%]	[mm]	Error [%]	[mm]	Error [%]	[mm]	Error [%]	[mm]	Error [%]
Sample 1	19.9	0.5	29.7	1	39.4	1.5	49.2	1.6	58.6	2.33
Sample 2	20	0	30	0	40	0	50	0	60	0
Sample 3	20	0	30	0	40	0	50	0	60	0
Sample 4	20.105	0.53	30.377	1.26	40.61	1.53	51.004	2.01	61.036	1.73
Sample 5	20.23	1.15	29.96	0.13	39.69	0.78	49.49	1.02	59.14	1.43
Sample 6	20.02	0.1	30.04	0.13	40.08	0.2	50.02	0.04	59.94	0.1
Sample 7	19.56	2.2	29.92	0.27	39.23	1.93	49.6	0.8	59.69	0.52
Sample 8	20.14	0.7	30.18	0.6	40.19	0.47	50.32	0.64	60.11	0.18
Sample 9	20	0	31	3.33	40	0	50.5	1	60	0
Sample 10	-	-	-	-	-	-	-	-	-	-
Sample 11	20	0	30	0	40	0	50	0	60	0
Sample 12	19.9	0.5	29.9	0.33	39.9	0.25	49.9	0.2	60.85	1.42
Sample 13	20.7	3.5	30.2	0.67	40.1	0.25	50.2	0.4	60.2	0.33
Sample 14	19.59	2.05	29.49	1.7	39.92	0.2	49.55	0.9	59.54	0.77
Sample 15	19.91	0.45	29.89	0.37	40	0	50.1	0.2	59.94	0.1
Sample 16	20.2	1	30.08	0.27	40.38	0.95	49.77	0.46	60.07	0.12
Avg	20.02		30.05		39.97		49.98		59.94	
SD	0.27		0.33		0.34		0.44		0.59	

Table 8
Measured center position of pins and hole in the negative y-axis with respect to the origin.

	HoleA Y Position [mm]	Error [%]	PinA Y Position [mm]	Error [%]	PinB Y Position [mm]	Error [%]	PinC Y Position [mm]	Error [%]	PinD Y Position [mm]	Error [%]
Sample 1	−58.9	1.83	−48.9	2.2	−40.2	0.5	−29.3	2.33	−19.5	2.5
Sample 2	−60	0	−50	0	−40	0	−30	0	−20	0
Sample 3	−60	0	−50	0	−40	0	−30	0	−20	0
Sample 4	−58.379	2.7	−48.394	3.21	−38.588	3.53	−28.875	3.75	−19.254	3.73
Sample 5	−59.05	1.58	−49.82	0.36	−39.69	0.78	−30.14	0.47	−20.02	0.1
Sample 6	−59.49	0.85	−49.83	0.34	−40.12	0.3	−30.04	0.13	−20.02	0.1
Sample 7	−60.57	0.95	−51.3	2.6	−41.2	3	−29.4	2	−21.2	6
Sample 8	−60.06	0.1	−49.33	1.34	−39.3	1.75	−29.35	2.17	−19.87	0.65
Sample 9	−60	0	−50	100	−40.2	0.5	−30	0	−20	0
Sample 10	-	-	-	-	-	-	-	-	-	-
Sample 11	−60	0	−50	0	−40.5	1.25	−30.5	1.67	−20.5	2.5
Sample 12	−60.75	1.25	−49.95	0.1	−39.95	0.12	−29.95	0.17	−19.95	0.25
Sample 13	−60.1	0.17	−50.4	0.8	−40.3	0.75	−30.5	1.67	−20.6	3
Sample 14	−59.71	0.48	−50.03	0.06	−40.41	1.02	−30.34	1.13	−20.41	2.05
Sample 15	−59.91	0.15	−49.99	0.02	−40.06	0.15	−29.91	0.3	−19.96	0.2
Sample 16	−59.89	0.18	−50.16	0.32	−40.02	0.05	−30.21	0.7	−20.05	0.25
Avg	−59.79		−49.87		−40.04		−29.9		−20.09	
SD	0.62		0.65		0.57		0.47		0.46	

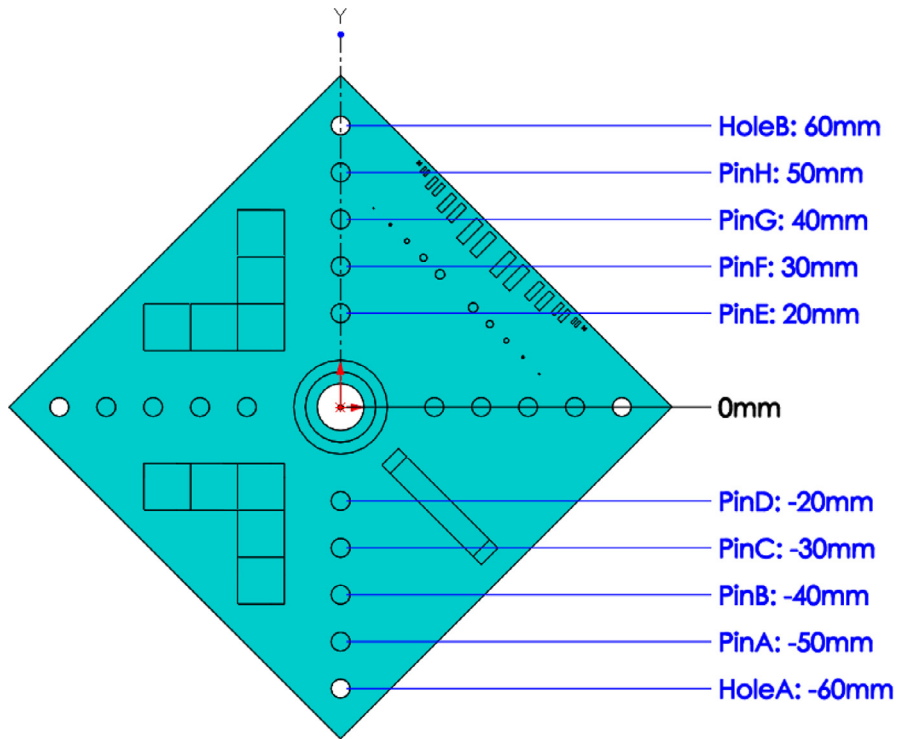


Fig. 5. Actual dimensions of location of pins and holes along y-axis with respect to the origin.

features that lie below the origin in the printed part. The average and standard deviation of all 16 measurements from each printed specimen is calculated. The error percentage from the measured location value to the nominal reference value is also calculated. Similarly, Table 9 shows the measurements and calculations for the pin and hole features that are located above the origin. The measurements for Sample 10 have been omitted due to limitations of that sample: there was an inability to accurately determine the location dimensions of the hole and pin features.

Fig. 6 shows the diameter of the pin and hole features located on the x and y axis of the NIST reference model. Each of these feature measures 4mm in diameter. There are a total of 8 circular pins located along the x-axis of the part and another set of 8 pins located on the y-axis. The average of the measurements of the pins' diameters from the printed parts are shown in Table 10. The average and standard deviation of the diameters are calculated. The percentage deviation from the nominal diameter value of 4mm are calculated for each feature's measurements.

Table 9
Measured center position of pins and hole in the positive y-axis with respect to the origin.

	PinE Y Position		PinF Y Position		PinG Y Position		PinH Y Position		HoleB Y Position	
	[mm]	Error [%]	[mm]	Error [%]	[mm]	Error [%]	[mm]	Error [%]	[mm]	Error [%]
Sample 1	19.8	1	30	0	39.1	2.25	48.8	2.4	59.7	0.5
Sample 2	20	0	30	0	40	0	50	0	60	0
Sample 3	20	0	30	0	40	0	50	0	60	0
Sample 4	19.455	2.73	29.098	3.01	38.704	3.24	48.31	3.38	58.294	2.84
Sample 5	19.78	1.1	30.23	0.77	40.02	0.05	49.63	0.74	60.08	0.13
Sample 6	19.6	2	30.1	0.33	40	0	49.78	0.44	59.96	0.07
Sample 7	20.4	2	31.75	5.83	40.64	1.6	50.8	1.6	60.32	0.53
Sample 8	19.97	0.15	30.48	1.6	40.09	0.23	50.07	0.14	59.73	0.45
Sample 9	20	0	30.3	1	40.3	0.75	50	0	59.3	1.17
Sample 10	-	-	-	-	-	-	-	-	-	-
Sample 11	20	0	30	0	40	0	50	0	60	0
Sample 12	19.95	0.25	29.95	0.17	39.95	0.12	49.95	0.1	60.75	1.25
Sample 13	20.6	3	30.4	1.33	40.35	0.88	50.35	0.7	60.2	0.33
Sample 14	19.85	0.75	29.54	1.53	39.58	1.05	49.63	0.74	59.43	0.95
Sample 15	19.97	0.15	29.98	0.07	40.11	0.27	50.07	0.14	59.91	0.15
Sample 16	20.04	0.2	29.78	0.73	40.15	0.37	50.02	0.04	59.92	0.13
Avg	19.96		30.11		39.93		49.83		59.84	
SD	0.28		0.57		0.48		0.59		0.55	

Table 10

Measured diameters of all the pins and holes located on the x and y axes.

	X Pins Diameter [mm]	Error [%]	X Holes Diameter [mm]	Error [%]	Y Pins Diameter [mm]	Error [%]	Y Holes Diameter [mm]	Error [%]
Sample 1	3.83	4.25	3.29	17.75	3.85	3.75	3.34	16.5
Sample 2	4	0	4	0	4	0	4	0
Sample 3	3.995	0.12	3.88	3	3.946	1.35	3.87	3.25
Sample 4	4.139	3.48	3.233	19.18	4.014	0.35	3.182	20.45
Sample 5	4.02	0.5	4.12	3	4.13	3.25	3.8	5
Sample 6	3.97	0.75	3.71	7.25	3.97	0.75	3.72	7
Sample 7	3.51	12.25	3.87	3.25	3.88	3	3.93	1.75
Sample 8	3.9656	0.86	3.44	14	4.136	3.4	3.35	16.25
Sample 9	3.76	6	3	25	3.98	0.5	3.35	16.25
Sample 10	3.988	0.3	3.985	0.38	3.987	0.32	3.988	0.3
Sample 11	4	0	4	0	4	0	4	0
Sample 12	4	0	3.9	2.5	3.8	5	3.9	2.5
Sample 13	3.98125	0.47	4	0	3.9214	1.96	4	0
Sample 14	4.06	1.5	4.01	0.25	4.09	2.25	4.01	0.25
Sample 15	3.96	1	4.04	1	4.01	0.25	3.96	1
Sample 16	3.84	4	3.99	0.25	3.9	2.5	3.89	2.75
Avg	3.94		3.78		3.98		3.77	
SD	0.15		0.34		0.09		0.29	

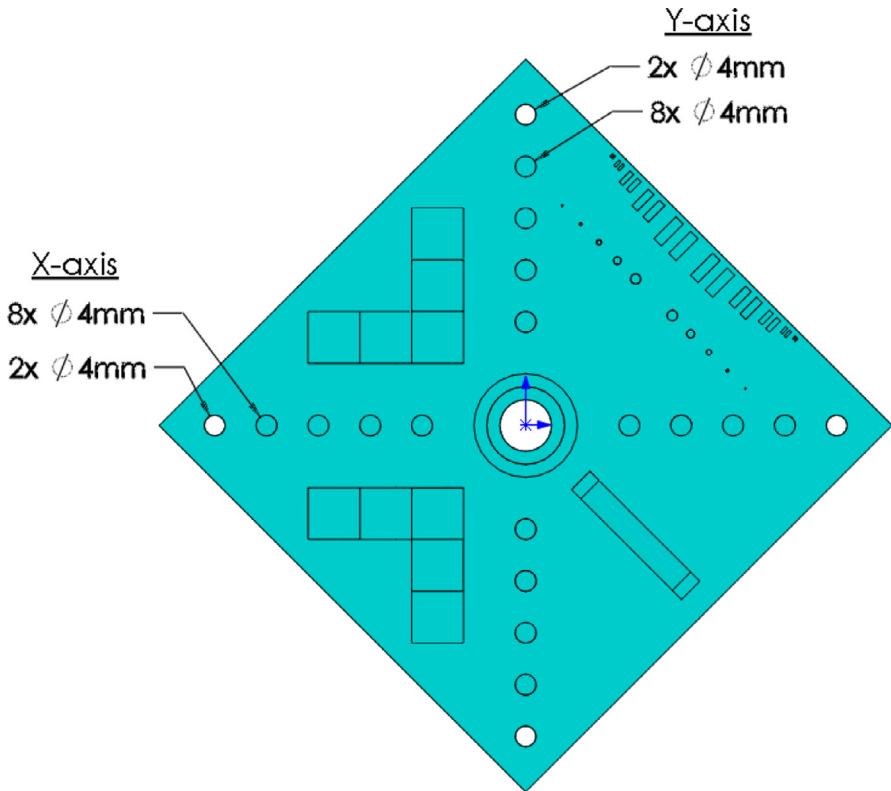


Fig. 6. Actual dimensions of the diameters of all pins and holes on the x and y axes.

2. Experimental Design, Materials and Methods

The NIST additive manufacturing (AM) standardized test artifact is used to evaluate a machine's dimensional accuracy for fused deposition modeling (FDM) and stereolithography (SLA) 3D printed features. Moylan proposed a standardized test artifact and provided the engineering drawing with geometric dimensions and tolerances [1]. The NIST artifact has been tested for the use in metal AM process [2]. Campioni et al. has shown the possible variation in the specimen dimensions and quality when the prints are obtained from online manufacturing service providers, which shows the need to overcome the challenges of obtaining high quality prints [3]. The data found in this article expands upon the use of the NIST artifact to test the performance of FDM and SLA additive manufacturing processes. The data presented can be helpful to visualize the discrepancies that arise in AM products from original design intent.

A group of graduate engineering students were asked to independently create CAD representations of the NIST test artifact only from the specifications (engineering drawings) of the reference NIST test artifact, and then to 3D print those artifacts. Each student was required to follow the standard additive manufacturing process to produce the test artifact using the printing process of their choice. Each student used a single sample of their NIST test artifact to conduct all the submitted measurements.

To perform this assignment, the students modelled their parts in the SolidWorks CAD software. All students started from the same point, that is, the same engineering specification for the NIST test artifact, so all model features and sizes should be the same across all the CAD designs. The next step had the students export their CAD models to the stereolithography file

Table 11

The printing parameters of each of the NIST artifact samples.

	Printer	Material	Layer Height [mm]	Infill [%]	Print Time [hours:minutes]
Sample 1	Ultimaker 3	PLA	0.1	30	11:18
Sample 2	Ultimaker 3	PLA	0.1	20	10:34
Sample 3	Ultimaker 3	PLA	0.1	100	24:48
Sample 4	Ultimaker 3	PLA	0.2	20	4:00
Sample 5	Ultimaker 3	PLA	0.2	20	4:22
Sample 6	Ultimaker 3	PLA	0.2	20	4:22
Sample 7	Ultimaker 3	PLA	0.2	20	4:26
Sample 8	Ultimaker 3	PLA	0.1	20	10:34
Sample 9	Ultimaker 3	PLA	0.2	20	4:02
Sample 10	Ultimaker 3	PLA	0.2	20	2:40
Sample 11	Ultimaker 3	PLA	0.1	20	8:37
Sample 12	Anycubic Mega X	PLA	0.2	20	5:56
Sample 13	Stratasys Dimension Elite	ABS	0.254	Sparse - high density	5:43
Sample 14	Stratasys Mojo	ABS	0.17	100	7:27
Sample 15	SLA	Resin	-	-	10:12
Sample 16	SLA	Resin	-	-	20:07

format. This common manufacturing file format is needed to import the test artifact into a slicer program like Ultimaker Cura or GrabCAD Print. Slicer programs are used to both define the printing parameters, such as layer height and printing speeds, as well as produce the toolpaths and printing commands (e.g. g-code) for the given model. Given the g-code file, a 3D printer is then used to print the part. Table 11 displays the printing conditions for each of the sample that was printed. Sample 15 and 16 was manufactured by an online 3D printing service and the printing parameters cannot be determined. Sample 13 was sliced using the GrabCAD Print software and there are only 3 options to choose for the infill. The default infill style was selected for sample 13.

A total of 16 test artifact samples were thus printed and the measured dimensions of the features on these printed parts are listed in the Data Description section. Students were not provided any guidance on the printer they could use, and they were free to print the artifact on any available polymer printer. Samples 1 through 11 were printed on Ultimaker 3 machines using a polylactic acid thermoplastic filament material. Sample 12 was printed on an Anycubic Mega X 3D printer. Samples 13 and 14 were printed on a Stratasys Dimension Elite and Stratasys Mojo 3D Printer, respectively. Samples 1 through 14 were all printed using the FDM process and were printed with a polymer material. Samples 15 and 16 were printed using the SLA process using a photosensitive resin material by an online 3D printing service provider. A collection of measurements from these different 3D printers are compared to the nominal values from the CAD model and the printer's performance on geometric accuracy can be determined.

Although Vernier calipers were used to measure the dimensions of the printed features on the printed artifacts by most students, these calipers were not provided to them. They were free to use any digital or analog measurement equipment. In this dataset, the primary focus is to determine the geometric dimensional accuracy of measured values in the printed part from the nominal values of the reference model. The other geometric parameters such as surface flatness, cylindrical roundness, and perpendicularity of surfaces has been excluded from analysis in this dataset. These geometric parameters require coordinate measuring machines (CMM) to determine with accuracy and not every participant collecting the measurements from the sample have access to such devices. In the raw data provided, values for these parameters are included and measured with methods to the individual's best ability.

In the group of 16 test artifact samples, measurements were taken for four main features and documented in the tables in the Data Description section. These features were the outer edge, lateral feature, staircase, pins, and holes. The outer edge feature included a measurement of the

length of the exterior side of the printed test artifact. The lateral features existed on the side surfaces of the part and these features were used to determine how well the printer can build these features along the z direction without support material. The staircase features can be used to determine the linear displacement errors of the printer's z-axis. Similarly, the pin and hole features are used to determine the linear displacement errors of the printer's x and y axis. The diameters of the pin and hole features are used to determine the printer's dimensional accuracy of circular features along the xy plane.

CRediT Author Statement

Gary Mac: Writing – original draft, Visualization, Data curation; **Hammond Pearce:** Data curation, Writing – review & editing; **Ramesh Karri:** Supervision; **Nikhil Gupta:** Conceptualization, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

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Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:[10.1016/j.dib.2021.107286](https://doi.org/10.1016/j.dib.2021.107286).

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