



The Printer Working Group

January 10, 2017  
Working Draft

## IPP 3D Printing Extensions (3D)

Status: Stable

Abstract: This specification defines an extension to the Internet Printing Protocol and IPP Everywhere that supports printing of physical objects by Additive Manufacturing devices such as 3D printers.

This document is a PWG Working Draft. For a definition of a "PWG Working Draft", see:

<http://ftp.pwg.org/pub/pwg/general/pwg-process30.pdf>

This document is available electronically at:

<http://ftp.pwg.org/pub/pwg/ipp/wd/wd-ipp3d10-20170110.docx>

<http://ftp.pwg.org/pub/pwg/ipp/wd/wd-ipp3d10-20170110.pdf>

1 Copyright © 2015-2017 The Printer Working Group. All rights reserved.

2 This document may be copied and furnished to others, and derivative works that comment  
3 on, or otherwise explain it or assist in its implementation may be prepared, copied,  
4 published and distributed, in whole or in part, without restriction of any kind, provided that  
5 the above copyright notice, this paragraph and the title of the Document as referenced  
6 below are included on all such copies and derivative works. However, this document itself  
7 may not be modified in any way, such as by removing the copyright notice or references to  
8 the IEEE-ISTO and the Printer Working Group, a program of the IEEE-ISTO.

9 Title: *IPP 3D Printing Extensions (3D)*

10 The IEEE-ISTO and the Printer Working Group DISCLAIM ANY AND ALL WARRANTIES,  
11 WHETHER EXPRESS OR IMPLIED INCLUDING (WITHOUT LIMITATION) ANY IMPLIED  
12 WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

13 The Printer Working Group, a program of the IEEE-ISTO, reserves the right to make  
14 changes to the document without further notice. The document may be updated, replaced  
15 or made obsolete by other documents at any time.

16 The IEEE-ISTO takes no position regarding the validity or scope of any intellectual  
17 property or other rights that might be claimed to pertain to the implementation or use of the  
18 technology described in this document or the extent to which any license under such rights  
19 might or might not be available; neither does it represent that it has made any effort to  
20 identify any such rights.

21 The IEEE-ISTO invites any interested party to bring to its attention any copyrights, patents,  
22 or patent applications, or other proprietary rights which may cover technology that may be  
23 required to implement the contents of this document. The IEEE-ISTO and its programs  
24 shall not be responsible for identifying patents for which a license may be required by a  
25 document and/or IEEE-ISTO Industry Group Standard or for conducting inquiries into the  
26 legal validity or scope of those patents that are brought to its attention. Inquiries may be  
27 submitted to the IEEE-ISTO by e-mail at: [ieee-isto@ieee.org](mailto:ieee-isto@ieee.org).

28 The Printer Working Group acknowledges that the IEEE-ISTO (acting itself or through its  
29 designees) is, and shall at all times, be the sole entity that may authorize the use of  
30 certification marks, trademarks, or other special designations to indicate compliance with  
31 these materials.

32 Use of this document is wholly voluntary. The existence of this document does not imply  
33 that there are no other ways to produce, test, measure, purchase, market, or provide other  
34 goods and services related to its scope.

35

## 36 **About the IEEE-ISTO**

37 The IEEE-ISTO is a not-for-profit corporation offering industry groups an innovative and  
38 flexible operational forum and support services. The IEEE-ISTO provides a forum not only  
39 to develop standards, but also to facilitate activities that support the implementation and  
40 acceptance of standards in the marketplace. The organization is affiliated with the IEEE  
41 (<http://www.ieee.org/>) and the IEEE Standards Association (<http://standards.ieee.org/>).

42 For additional information regarding the IEEE-ISTO and its industry programs visit:

43 <http://www.ieee-isto.org>

## 44 **About the IEEE-ISTO PWG**

45 The Printer Working Group (or PWG) is a Program of the IEEE Industry Standards and  
46 Technology Organization (ISTO) with member organizations including printer  
47 manufacturers, print server developers, operating system providers, network operating  
48 system providers, network connectivity vendors, and print management application  
49 developers. The group is chartered to make printers and the applications and operating  
50 systems supporting them work together better. All references to the PWG in this  
51 document implicitly mean “The Printer Working Group, a Program of the IEEE ISTO.” In  
52 order to meet this objective, the PWG will document the results of their work as open  
53 standards that define print related protocols, interfaces, procedures and conventions.  
54 Printer manufacturers and vendors of printer related software will benefit from the  
55 interoperability provided by voluntary conformance to these standards.

56 In general, a PWG standard is a specification that is stable, well understood, and is  
57 technically competent, has multiple, independent and interoperable implementations with  
58 substantial operational experience, and enjoys significant public support.

59 For additional information regarding the Printer Working Group visit:

60 <http://www.pwg.org>

61 Contact information:

62 The Printer Working Group  
63 c/o The IEEE Industry Standards and Technology Organization  
64 445 Hoes Lane  
65 Piscataway, NJ 08854  
66 USA  
67

**68 About the Internet Printing Protocol Workgroup**

69 The Internet Printing Protocol (IPP) workgroup has developed a modern, full-featured  
70 network printing protocol, which is now the industry standard. IPP allows a print client to  
71 query a printer for its supported capabilities, features, and parameters to allow the  
72 selection of an appropriate printer for each print job. IPP also provides job information prior  
73 to, during, and at the end of job processing.

74 For additional information regarding IPP visit:

75 <http://www.pwg.org/ipp/>

76 Implementers of this specification are encouraged to join the IPP mailing list in order to  
77 participate in any discussions of the specification. Suggested additions, changes, or  
78 clarification to this specification, should be sent to the IPP mailing list for consideration.  
79

## Table of Contents

80		
81	1. Introduction.....	10
82	2. Terminology.....	10
83	2.1 Conformance Terminology .....	10
84	2.2 Printing Terminology.....	10
85	2.3 Protocol Role Terminology .....	11
86	2.4 3D Printing Terminology .....	11
87	2.5 Other Terminology .....	12
88	2.6 Acronyms and Organizations.....	12
89	3. Rationale for IPP 3D Printing Extensions.....	14
90	3.1 Use Cases .....	14
91	3.1.1 Print a 3D Object.....	14
92	3.1.2 Print a 3D Object Using Loaded Materials .....	14
93	3.1.3 Print a 3D Object with Multiple Materials .....	14
94	3.1.4 Print a Tool.....	15
95	3.1.5 View a 3D Object During Printing.....	15
96	3.2 Exceptions .....	15
97	3.2.1 Clogged Extruder .....	15
98	3.2.2 Extruder Temperature Out of Range.....	15
99	3.2.3 Extruder Head Movement Issues .....	15
100	3.2.4 Filament Feed Jam .....	15
101	3.2.5 Filament Feed Skip .....	16
102	3.2.6 Material Empty .....	16
103	3.2.7 Material Adhesion Issues .....	16
104	3.2.8 Print Bed Temperature Out of Range .....	16
105	3.2.9 Print Bed Not Clear .....	16
106	3.3 Out of Scope.....	16
107	3.4 Design Requirements .....	17
108	4. 3D Print Service Model.....	18
109	4.1 3D Print Service .....	20
110	4.2 3D Printer Subunits.....	20
111	4.2.1 Finishing Devices .....	20
112	4.2.2 Input Trays/Rolls .....	20
113	4.2.3 Marker Supplies .....	20
114	4.2.4 Markers .....	21
115	4.2.5 Media Paths .....	21
116	4.3 3D Printer Coordinate System .....	21
117	4.4 Output Intent and Job Processing .....	22
118	4.5 Job Spooling .....	22
119	4.6 Multiple Document Jobs .....	22
120	4.7 Cloud-Based Printing.....	22
121	5. Discovery Protocols.....	23
122	5.1 DNS Service Discovery (DNS-SD) .....	23
123	5.1.1 Service Instance Name .....	23
124	5.1.2 Service Type .....	23
125	5.1.3 TXT Record.....	23

126	5.2 LDAP Discovery .....	24
127	5.2.1 printerIPPS3D Class .....	24
128	6. Protocol Binding .....	25
129	6.1 Transport and Resource Path.....	25
130	6.2 HTTP Features .....	25
131	6.2.1 Host.....	25
132	6.2.2 If-Modified-Since, Last-Modified, and 304 Not Modified .....	25
133	6.2.3 Cache-Control .....	25
134	6.3 IPP Operations .....	26
135	6.4 IPP Operation Attributes .....	26
136	6.5 IPP Printer Description Attributes .....	26
137	6.6 IPP Printer Status Attributes .....	29
138	6.7 IPP Job Template Attributes .....	30
139	6.8 IPP Job Description Attributes .....	30
140	6.9 IPP Job Status Attributes .....	30
141	6.9.1 job-id (integer) .....	31
142	6.9.2 job-uri (uri).....	31
143	7. Document Formats .....	31
144	8. New Attributes .....	32
145	8.1 Job Template Attributes .....	32
146	8.1.1 materials-col (1setOf collection).....	32
147	8.1.2 multiple-object-handling (type2 keyword).....	36
148	8.1.3 print-accuracy (collection) .....	37
149	8.1.4 print-objects (1setOf collection).....	38
150	8.1.5 print-rafts (type2 keyword) .....	39
151	8.1.6 print-supports (type2 keyword).....	39
152	8.1.7 printer-bed-temperature (integer(-273:MAX)) .....	39
153	8.2 Job Status Attributes .....	40
154	8.2.1 materials-col-actual (1setOf collection) .....	40
155	8.2.2 multiple-object-handling-actual (type2 keyword).....	40
156	8.2.3 print-objects-actual (1setOf collection).....	40
157	8.2.4 print-rafts-actual (1setOf type2 keyword).....	40
158	8.2.5 print-supports-actual (1setOf type2 keyword) .....	41
159	8.2.6 printer-bed-temperature-actual (1setOf integer(-273:MAX)) .....	41
160	8.3 Printer Description Attributes .....	41
161	8.3.1 accuracy-units-supported (1setOf type2 keyword).....	41
162	8.3.2 material-amount-units-supported (1setOf type2 keyword).....	41
163	8.3.3 material-diameter-supported (1setOf (integer   rangeOfInteger)).....	41
164	8.3.4 material-purpose-supported (1setOf type2 keyword).....	41
165	8.3.5 material-rate-supported (1setOf (integer   rangeOfInteger)).....	41
166	8.3.6 material-rate-units-supported (1setOf type2 keyword).....	41
167	8.3.7 material-shell-thickness-supported (1setOf (integer(1:MAX)	
168	rangeOfInteger(1:MAX))) .....	42
169	8.3.8 material-temperature-supported (1setOf (integer(-273:MAX)   rangeOfInteger(-	
170	273:MAX))).....	42
171	8.3.9 material-type-supported (1setOf type2 keyword) .....	42

172	8.3.10 materials-col-database (1setOf collection).....	42
173	8.3.11 materials-col-default (1setOf collection).....	43
174	8.3.12 materials-col-ready (1setOf collection).....	43
175	8.3.13 materials-col-supported (1setOf type2 keyword) .....	43
176	8.3.14 max-materials-col-supported (integer(1:MAX)) .....	43
177	8.3.15 multiple-object-handling-default (type2 keyword).....	43
178	8.3.16 multiple-object-handling-supported (1setOf type2 keyword).....	43
179	8.3.17 pdf-features-supported (1setOf type2 keyword).....	44
180	8.3.18 print-accuracy-default (collection) .....	44
181	8.3.19 print-accuracy-supported (collection) .....	44
182	8.3.20 print-objects-supported (1setOf type2 keyword) .....	44
183	8.3.21 print-rafts-default (type2 keyword) .....	44
184	8.3.22 print-rafts-supported (1setOf type2 keyword).....	44
185	8.3.23 print-supports-default (type2 keyword).....	44
186	8.3.24 print-supports-supported (1setOf type2 keyword).....	44
187	8.3.25 printer-bed-temperature-default (integer(-273:MAX)) .....	44
188	8.3.26 printer-bed-temperature-supported (1setOf (integer(-273:MAX)	
189	rangeOfInteger(-273:MAX))) .....	45
190	8.3.27 printer-camera-image-uri (1setOf uri).....	45
191	8.3.28 printer-volume-supported (collection).....	45
192	9. New Values for Existing Attributes .....	46
193	9.1 ipp-features-supported (1setOf type2 keyword) .....	46
194	9.2 printer-state-reasons (1setOf type2 keyword) .....	46
195	10. Conformance Requirements .....	48
196	10.1 Printer Conformance Requirements .....	48
197	10.2 Client Conformance Requirements.....	48
198	11. Internationalization Considerations .....	49
199	12. Security Considerations .....	50
200	12.1 Confidentiality .....	50
201	12.2 Access Control.....	50
202	12.3 Physical Safety .....	50
203	12.4 Material Safety.....	50
204	12.5 Temperature Control.....	50
205	13. IANA and PWG Considerations .....	51
206	13.1 Attribute Registrations .....	51
207	13.2 Attribute Value Registrations .....	53
208	13.3 Service Type Registration.....	55
209	13.4 MIME Media Type Registration .....	55
210	13.5 Semantic Model Registrations .....	56
211	14. References .....	57
212	14.1 Normative References .....	57
213	14.2 Informative References.....	60
214	15. Author's Address .....	61
215	16. Object Definition Languages (ODLs).....	62
216	16.1 3D Manufacturing Format (3MF) .....	62
217	16.2 Additive Manufacturing Format (AMF).....	62

218 16.3 Portable Document Format (PDF) ..... 62

219 16.4 Standard Tessellation Language (STL) ..... 62

220 17. Design Choices ..... 63

221 17.1 Units for Length Values ..... 63

222 17.2 Units for Thickness Values ..... 63

223 17.3 Use of Celsius for Temperatures ..... 63

224 17.4 Explicit Units for Other Values ..... 63

225 17.5 Intent vs. Process ..... 63

226 17.6 Choosing a Required Document Format ..... 64

227 18. Change History ..... 65

228 18.1 January 10, 2017 ..... 65

229 18.2 December 13, 2016 ..... 65

230 18.3 November 14, 2016 ..... 65

231 18.4 August 24, 2016 ..... 65

232 18.5 August 16, 2016 ..... 66

233 18.6 July 14, 2016 ..... 66

234 18.7 April 30, 2016 ..... 67

235 18.8 April 20, 2016 ..... 67

236 18.9 March 3, 2016 ..... 67

237 18.10 February 17, 2016 ..... 68

238 18.11 February 1, 2016 ..... 68

239 18.12 January 28, 2016 ..... 68

240 18.13 November 16, 2015 ..... 69

241 18.14 October 29, 2015 ..... 69

242 18.15 August 12, 2015 ..... 69

243 18.16 July 29, 2015 ..... 70

244 18.17 April 13, 2015 ..... 70

245 18.18 April 5, 2015 ..... 70

246 18.19 January 23, 2015 ..... 70

247  
248

**List of Figures**

249

250 Figure 1 - Generalized IPP Model (RFC 8011) ..... 19

251 Figure 2 - 3D Build Volume ..... 21

252  
253

**List of Tables**

254

255 Table 1 - 3D Printer Subunits ..... 20

256 Table 2 - IPPS 3D Print Service TXT Record Keys ..... 23

257 Table 3 - IPP 3D REQUIRED Operations ..... 26

258 Table 4 - IPP 3D REQUIRED Operation Attributes ..... 26

259 Table 5 - IPP 3D REQUIRED Printer Description Attributes ..... 27

260 Table 6 - IPP 3D REQUIRED Printer Status Attributes ..... 29

261 Table 7 - IPP 3D REQUIRED Job Template Attributes ..... 30

262 Table 8 - IPP 3D REQUIRED Job Description Attributes ..... 30



263 Table 9 - IPP 3D REQUIRED Job Status Attributes..... 30  
264 Table 10 - New Job Template Attributes ..... 32  
265 Table 11 - "materials-col" Member Attributes ..... 33  
266 Table 12 - REQUIRED "print-accuracy" Member Attributes..... 37  
267 Table 13 - REQUIRED "print-objects" Member Attributes..... 38  
268 Table 14 - New "-actual" Job Status Attributes..... 40  
269 Table 15 - REQUIRED "printer-volume-supported" Member Attributes ..... 45  
270  
271

## 272 **1. Introduction**

273 This specification defines an extension to the Internet Printing Protocol (IPP) that supports  
274 printing of physical objects by Additive Manufacturing devices such as three-dimensional  
275 (3D) printers.

276 The primary focus of this specification is on popular Fused Deposition Modeling (FDM)  
277 devices that melt and extrude filaments of ABS, PLA, or other materials in layers to  
278 produce a physical, 3D object. However, the same attributes can be used for other types of  
279 3D printers that use different methods and materials such as Laser Sintering of powdered  
280 materials and curing of liquids using ultraviolet light.

281 Discovery of IPP 3D Printers is based on the methods defined in IPP Everywhere  
282 [PWG5100.14].

283 In order to promote adoption and interoperability, this specification requires support for a  
284 common Object Definition Language (ODL). Recommendations and guidance for other  
285 ODLs are also provided, including material mapping strategies, in order to provide the  
286 greatest flexibility while ensuring consistency and interoperability for future formats.

287 This specification also addresses common Cloud-based issues by extending the IPP  
288 Shared Infrastructure Extensions [PWG5100.18], although how such services are  
289 provisioned or managed is out of scope.

290 Sample code implementing this specification has been published in the ISTO-PWG IPP  
291 Sample Code Repository [IPPSAMPLE].

## 292 **2. Terminology**

### 293 **2.1 Conformance Terminology**

294 Capitalized terms, such as MUST, MUST NOT, RECOMMENDED, REQUIRED, SHOULD,  
295 SHOULD NOT, MAY, and OPTIONAL, have special meaning relating to conformance as  
296 defined in Key words for use in RFCs to Indicate Requirement Levels [RFC2119]. The  
297 term CONDITIONALLY REQUIRED is additionally defined for a conformance requirement  
298 that applies when a specified condition is true.

### 299 **2.2 Printing Terminology**

300 Normative definitions and semantics of printing terms are imported from IETF Printer MIB  
301 v2 [RFC3805], IETF Finisher MIB [RFC3806], and IETF Internet Printing Protocol/1.1:  
302 Model and Semantics [RFC8011].

303 *Document*: An object created and managed by a Printer that contains the description,  
304 processing, and status information. A Document object may have attached data and is  
305 bound to a single Job.

306 *Job*: An object created and managed by a Printer that contains description, processing,  
307 and status information. The Job also contains zero or more Document objects.

308 *Logical Device*: a print server, software service, or gateway that processes jobs and either  
309 forwards or stores the processed job or uses one or more Physical Devices to render  
310 output.

311 *Output Device*: a single Logical or Physical Device

312 *Physical Device*: a hardware implementation of a endpoint device, e.g., a marking engine,  
313 a fax modem, etc.

## 314 **2.3 Protocol Role Terminology**

315 This document also defines the following protocol roles in order to specify unambiguous  
316 conformance requirements:

317 *Client*: Initiator of outgoing connections and sender of outgoing operation requests  
318 (Hypertext Transfer Protocol -- HTTP/1.1 [RFC7230] User Agent).

319 *Printer*: Listener for incoming connections and receiver of incoming operation requests  
320 (Hypertext Transfer Protocol -- HTTP/1.1 [RFC7230] Server) that represents one or more  
321 Physical Devices or a Logical Device.

## 322 **2.4 3D Printing Terminology**

323 *Additive Manufacturing*: A 3D printing process where material is progressively added to  
324 produce the final output.

325 *Binder Jetting*: A 3D printing process that uses a liquid binder that is jetted to fuse layers of  
326 powdered materials.

327 *Digital Light Processing*: A 3D printing process that uses light with a negative image to  
328 selectively cure layers of a liquid material.

329 *Fused Deposition Modeling*: A 3D printing process that extrudes a molten material to draw  
330 layers.

331 *Laser Sintering*: A 3D printing process that uses a laser to melt and fuse layers of  
332 powdered materials.

333 *Material Jetting*: A 3D printing process that jets the actual build materials in liquid or molten  
334 state to produce layers.

335 *Selective Deposition Lamination*: A 3D printing process that laminates cut sheets of  
336 material.

337 *Stereo Lithography*: A 3D printing process that uses a laser to cure and fuse layers of  
338 liquid materials.

339 *Subtractive Manufacturing*: A 3D printing process where material is progressively removed  
340 to produce the final output.

## 341 **2.5 Other Terminology**

342 *Directory Service*: A Service providing query and enumeration of information using names  
343 or other identifiers.

344 *Discovery*: Finding Printers by querying or browsing local network segments or  
345 Enumeration of Directory or Name Services.

346 *Enumeration*: Listing Printers that are registered with a Directory or other Service.

347 *Service*: Software providing access to physical, logical, or virtual resources and (typically)  
348 processing of queued Jobs.

## 349 **2.6 Acronyms and Organizations**

350 *3D PDF Consortium*: <http://www.3dpdfconsortium.org/>

351 *3MF Consortium*: 3D Manufacturing Format Consortium, <http://www.3mf.io/>

352 *CNC*: Computer Numerical Control

353 *DLP*: Digital Light Processing

354 *FDM*: Fused Deposition Modeling

355 *IANA*: Internet Assigned Numbers Authority, <http://www.iana.org/>

356 *IETF*: Internet Engineering Task Force, <http://www.ietf.org/>

357 *ISO*: International Organization for Standardization, <http://www.iso.org/>

358 *ODL*: Object Definition Language

359 *PWG*: Printer Working Group, <http://www.pwg.org/>

360 *SD*: SD Card Association, <http://www.sdcard.org/>

361 *SDL*: Selective Deposition Lamination

362 *SL*: Stereo Lithography

363 *USB*: Universal Serial Bus, <http://www.usb.org/>

364

### 365 **3. Rationale for IPP 3D Printing Extensions**

366 Existing specifications define the following:

- 367 1. IPP/2.0 Second Edition [PWG5100.12] defines version 2.0, 2.1, and 2.2 of the  
368 Internet Printing Protocol which defines a standard operating and data model,  
369 interface protocol, and extension mechanism to support traditional Printers;
- 370 2. IPP Everywhere [PWG5100.14] defines a profile of existing IPP specifications,  
371 standard Job Template attributes, and standard document formats;
- 372 3. IPP Shared Infrastructure Extensions (INFRA) [PWG5100.18] defines an  
373 interface for printing through shared services based in infrastructure such as  
374 Cloud servers;
- 375 4. The 3D Manufacturing Format Core Specification & Reference Guide v1.0 [3MF]  
376 defines an XML schema and file format for describing 3D objects with one or  
377 more materials;
- 378 5. The Universal 3D File Format [ECMA363] defines a binary format for 3D objects  
379 embedded in PDF files;
- 380 6. Document management -- 3D use of Product Representation Compact (PRC)  
381 format -- Part 1: PRC 10001 [ISO14739] defines a binary format for 3D objects  
382 embedded in PDF files; and
- 383 7. Document management — Portable document format — Part 1: PDF 1.7  
384 [ISO32000] defines a binary file format that supports embedded 3D objects with  
385 one or more materials.

386 Therefore, this IPP 3D Printing Extensions (3D) document should define IPP attributes,  
387 values, and operations needed to support printing of 3D objects, status monitoring of 3D  
388 printers and print jobs, and configuration of 3D printer characteristics and capabilities.

### 389 **3.1 Use Cases**

#### 390 **3.1.1 Print a 3D Object**

391 Jane is viewing a 3D object and wishes to print it. After initiating a print action, she selects  
392 a 3D printer on the network, specifies material and print settings, and submits the object  
393 for printing.

#### 394 **3.1.2 Print a 3D Object Using Loaded Materials**

395 Jane is viewing a 3D object and wishes to print it. After initiating a print action, she selects  
396 a 3D printer on the network that has the material(s) she wishes to use, specifies additional  
397 print settings, and submits the object for printing.

#### 398 **3.1.3 Print a 3D Object with Multiple Materials**

399 Jane wants to print a multi-material object on a single-material Printer. Jane uses software  
400 on her Client device to create Document data that instructs the Printer to pause printing

401 and provide status information at specific layers so that she can change materials at the  
402 Printer and resume printing with the new material.

#### 403 **3.1.4 Print a Tool**

404 Jane wants to print an adjustable wrench. Because the wrench contains interlocking  
405 pieces that must be printed accurately for it to work properly, Jane specifies the required  
406 dimensional accuracy with the software on her Client device prior to submitting the print.  
407 The Printer then validates that it can support the required accuracy before accepting the  
408 Job.

#### 409 **3.1.5 View a 3D Object During Printing**

410 Jane has submitted a 3D print Job that will take 4 hours to complete. She can visually  
411 monitor the progress of the Job through a web page provided by the Printer.

### 412 **3.2 Exceptions**

#### 413 **3.2.1 Clogged Extruder**

414 While printing a 3D object, the extruder becomes clogged. The printer stops printing and  
415 sets the corresponding state reason to allow Jane's Client device to discover the issue and  
416 display an appropriate alert.

#### 417 **3.2.2 Extruder Temperature Out of Range**

418 While printing a 3D object, the extruder temperature goes out of range for the material  
419 being printed. The printer pauses printing until the temperature stabilizes and sets the  
420 corresponding state reason to allow Jane's Client device to discover the issue and display  
421 an appropriate alert.

#### 422 **3.2.3 Extruder Head Movement Issues**

423 While printing a 3D object, the extruder head movement becomes irregular. The Printer  
424 stops printing and sets the corresponding state reason to allow Jane's Client device to  
425 discover the issue and display an appropriate alert.

#### 426 **3.2.4 Filament Feed Jam**

427 While printing a 3D object, the filament jams and cannot be fed into the extruder. The  
428 printer stops printing and sets the corresponding state reason to allow Jane's Client device  
429 to discover the issue and display an appropriate alert.

**430 3.2.5 Filament Feed Skip**

431 While printing a 3D object, the filament extrusion rate is insufficient to maintain proper  
432 printing. The printer stops printing and sets the corresponding state reason to allow Jane's  
433 Client device to discover the issue and display an appropriate alert.

**434 3.2.6 Material Empty**

435 While printing a 3D object, the printer runs out of the printing material. The printer pauses  
436 printing until more material is loaded and sets the corresponding state reason to allow  
437 Jane's Client device to discover the issue and display an appropriate alert.

**438 3.2.7 Material Adhesion Issues**

439 While printing a 3D object, the printed object releases from the build platform or the current  
440 layer is not adhering to the previous one. The printer stops printing and sets the  
441 corresponding state reason to allow Jane's Client device to discover the issue and display  
442 an appropriate alert.

**443 3.2.8 Print Bed Temperature Out of Range**

444 While printing a 3D object, the print bed temperature goes out of the requested range. The  
445 printer pauses printing until the temperature stabilizes and sets the corresponding state  
446 reason to allow Jane's Client device to discover the issue and display an appropriate alert.

**447 3.2.9 Print Bed Not Clear**

448 When starting to print a 3D object, the Printer detects that the build platform is not  
449 empty/clear. The Printer stops printing and sets the corresponding state reason to allow  
450 Jane's Client device to discover the issue and display an appropriate alert. The Printer  
451 starts printing once the build platform is cleared.

**452 3.3 Out of Scope**

453 The following are considered out of scope for this document:

- 454 1. Definition of new file formats;
- 455 2. Support for Subtractive Manufacturing technologies such as CNC milling  
456 machines; and
- 457 3. Support for industrial and/or medical printing technologies.

458



### 459 **3.4 Design Requirements**

460 The design requirements for this document are:

- 461 1. Define attributes and values to describe supported and loaded (ready) materials  
462 used for consumer desktop 3D Printers and print services, including color, fill,  
463 purpose, thickness, and type;
- 464 2. Define attributes and values to describe consumer desktop 3D Printer and print  
465 service capabilities and state;
- 466 3. Define attributes and values to describe printing features and/or constraints  
467 including dimensional accuracy and generation of rafts and supports;
- 468 4. Define attributes and values to describe the objects being printed, including  
469 UUID, bounding box, and offsets;
- 470 5. Define attributes to provide a receipt of the printed Job;
- 471 6. Define discovery mechanisms for 3D Printers;
- 472 7. Define security requirements necessary to support privacy and device safety;
- 473 8. Identify secure transport mechanisms for 3D Printers; and
- 474 9. Define sections to register all attributes, values, operations, and service types  
475 with IANA.

476 The design recommendations for this document are:

- 477 1. Support 3D printing technologies other than FDM

478

## 479 **4. 3D Print Service Model**

480 The IPP/1.1 Model and Semantics [RFC8011], the IETF Printer MIB [RFC3805], and the  
481 IETF Finisher MIB [RFC3806] already define a comprehensive model for the operation and  
482 data elements of a typical 2D printer. Figure 1 shows the generalized IPP model. The IPP  
483 Server provides the external network interface for IPP Clients, while the Print Service  
484 manages and processes Jobs and communicates with the Output Device(s) and their sub-  
485 units.

486 IPP objects in the model include Printers, Jobs, Documents, and Subscriptions. Each  
487 object has associated named attributes, each with one or more strongly typed values.  
488 Status attributes are immutable (READ-ONLY) while Description and Template attributes  
489 can be mutable (READ-WRITE). Objects can be the target of IPP operations, for example  
490 the Printer object accepts the Create-Job operation to create new Job objects for that  
491 Printer.

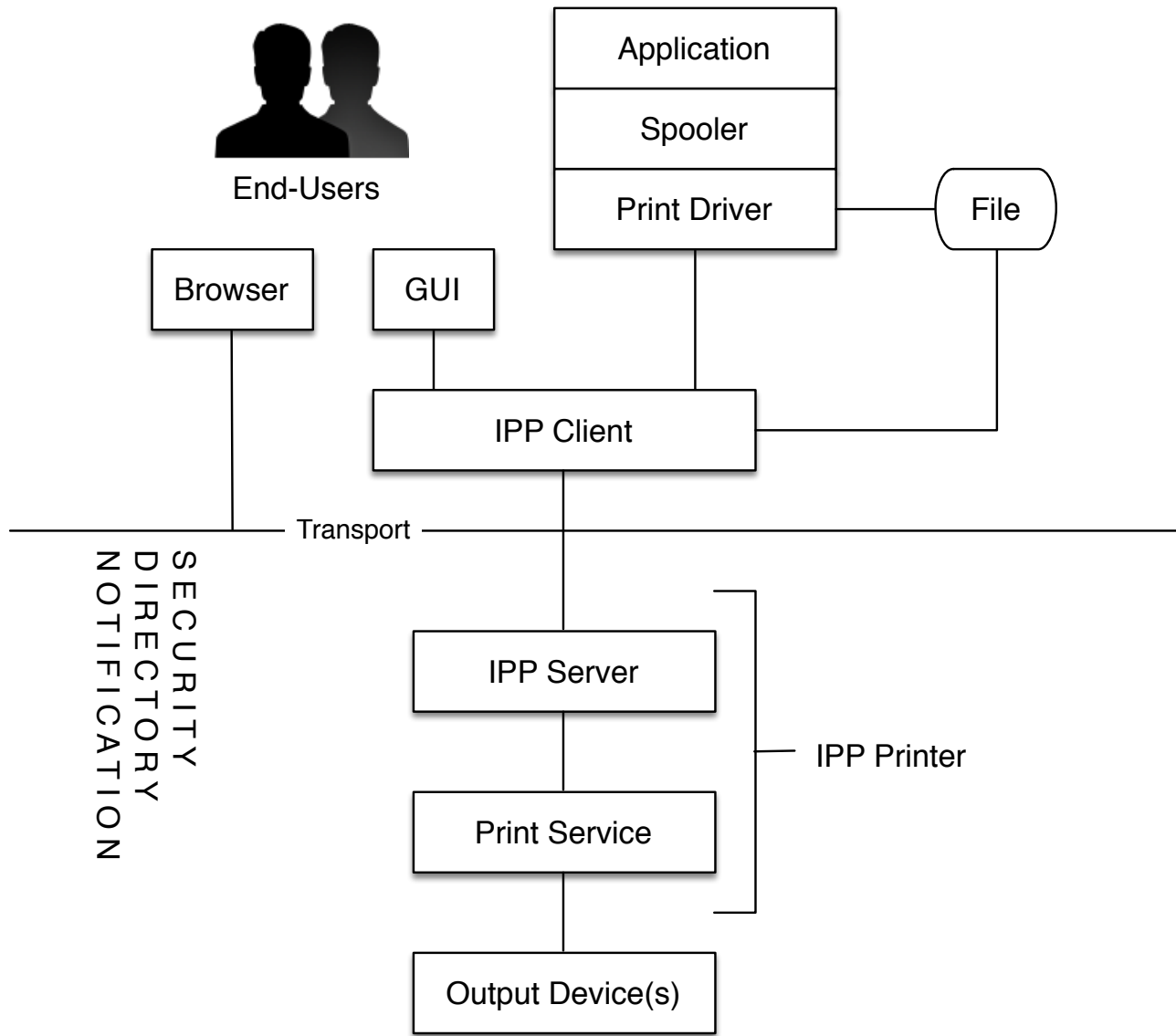
492 The IPP Printer object contains zero or more Job objects and is responsible for managing,  
493 scheduling, and processing Jobs. It also provides the current state of the Output Device(s)  
494 and communicates with them as needed.

495 The IPP Job object contains zero or more Document objects and tracks the progress of the  
496 Job throughout its life cycle. The Job Ticket (attributes supplied when creating the Job)  
497 and Job Receipt (attributes describing the final disposition of the Job) are also stored here.

498 The IPP Document object contains the document data or a reference (URI) to the data and  
499 tracks the progress of the Document throughout its life cycle. The Document Ticket  
500 (attributed supplied when creating the Document) and Document Receipt (attributes  
501 describing the final disposition of the Document) are also stored here.

502 The IPP Subscription object contains event notifications for one or more conditions that are  
503 being monitored. The Subscription Ticket (attribute supplied when creating the  
504 Subscription) is also stored here and determines whether notifications are pushed (email,  
505 instant messaging, etc.) or pulled (Get-Notifications operation).

506



507

508

509

Figure 1 - Generalized IPP Model (RFC 8011)

## 510 4.1 3D Print Service

511 3D printing uses a variation of the traditional Print service that maintains state and  
 512 capability information specific to 3D printing. The 3D Print service supports all of the same  
 513 operations of the Print service described in [RFC8011] except for the Print-Job and Print-  
 514 URI operations which are compound requests that are not used in newer IPP services.  
 515 Similarly, the 3D Print service uses a superset of the Print service attributes except where  
 516 such attributes are not applicable, for example the "media" attributes for a 3D printer that  
 517 does not use media sheets. Attributes specific to the 3D Print Service are defined in  
 518 section 8.

## 519 4.2 3D Printer Subunits

520 Table 1 lists the subunits of 3D printers for different technologies. Not all subunits are  
 521 exposed by Printers due to hardware or implementation limitations.

522 **Table 1 - 3D Printer Subunits**

2D Subunit	3D Subunit(s)	Technology	Reference
Finishing Devices	Trimmers	All	RFC 3806
Input Trays/Rolls	Input Trays/Rolls	SDL	RFC 3805
Marker Supplies	Filament, Granules, Liquids, Powders, Reservoirs	All	RFC 3805
Markers	Extruders, Lamps, Lasers, Projectors	All	RFC 3805
Media Path	Build Platforms, Chambers	Many	RFC 3805

### 523 4.2.1 Finishing Devices

524 Finishing Devices include Trimmers that are used to trim support material on printed  
 525 objects and/or remove regions of media that are not part of the final printed object.

### 526 4.2.2 Input Trays/Rolls

527 Input Trays/Rolls provide sheet or roll media for printing.

### 528 4.2.3 Marker Supplies

529 Marker Supplies include Filament, Granules, Liquids, Powders, and Reservoirs that are  
 530 used to supply the Marker(s) with material for printing.

#### 531 4.2.4 Markers

532 Markers can print an image on sheets of paper (SDL), melt and extrude material onto the  
533 Build Platform or previous layer, project an inverse image on the surface of a liquid  
534 material (DLP), or perform any other action to print an object.

535 Markers include fans, lasers, lamps, motors, and other components that are sometimes  
536 manually controlled by Printer-specific software but are not exposed by the IPP model.

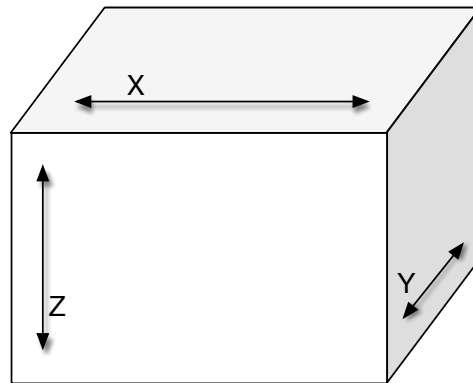
#### 537 4.2.5 Media Paths

538 Media Paths include traditional Media Sheet paths (SDL) as well as Build Platforms and  
539 Chambers. Build Platforms hold the printed object. The platform typically moves up or  
540 down during printing as layers are applied, although in some cases it moves along all three  
541 axis.

542 Chambers are the volumes containing the objects being printed. Chambers are sometimes  
543 temperature controlled and/or have doors that provide access to the printed objects.

### 544 4.3 3D Printer Coordinate System

545 3D printers operate in three dimensions and thus have three axis of movement. For the  
546 purposes of IPP, the build volume is defined as a rectangular prism (Figure 2) with the X  
547 axis representing the width, the Y axis representing the depth, and the Z axis representing  
548 the height. The origin is implementation-specific.



549

550

**Figure 2 - 3D Build Volume**

551 The Printer's coordinate system is often different than the coordinate system used in the  
552 ODL file to describe the object(s) being printed. The ODL interpreter on the Printer is  
553 responsible for performing any transformations needed to prepare the geometry for slicing  
554 in the Printer's coordinate system.

#### 555 **4.4 Output Intent and Job Processing**

556 As with 2D printing, the focus of 3D printing using IPP is specification of output intent and  
557 not for process or device control. Clients can specify general material selections (“red  
558 PLA”, “brown wood PLA”, “clear ABS”, etc.), print preferences and quality,, and whether  
559 supports and rafts should be printed. Printers then use the implementation specific device  
560 control and (ordered) processes to satisfy the Client-supplied output intent when  
561 processing the Job.

562 Also as with 2D printing, 3D Printers process Jobs using one or more interpreters. 2D  
563 printing typically involves rasterization of the Document data while 3D printing involves  
564 geometric transformations, addition of support geometry, and slicing (layering) of the  
565 object(s) in the Document data so that they can be printed.

#### 566 **4.5 Job Spooling**

567 Because common ODL formats are not designed to be incrementally processed as a  
568 stream of data, 3D printers will likely only support spooled (stored) processing of Jobs and  
569 Documents.

#### 570 **4.6 Multiple Document Jobs**

571 Printers that support Jobs with multiple Documents SHOULD be capable of printing the  
572 objects defined in those Documents side-by-side. For example, if a Client submits two  
573 Documents, of a cat and a dog respectively, the Printer SHOULD be able to print the cat  
574 and dog at the same time as long as they fit within the build volume.

575 The "multiple-object-handling" (section 8.1.2) Job Template attribute controls whether the  
576 Printer performs this optimization.

#### 577 **4.7 Cloud-Based Printing**

578 Cloud-based printing is supported by the existing IPP Shared Infrastructure Extensions  
579 (INFRA) [PWG5100.18]. Infrastructure Printers might require additional configuration or  
580 selection of drivers for the printer being configured, however that is outside the scope of  
581 this specification and can be considered a part of provisioning the Cloud Service.

582 Snapshots of camera video are uploaded as JPEG image resources using HTTP PUT  
583 requests from the Proxy to the Infrastructure Printer. Such resources MUST be updated in  
584 an atomic fashion to allow Clients to safely poll for updates to the camera video.

585

## 586 5. Discovery Protocols

587 Clients and Printers MUST support DNS-SD based Discovery. Clients and Printers MAY  
588 support other Discovery protocols such as LDAP.

### 589 5.1 DNS Service Discovery (DNS-SD)

590 DNS Service Discovery [RFC6762] uses service (SRV) records and traditional unicast and  
591 multicast DNS (mDNS) [RFC6763] queries. Printers MUST support mDNS and MAY  
592 support dynamic DNS updates via Dynamic Updates in the Domain Name System (DNS  
593 UPDATE) [RFC2136] and other mechanisms.

#### 594 5.1.1 Service Instance Name

595 Printers MUST NOT use a service instance name containing a unique identifier by default.  
596 A unique identifier MAY be added to the instance if there is a name collision.

597 The domain portion of the service instance name MUST BE "local." for mDNS.

#### 598 5.1.2 Service Type

599 Printers MUST advertise the "\_ippes-3d.\_tcp" (IPPS 3D Print) service over DNS-SD.

#### 600 5.1.3 TXT Record

601 Table 2 lists the TXT record key/value pairs for IPPS 3D Print services. The TXT record  
602 associated with the service MUST include the "adminurl" and "UUID" keys and MUST  
603 include the "note" and "rp" keys when they are not the default values.

604 **Table 2 - IPPS 3D Print Service TXT Record Keys**

Key	Description	Default Value
adminurl	The 'https' URL for the Printer's embedded web server.	None
note	The value of the "printer-location" Printer Description attribute.	""
pdl	The values of the "document-formats-supported" Printer Description attribute.	"model/3mf"
rp	The resource path for this service instance without the leading "/".	"ipp/print3d"
ty	The value of the "printer-make-and-model" Printer Description attribute.	""
UUID	The value of the "printer-uuid" Printer Status attribute without the leading 'urn:uuid:'.	None

## 605 5.2 LDAP Discovery

606 LDAP Discover uses Lightweight Directory Access Protocol v3 [RFC4510]. A single class  
607 for 3D Print services is used. The schema defined in this document is based on the LDAP  
608 Schema for Print Services [RFC7612] used for 2D Printer services.

### 609 5.2.1 printerIPPS3D Class

610 This auxiliary class defines 3D Printer information. It is used to extend the existing  
611 "printerService" structural class with 3D-specific Printer information.

```
612 ( 1.3.18.0.2.24.46.2.1
613     NAME 'printerIPPS3D'
614     DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
615     AUXILIARY
616     SUP top
617     MAY ( printer-ipp-versions-supported $
618           printer-ipp-features-supported $
619           printer-multiple-document-jobs-supported )
620 )
621
```



## 622 **6. Protocol Binding**

623 Printers and Clients MUST support IPP/2.0 as defined in IPP 2.0, 2.1, and 2.2  
624 [PWG5100.12]. While this specification defines an IPP binding, the same set of Semantic  
625 Elements can be applied to any protocol that conforms to the PWG Semantic Model.

### 626 **6.1 Transport and Resource Path**

627 Printers MUST support and use the IPP over HTTPS Transport Binding and 'ipps' URI  
628 Scheme [RFC7472] for network-connected Clients and/or the The IPP URL Scheme  
629 [RFC3510] and IPP-USB [IPP-USB] for USB-connected Clients. Printers MUST NOT  
630 support the "ipp" URI scheme for network-connected Clients since it does not satisfy the  
631 security requirements defined in section 12.

632 Printers MUST use a URI resource path of "/ipp/print3d" or "/ipp/print3d/NAME" where  
633 "NAME" identifies a specific instance of a 3D Print service.

### 634 **6.2 HTTP Features**

635 In addition to the IPP over HTTP conformance requirements defined in section 7.3 of IPP  
636 2.0, 2.1, and 2.2 [PWG5100.12], Printers MUST support the following additional HTTP  
637 headers and status codes defined in Hypertext Transfer Protocol -- HTTP/1.1 [RFC7230].

#### 638 **6.2.1 Host**

639 Printers MUST validate the Host request header and SHOULD use the Host value in  
640 generated URIs.

#### 641 **6.2.2 If-Modified-Since, Last-Modified, and 304 Not Modified**

642 Printers MUST support the If-Modified-Since request header (section 3.3 [RFC7232]), the  
643 corresponding response status ("304 Not Modified", section 4.1 [RFC7232]), and the Last-  
644 Modified response header (section 2.2 [RFC7232]).

645 The If-Modified-Since request header allows a Client to efficiently determine whether a  
646 particular resource file (icon, camera image, localization file, etc.) has been updated since  
647 the last time the Client requested it.

#### 648 **6.2.3 Cache-Control**

649 Printers and Clients MUST conform to the caching semantics defined in section 5.2  
650 [RFC7234]. Typically, most resource files provided by a Printer in a GET response will be  
651 cacheable but IPP responses in a POST response are not. Therefore, Printers MAY  
652 provide a Cache-Control header in GET responses with an appropriate "max-age" value  
653 and MUST provide a Cache-Control header in IPP POST responses with the value "no-  
654 cache".

### 655 6.3 IPP Operations

656 Table 3 lists the REQUIRED operations for a Printer. The Create-Job and Send-Document  
 657 operations are required in order to support reliable job management (e.g., cancellation)  
 658 during print job submission, but Printers are not required to support multiple document  
 659 jobs.

660

**Table 3 - IPP 3D REQUIRED Operations**

Code	Operation Name	Reference
0x0004	Validate-Job	RFC 8011
0x0005	Create-Job	RFC 8011
0x0006	Send-Document	RFC 8011
0x0008	Cancel-Job	RFC 8011
0x0009	Get-Job-Attributes	RFC 8011
0x000A	Get-Jobs	RFC 8011
0x000B	Get-Printer-Attributes	RFC 8011
0x0039	Cancel-My-Jobs	PWG 5100.11
0x003B	Close-Job	PWG 5100.11
0x003C	Identify-Printer	PWG 5100.13

### 661 6.4 IPP Operation Attributes

662 Table 4 lists the REQUIRED operation attributes for a Printer.

663

**Table 4 - IPP 3D REQUIRED Operation Attributes**

Attribute	Reference
compression	RFC 8011
document-format	RFC 8011
document-name	RFC 8011, PWG 5100.5
first-index	PWG 5100.13
identify-actions	PWG 5100.13
ipp-attribute-fidelity	RFC 8011
job-ids	PWG 5100.11
job-mandatory-attributes	PWG 5100.7
job-name	RFC 8011
last-document	RFC 8011
limit	RFC 8011
requesting-user-name	RFC 8011
requesting-user-uri	PWG 5100.13
which-jobs	RFC 8011, PWG 5100.11

### 664 6.5 IPP Printer Description Attributes

665 Table 5 lists the REQUIRED Printer Description attributes for a Printer.

666

**Table 5 - IPP 3D REQUIRED Printer Description Attributes**

<b>Attribute</b>	<b>Reference</b>
accuracy-units-supported	Section 8.3.1
charset-configured	RFC 8011
charset-supported	RFC 8011
color-supported	RFC 8011
compression-supported	RFC 8011
document-format-default	RFC 8011
document-format-supported	RFC 8011
generated-natural-language-supported	RFC 8011
identify-actions-default	PWG 5100.13
identify-actions-supported	PWG 5100.13
ipp-features-supported	PWG 5100.13
ipp-versions-supported	RFC 8011
job-creation-attributes-supported	PWG 5100.11
job-ids-supported	PWG 5100.11
material-diameter-supported (note 2)	Section 8.3.3
material-purpose-supported	Section 8.3.4
material-rate-supported	Section 8.3.5
material-rate-units-supported	Section 8.3.6
material-shell-thickness-supported	Section 8.3.7
material-temperature-supported (note 3)	Section 8.3.7
material-type-supported	Section 8.3.9
materials-col-default	Section 8.3.11
materials-col-ready	Section 8.3.12
materials-col-supported	Section 8.3.13
max-materials-col-supported	Section 8.3.14
multiple-document-jobs-supported	RFC 8011
multiple-object-handling-default	Section 8.3.15
multiple-object-handling-supported	Section 8.3.16
multiple-operation-timeout	RFC 8011
multiple-operation-timeout-action	PWG 5100.13
natural-language-configured	RFC 8011
operations-supported	RFC 8011
print-accuracy-default	Section 8.3.18
print-accuracy-supported	Section 8.3.19
print-objects-supported	Section 8.3.20
print-quality-default	RFC 8011
print-quality-supported	RFC 8011
print-rafts-default	Section 8.3.21
print-rafts-supported	Section 8.3.22
print-supports-default	Section 8.3.23
print-supports-supported	Section 8.3.24
printer-bed-temperature-default (note 4)	Section 8.3.25
printer-bed-temperature-supported (note 4)	Section 8.3.26

---

printer-geo-location	PWG 5100.13
printer-get-attributes-supported	PWG 5100.13
printer-icons (note 1)	PWG 5100.13
printer-info	RFC 8011
printer-location	RFC 8011
printer-make-and-model	RFC 8011
printer-more-info	RFC 8011
printer-name	RFC 8011
printer-organization	PWG 5100.13
printer-organizational-unit	PWG 5100.13
printer-volume-supported	Section 8.3.28
printer-xri-supported (note 1)	RFC 3380
queued-job-count	RFC 8011
which-jobs-supported	PWG 5100.11
xri-authentication-supported	RFC 3380
xri-security-supported	RFC 3380
xri-uri-scheme-supported	RFC 3380

---

667 Note 1: URIs SHOULD use Host value from HTTP header (section 6.2.1) and  
668 MUST NOT use link-local addresses (section 8.4 of [PWG5100.14]).

669 Note 2: REQUIRED for Printers that use filament-based materials.

670 Note 3: REQUIRED for Printers that control the material temperature during  
671 printing.

672 Note 4: REQUIRED for Printers that have a temperature-controlled build platform.  
673

674 **6.6 IPP Printer Status Attributes**

675 Table 6 lists the REQUIRED Printer Status attributes for a Printer.

676 **Table 6 - IPP 3D REQUIRED Printer Status Attributes**

<b>Attribute</b>	<b>Reference</b>
printer-config-change-date-time	PWG 5100.13
printer-camera-image-uri (notes 1, 2)	Section 8.3.27
printer-config-change-time	PWG 5100.13
printer-is-accepting-jobs	RFC 8011
printer-state	RFC 8011
printer-state-change-date-time	RFC 3995
printer-state-change-time	RFC 3995
printer-state-message	RFC 8011
printer-state-reasons	RFC 8011
printer-up-time	RFC 8011
printer-uri-supported (note 1)	RFC 8011
printer-uuid	PWG 5100.13
queued-job-count	RFC 8011
uri-security-supported	RFC 8011
uri-authentication-supported	RFC 8011

677 Note 1: URIs SHOULD use Host value from HTTP header (section 6.2.1) and  
678 MUST NOT use link-local addresses (section 8.4 of [PWG5100.14]).

679 Note 2: REQUIRED for Printers that have one or more cameras.

680

## 681 **6.7 IPP Job Template Attributes**

682 Table 7 lists the REQUIRED Job Template attributes for a Printer.

683 **Table 7 - IPP 3D REQUIRED Job Template Attributes**

<b>Attribute</b>	<b>Reference</b>
materials-col	Section 8.1.1
multiple-document-handling	RFC 8011
multiple-object-handling (note 1)	Section 8.1.2
print-accuracy	Section 8.1.3
print-objects (note 1)	Section 8.1.4
print-quality	RFC 8011
print-rafts	Section 8.1.5
print-supports	Section 8.1.6
printer-bed-temperature (note 2)	Section 8.1.7

684 Note 1: REQUIRED for Printers that support the 'application/pdf' document format.

685 Note 2: REQUIRED for Printers that have a temperature-controlled build platform.

## 686 **6.8 IPP Job Description Attributes**

687 Table 8 lists the REQUIRED Job Description attributes for a Printer.

688 **Table 8 - IPP 3D REQUIRED Job Description Attributes**

<b>Attribute</b>	<b>Source</b>
job-name	RFC 8011

## 689 **6.9 IPP Job Status Attributes**

690 Table 8 lists the REQUIRED Job Status attributes for a Printer.

691 **Table 9 - IPP 3D REQUIRED Job Status Attributes**

<b>Attribute</b>	<b>Source</b>
compression-supplied	PWG 5100.7
date-time-at-completed	RFC 8011
date-time-at-creation	RFC 8011
date-time-at-processing	RFC 8011
document-format-supplied	PWG 5100.7
document-name-supplied	PWG 5100.7
job-id	RFC 8011
job-originating-user-name	RFC 8011
job-printer-up-time	RFC 8011
job-printer-uri	RFC 8011

<b>Attribute</b>	<b>Source</b>
job-state	RFC 8011
job-state-message	RFC 8011
job-state-reasons	RFC 8011
job-uri	RFC 8011
job-uuid	PWG 5100.13
materials-col-actual	Section 8.2.1
multiple-object-handling-actual (note 1)	Section 8.2.2
print-objects-actual (note 1)	Section 8.2.3
print-rafts-actual	Section 8.2.4
print-supports-actual	Section 8.2.5
printer-bed-temperature-actual (note 2)	Section 8.2.6
time-at-completed	RFC 8011
time-at-creation	RFC 8011
time-at-processing	RFC 8011

692 Note 1: REQUIRED for Printers that support the 'application/pdf' document format.

693 Note 2: REQUIRED for Printers that have a temperature-controlled Build Platform.

#### 694 **6.9.1 job-id (integer)**

695 The REQUIRED "job-id" Job Description attribute contains the ID of the Job. In order to  
 696 support reliable job submission and management, Printers MUST NOT reuse "job-id"  
 697 values since the last power cycle of the Printer and SHOULD NOT reuse "job-id" values for  
 698 the life of the Printer as described in section 3.1.2.3.9 of the Internet Printing Protocol/1.1:  
 699 Implementer's Guide [RFC3196].

#### 700 **6.9.2 job-uri (uri)**

701 The REQUIRED "job-uri" Job Description attribute contains the URI of the Job. In order to  
 702 support reliable job submission and management, Printers MUST NOT reuse "job-uri"  
 703 values since the Printer was last powered up and SHOULD NOT reuse "job-uri" values for  
 704 the life of the Printer as described in section 3.1.2.3.9 of the Internet Printing Protocol/1.1:  
 705 Implementer's Guide [RFC3196]. In addition, the "job-uri" value SHOULD be derived from  
 706 the "job-id" value as described in the IPP URL Scheme [RFC3510].

## 707 **7. Document Formats**

708 Printers MUST support Documents conforming to the 3MF [3MF] ("model/3mf") format and  
 709 SHOULD support Documents conforming to the PDF [ISO32000] ("application/pdf") format  
 710 containing U3D [U3D] or PRC [PRC] content.

711 **8. New Attributes**712 **8.1 Job Template Attributes**

713 Table 10 lists the Job Template attributes and their corresponding “-default” and “-  
714 supported” attributes.

715 **Table 10 - New Job Template Attributes**

<b>Job Template</b>	<b>Printer: Default</b>	<b>Printer: Supported</b>
materials-col (collection)	materials-col-default (1setOf collection)	materials-col-database (1setOf collection) materials-col-ready (1setOf collection) materials-col-supported (1setOf type2 keyword)
multiple-object-handling (type2 keyword)	multiple-object-handling-default (type2 keyword)	multiple-object-handling-supported (1setOf type2 keyword)
print-accuracy (collection)	print-accuracy-default (collection)	accuracy-units-supported (1setOf type2 keyword) print-accuracy-supported (collection)
print-objects (1setOf collection)	N/A	print-objects-supported (boolean)
print-rafts (type2 keyword)	print-rafts-default (type2 keyword)	print-rafts-supported (1setOf type2 keyword)
print-supports (type2 keyword)	print-supports-default (type2 keyword)	print-supports-supported (1setOf type2 keyword)
printer-bed-temperature (integer   no-value)	printer-bed-temperature-default (integer   no-value)	printer-bed-temperature-supported (1setOf (integer   rangeOfInteger)   no-value)

716 **8.1.1 materials-col (1setOf collection)**

717 This REQUIRED Job Template attribute defines the materials to be used for the Job.  
718 When specified, the Printer validates the requested materials both when the Job is created  
719 and when it enters the 'processing' state. If the requested materials are not loaded, the  
720 'material-needed' keyword is added to the Printer's "printer-state-reasons" values and the  
721 Job is placed in the 'processing-stopped' state.

722 The Printer advertises which "materials-col" member attributes are supported in the  
723 "materials-col-supported" (section 8.3.13) Printer Description attribute. The Printer lists  
724 only those member attributes that are applicable to the technology being used for printing.



725 The Client typically supplies "materials-col" values matching those returned in the  
 726 "materials-col-database" (section 8.3.1) or "materials-col-ready" (section 8.3.12) Printer  
 727 Description attributes, although specifying the "material-name" or "material-key" member  
 728 attribute from either of these Printer Description attributes is enough to specify the default  
 729 values for the named material. Table 11 lists the member attributes.

730 **Table 11 - "materials-col" Member Attributes**

<b>Member Attribute</b>	<b>Printer: Supported Values</b>
material-amount	N/A
material-amount-units	material-amount-units-supported
material-color	N/A
material-diameter	material-diameter-supported
material-diameter-tolerance	N/A
material-fill-density	N/A
material-key	materials-col-database materials-col-ready
material-name	materials-col-database materials-col-ready
material-purpose	material-purpose-supported
material-rate	material-rate-supported
material-rate-units	material-rate-units-supported
material-shell-thickness	material-shell-thickness-supported
material-temperate	material-temperature-supported
material-type	material-type-supported

731 **8.1.1.1 material-amount (integer(0:MAX) | unknown)**

732 This RECOMMENDED member attribute provides the estimated amount of material that is  
 733 available ("materials-col-database" and "materials-col-ready" values), the estimated  
 734 amount of material that is required ("materials-col" values), or the actual amount of  
 735 material that has been used ("materials-col-actual" values).

736 **8.1.1.2 material-amount-units (type2 keyword)**

737 This RECOMMENDED member attribute provides the units for the "material-amount"  
 738 value. Values include:

739 'g': Value is mass in grams.

740 'kg': Value is mass in kilograms.

741 'l': Value is volume in liters.

742 'm': Value is length in meters.

743 'ml': Value is volume in milliliters.

744 'mm': Value is length in millimeters.

745 **8.1.1.3 material-color (type2 keyword)**

746 This RECOMMENDED member attribute provides a PWG media color [PWG5101.1] value  
747 representing the color of the material.

748 **8.1.1.4 material-diameter (integer(0:MAX))**

749 This CONDITIONALLY REQUIRED member attribute provides the diameter of the filament  
750 in nanometers, with the value 0 being used for diameters less than 0.000001mm. Printers  
751 that use filament materials MUST support this member attribute.

752 **8.1.1.5 material-diameter-tolerance (integer(0:MAX))**

753 This member attribute provides a tolerance for the "material-diameter" value in  
754 nanometers, with the value 0 being used for tolerances less than 0.000001mm.

755 **8.1.1.6 material-fill-density (integer(0:100))**

756 This REQUIRED member attribute specifies the desired density of filled interior regions in  
757 percent.

758 **8.1.1.7 material-key (keyword)**

759 This REQUIRED member attribute provides an unlocalized name of the material that can  
760 be localized using the strings file referenced by the "printer-strings-uri" Printer attribute.

761 **8.1.1.8 material-name (name(MAX))**

762 This REQUIRED member attribute provides a localized name of the material.

763 **8.1.1.9 material-purpose (1setOf type2 keyword)**

764 This REQUIRED member attribute specifies what the material will be used for. Values  
765 include:

766 'all': The material will be used for all parts of the printed object.

767 'in-fill': The material will be used to fill the interior of the printed object.

768 'raft': The material will be used to print a raft under the printed object.

769 'shell': The material will be used for the surface of the printed object.

770 'support': The material will be used to support the printed object.

**771 8.1.1.10 material-rate (integer(1:MAX))**

772 This member attribute provides the flow rate of the material per second. The units are  
773 defined by the "material-rate-units" member attribute.

**774 8.1.1.11 material-rate-units (type2 keyword)**

775 This member attribute provides the units for the "material-rate" member attribute. Values  
776 include:

777 'mg\_sec ': Value is milligrams per second.

778 'ml\_sec ': Value is milliliters per second.

779 'mm\_sec ': Value is millimeters per second.

**780 8.1.1.12 material-shell-thickness (integer(0:MAX))**

781 This REQUIRED member attribute specifies the thickness of exterior walls in nanometers,  
782 with 0 representing the thinnest possible wall.

**783 8.1.1.13 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))**

784 This CONDITIONALLY REQUIRED member attribute specifies the printing temperature (or  
785 range of temperatures) for the material in degrees Celsius. Printers that control the  
786 temperature of materials MUST support this attribute.

**787 8.1.1.14 material-type (type2 keyword | name(MAX))**

788 This REQUIRED member attribute specifies the type of material. Keyword values are  
789 general names for materials (sometimes qualified) and are localized using the message  
790 catalog specified by the "printer-strings-uri" Printer Description attribute [PWG5100.13].  
791 Name values are vendor or site specific human readable (already localized) strings.  
792 Values include:

793 'abs': Acrylonitrile Butadiene Styrene (ABS).

794 'abs-carbon-fiber': ABS reinforced with carbon fibers.

795 'abs-carbon-nanotube': ABS reinforced with carbon nanotubes.

796 'chocolate': Chocolate.

797 'gold': Gold (metal).

798 'nylon': Nylon.

799 'pet': Polyethylene terephthalate (PET).

800 'photopolymer': Photopolymer (liquid) resin.

801 'pla': Polylactic Acid (PLA).

802 'pla-conductive': Conductive PLA.

803 'pla-dissolvable': Dissolvable PLA.

804 'pla-flexible': Flexible PLA.

805 'pla-magnetic': PLA with embedded iron particles.

806 'pla-steel': PLA with embedded steel particles.

807 'pla-stone': PLA with embedded stone chips.

808 'pla-wood': PLA with embedded wood fibers.

809 'polycarbonate': Polycarbonate.

810 'silver': Silver (metal).

811 'titanium': Titanium (metal).

812 'wax': Wax.

### 813 **8.1.2 multiple-object-handling (type2 keyword)**

814 This CONDITIONALLY REQUIRED Job Template attribute specifies how multiple objects  
815 are printed, including those within a single Document, across multiple Documents, and/or  
816 copies that are produced. Printers that support the 'application/pdf' Document format  
817 MUST support this attribute. Values include:

818 'auto': Automatically determine the best way to print multiple objects in a Job.

819 'best-fit': Fit as many objects as possible within the build volume.

820 'best-quality': Optimize the number of objects for print quality.

821 'best-speed': Optimize the number of objects for print speed.

822 'one-at-a-time': Print one object at a time.

823

### 824 **8.1.3 print-accuracy (collection)**

825 This REQUIRED Job Template attribute specifies the requested general positioning and  
826 feature accuracy for the Job. Table 12 lists the REQUIRED member attributes.

827 When enforcing attribute fidelity ("ipp-attribute-fidelity" with a value of 'true'), Printers only  
828 reject "print-accuracy" values that are smaller than the "print-accuracy-supported" (section  
829 8.3.19) value.

830 **Table 12 - REQUIRED "print-accuracy" Member Attributes**

<b>Member Attribute</b>	<b>Printer: Supported Values</b>
accuracy-units (type2 keyword)	accuracy-units-supported (1setOf type2 keyword)
x-accuracy (integer(0:MAX))	N/A
y-accuracy (integer(0:MAX))	N/A
z-accuracy (integer(0:MAX))	N/A

#### 831 **8.1.3.1 accuracy-units (type2 keyword)**

832 This member attribute specifies the units for the "x-accuracy", "y-accuracy", and "z-  
833 accuracy" member attribute values. Keyword values include:

834 'mm': Accuracy numbers are in millimeters.

835 'um': Accuracy numbers are in micrometers.

836 'nm': Accuracy numbers are in nanometers.

#### 837 **8.1.3.2 x-accuracy (integer(0:MAX))**

838 This REQUIRED member attribute specifies the X axis accuracy in the units specified by  
839 the "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller)  
840 than 1 unit.

#### 841 **8.1.3.3 y-accuracy (integer(0:MAX))**

842 This REQUIRED member attribute specifies the Y axis accuracy in the units specified by  
843 the "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller)  
844 than 1 unit.

#### 845 **8.1.3.4 z-accuracy (integer(0:MAX))**

846 This REQUIRED member attribute specifies the Z axis accuracy in the units specified by  
847 the "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller)  
848 than 1 unit.

849 **8.1.4 print-objects (1setOf collection)**

850 This CONDITIONALLY REQUIRED Job Template attribute specifies the objects to be  
851 printed within the Documents. Printers that support the 'application/pdf' Document format  
852 MUST support this attribute. Table 13 lists the REQUIRED member attributes.

853 If not specified in a Job Creation request, the Printer MUST print all objects in each  
854 Document. There is no "print-objects-default" Printer Description attribute.

855 **Table 13 - REQUIRED "print-objects" Member Attributes**

Member Attribute	Sub-Member Attributes
document-number (integer(1:MAX))	N/A
object-offset (collection)	x-offset (integer(0:MAX)) y-offset (integer(0:MAX)) z-offset (integer(0:MAX))
object-size (collection)	x-dimension (integer(1:MAX)) y-dimension (integer(1:MAX)) z-dimension (integer(1:MAX))
object-uuid (uri)	N/A

856

857 **8.1.4.1 document-number (integer(1:MAX))**

858 This member attribute specifies the numbered document containing the object. The first  
859 document is number 1, the second document is 2, etc.

860 **8.1.4.2 object-offset (collection)**

861 This member attribute specifies the offset to apply to the object. The "x-offset  
862 (integer(0:MAX))", "y-offset (integer(0:MAX))", and "z-offset (integer(0:MAX))" member  
863 attributes specify the offsets from the left, front, and build platform respectively in  
864 hundredths of millimeters (1/2540th of an inch).

865 **8.1.4.3 object-size (collection)**

866 This member attribute specifies the dimensions of the object. The "x-dimension  
867 (integer(1:MAX))", "y-dimension (integer(1:MAX))", and "z-dimension (integer(1:MAX))"  
868 member attributes specify the dimensions in hundredths of millimeters (1/2540th of an  
869 inch).

870 **8.1.4.4 object-uuid (uri)**

871 This member attribute specifies the object's unique identifier that MUST be a 45-octet  
872 "urn:uuid" URI [RFC4122].

**873 8.1.5 print-rafts (type2 keyword)**

874 This REQUIRED Job Template attribute specifies whether to print brims, rafts, or skirts  
875 under the object. Values include:

876 'none': Do not print brims, rafts, or skirts.

877 'brim': Print brims using the 'raft' material specified for the Job.

878 'raft': Print rafts using the 'raft' material specified for the Job.

879 'skirt': Print skirts using the 'raft' material specified for the Job.

880 'standard': Print brims, rafts, and/or skirts using implementation-defined default  
881 parameters.

**882 8.1.6 print-supports (type2 keyword)**

883 This REQUIRED Job Template attribute specifies whether to print supports under the  
884 object. Values include:

885 'none': Do not print supports.

886 'standard': Print supports using implementation-defined default parameters.

887 'material': Print supports using the 'support' material specified for the Job.

**888 8.1.7 printer-bed-temperature (integer(-273:MAX))**

889 This CONDITIONALLY REQUIRED Job Template attribute specifies the desired  
890 temperature of the Build Platform in degrees Celsius. Printers that have a temperature-  
891 controlled Build Platform MUST support this attribute.

892

## 893 8.2 Job Status Attributes

894 Table 14 lists the "-actual" Job Status attributes that provide the receipt of Job Template  
895 attributes that were used when processing a Job.

896 **Table 14 - New "-actual" Job Status Attributes**

<b>Job Status Attribute</b>	<b>Conformance</b>
materials-col-actual (1setOf collection)	REQUIRED
multiple-object-handling-actual (type2 keyword)	REQUIRED (note 1)
print-accuracy-actual (collection)	REQUIRED
print-objects-actual (1setOf collection)	REQUIRED (note 1)
print-rafts-actual (1setOf type2 keyword)	REQUIRED
print-supports-actual (1setOf type2 keyword)	REQUIRED
printer-bed-temperature-actual (1setOf integer(-273:MAX))	REQUIRED (note 2)

897 Note 1: REQUIRED for Printers that support the 'application/pdf' document format.

898 Note 2: REQUIRED for Printers that provide a temperature-controlled Build  
899 Platform.

### 900 8.2.1 materials-col-actual (1setOf collection)

901 This REQUIRED Job Status attribute contains the material(s) that were used when  
902 processing the Job.

### 903 8.2.2 multiple-object-handling-actual (type2 keyword)

904 This CONDITIONALLY REQUIRED Job Status attribute specifies how multiple objects  
905 were handled in the Job. Printers that support the 'application/pdf' document format MUST  
906 support this attribute.

907 print-accuracy-actual (collection)

908 This REQUIRED Job Status attribute specifies the accuracy of the processed Job.

### 909 8.2.3 print-objects-actual (1setOf collection)

910 This CONDITIONALLY REQUIRED Job Status attribute lists the objects that were  
911 processed. Printers that support the 'application/pdf' document format MUST support this  
912 attribute.

### 913 8.2.4 print-rafts-actual (1setOf type2 keyword)

914 This REQUIRED Job Status attribute specifies whether rafts were printed during the  
915 processing of the Job.



**916 8.2.5 print-supports-actual (1setOf type2 keyword)**

917 This REQUIRED Job Status attribute specifies whether supports were printed during the  
918 processing of the Job.

**919 8.2.6 printer-bed-temperature-actual (1setOf integer(-273:MAX))**

920 This CONDITIONALLY REQUIRED Job Status attribute specifies the printer bed  
921 temperature(s) that were used during the process of the Job. Printers that provide a  
922 temperature-controlled Build Platform MUST support this attribute.

**923 8.3 Printer Description Attributes****924 8.3.1 accuracy-units-supported (1setOf type2 keyword)**

925 This REQUIRED Printer Description attribute specifies the supported "accuracy-units"  
926 member attribute values.

**927 8.3.2 material-amount-units-supported (1setOf type2 keyword)**

928 This Printer Description attribute lists the supported "material-amount-units" values for the  
929 Printer. This attribute MUST be supported if the "material-amount-units" member attribute  
930 (Section 8.1.1.2) is supported.

**931 8.3.3 material-diameter-supported (1setOf (integer | rangeOfInteger))**

932 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
933 "material-diameter" values for the Printer. This attribute MUST be supported if the  
934 "material-diameter" member attribute (Section 8.1.1.4) is supported.

**935 8.3.4 material-purpose-supported (1setOf type2 keyword)**

936 This REQUIRED Printer Description attribute lists the supported "material-purpose" values  
937 for the Printer.

**938 8.3.5 material-rate-supported (1setOf (integer | rangeOfInteger))**

939 This Printer Description attribute lists the supported "material-rate" values for the Printer.  
940 This attribute MUST be supported if the "material-rate" member attribute (Section 8.1.1.10)  
941 is supported.

**942 8.3.6 material-rate-units-supported (1setOf type2 keyword)**

943 This Printer Description attribute lists the supported "material-rate-units" values for the  
944 Printer. This attribute MUST be supported if the "material-rate-units" member attribute  
945 (Section 8.1.1.11) is supported.

946 **8.3.7 material-shell-thickness-supported (1setOf (integer(1:MAX) |**  
947 **rangeOfInteger(1:MAX)))**

948 This REQUIRED Printer Description attribute specifies the supported "material-shell-  
949 thickness" values (or ranges of values) in nanometers.

950 **8.3.8 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-**  
951 **273:MAX)))**

952 This CONDITIONALLY REQUIRED Printer Description attribute specifies the supported  
953 "material-temperature" values (or ranges of values) in degrees Celsius. This attribute  
954 MUST be supported if the "material-temperature" member attribute (Section 8.1.1.13) is  
955 supported.

956 **8.3.9 material-type-supported (1setOf type2 keyword)**

957 This REQUIRED Printer Description attribute lists the supported "material-type" values for  
958 the Printer.

959 **8.3.10 materials-col-database (1setOf collection)**

960 This RECOMMENDED Printer Description attribute lists the pre-configured materials for  
961 the Printer. Each value contains the corresponding "materials-col" member attributes and  
962 will typically reflect vendor and site ("third party") materials that are supported by the  
963 Printer.

964 In order to optimize the total size of this attribute, Printers MAY omit member attributes that  
965 allow the full range of supported values in a particular collection. For example, a Printer  
966 that supports generic PLA filament can report a single collection value:

```
967     materials-col-database =  
968         { material-name="Generic PLA Filament" material-key="generic-pla"  
969           material-diameter=285 material-temperature=215-235 }  
970
```

971 Such "wildcard" values can be combined with more precise collections that identify a  
972 specific product, for example:

```
973     materials-col-database =  
974     { material-name="Generic PLA Filament" material-key="generic-pla"  
975     material-diameter=285 material-temperature=215-235 },  
976     { material-name="Example Corp Flexible Midnight Blue PLA" material-  
977     key="com.example.flexible-midnight-blue" material-  
978     color="com.example.midnight-blue_000027" material-diameter=285 material-  
979     temperature=210-225 }
```

### 980 **8.3.11 materials-col-default (1setOf collection)**

981 This REQUIRED Printer Description attribute lists the default materials that will be used if  
982 the "materials-col" Job Template attribute (Section 8.1.1) is not specified.

### 983 **8.3.12 materials-col-ready (1setOf collection)**

984 This REQUIRED Printer Description attribute lists the materials that have been loaded into  
985 the Printer. Each value contains the corresponding "materials-col" member attributes.

### 986 **8.3.13 materials-col-supported (1setOf type2 keyword)**

987 This REQUIRED Printer Description attribute lists the "materials-col" member attributes  
988 that are supported by the Printer. Printers MUST include the following values: 'material-fill-  
989 density', 'material-key', 'material-name', 'material-purpose', 'material-shell-thickness', and  
990 'material-type'.

### 991 **8.3.14 max-materials-col-supported (integer(1:MAX))**

992 This REQUIRED Printer Description attribute specifies the maximum number of values that  
993 can be provided with the "materials-col" Job Template attribute (section 8.1.1).

### 994 **8.3.15 multiple-object-handling-default (type2 keyword)**

995 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
996 "multiple-object-handling" value. Printers that support the 'application/pdf' Document format  
997 MUST support this attribute.

### 998 **8.3.16 multiple-object-handling-supported (1setOf type2 keyword)**

999 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
1000 "multiple-object-handling" values. Printers that support the 'application/pdf' Document  
1001 format MUST support this attribute.  
1002

**1003 8.3.17 pdf-features-supported (1setOf type2 keyword)**

1004 This CONDITIONALLY REQUIRED Printer Description attribute lists the PDF features that  
1005 are supported by the Printer. Printers that support the 'application/pdf' Document format  
1006 MUST support this attribute.

1007 Values include:

1008       'prc': The Printer supports 3D objects in the Product Representation Compact  
1009       (PRC) format [ISO14739-1].

1010       'u3d': The Printer supports 3D objects in the Universal 3D (U3D) format [ECMA363].

**1011 8.3.18 print-accuracy-default (collection)**

1012 This REQUIRED Printer Description attribute specifies the default "print-accuracy" value.

**1013 8.3.19 print-accuracy-supported (collection)**

1014 This REQUIRED Printer Description attribute specifies the best "print-accuracy" value that  
1015 is supported by the Printer.

**1016 8.3.20 print-objects-supported (1setOf type2 keyword)**

1017 This CONDITIONALLY REQUIRED Printer Description attribute specifies which "print-  
1018 objects" member attributes are supported. Printers that support the 'application/pdf'  
1019 Document format MUST support this attribute.

**1020 8.3.21 print-rafts-default (type2 keyword)**

1021 This REQUIRED Printer Description attribute specifies the default "print-rafts" value.

**1022 8.3.22 print-rafts-supported (1setOf type2 keyword)**

1023 This REQUIRED Printer Description attribute lists the supported "print-rafts" values.

**1024 8.3.23 print-supports-default (type2 keyword)**

1025 This REQUIRED Printer Description attribute specifies the default "print-supports" value.

**1026 8.3.24 print-supports-supported (1setOf type2 keyword)**

1027 This REQUIRED Printer Description attribute lists the supported "print-supports" values.

**1028 8.3.25 printer-bed-temperature-default (integer(-273:MAX))**

1029 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
1030 "printer-bed-temperature" value. Printers that control the temperature of the Build Platform  
1031 MUST support this attribute.

1032 **8.3.26 printer-bed-temperature-supported (1setOf (integer(-273:MAX) |**  
 1033 **rangeOfInteger(-273:MAX)))**

1034 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
 1035 "printer-bed-temperature" values and/or ranges. Printers that control the temperature of  
 1036 the Build Platform MUST support this attribute.

1037 **8.3.27 printer-camera-image-uri (1setOf uri)**

1038 This Printer Description attribute lists the URIs for one or more resident camera snapshots.  
 1039 Each URI corresponds to a separate resident camera. The images referenced by each  
 1040 URI can change at any time so it is up to the Client to periodically poll for changes and for  
 1041 the Printer to atomically update the images so that Clients can safely do so. The  
 1042 referenced images MUST be PNG [RFC2083] or JPEG [JFIF] format.

1043 **8.3.28 printer-volume-supported (collection)**

1044 This REQUIRED Printer Description attribute specifies the maximum build volume  
 1045 supported by the Printer. Table 15 lists the REQUIRED member attributes.

1046 **Table 15 - REQUIRED "printer-volume-supported" Member Attributes**

**Member Attribute**

x-dimension (integer(1:MAX))

y-dimension (integer(1:MAX))

z-dimension (integer(1:MAX))

1047 **8.3.28.1 x-dimension (integer(1:MAX))**

1048 This member attributes specifies the width of the build volume in hundredths of millimeters  
 1049 (1/2540th of an inch).

1050 **8.3.28.2 y-dimension (integer(1:MAX))**

1051 This member attributes specifies the depth of the build volume in hundredths of millimeters  
 1052 (1/2540th of an inch).

1053 **8.3.28.3 z-dimension (integer(1:MAX))**

1054 This member attributes specifies the height of the build volume in hundredths of  
 1055 millimeters (1/2540th of an inch).

## 1056 **9. New Values for Existing Attributes**

### 1057 **9.1 ipp-features-supported (1setOf type2 keyword)**

1058 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-  
1059 supported" Printer Description attribute.

### 1060 **9.2 printer-state-reasons (1setOf type2 keyword)**

1061 This specification registers the following new values for the "printer-state-reasons" Printer  
1062 Status attribute:

1063 'camera-failure': A camera is no longer working.

1064 'chamber-cooling': A chamber is being cooled.

1065 'chamber-heating': A chamber is being heated.

1066 'chamber-temperature-high': The temperature of a chamber is high.

1067 'chamber-temperature-low': The temperature of a chamber is low.

1068 'extruder-cooling': An extruder is being cooled.

1069 'extruder-failure': An extruder has failed and requires maintenance or replacement.

1070 'extruder-heating': An extruder is being heated.

1071 'extruder-jam': An extruder is jammed or clogged.

1072 'extruder-temperature-high': The temperature of an extruder is too high.

1073 'extruder-temperature-low': The temperature of an extruder is too low.

1074 'fan-failure': A fan has failed.

1075 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.

1076 'lamp-failure': A lamp has failed.

1077 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.

1078 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.

1079 'laser-failure': A laser has failed.

1080 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.

- 1081 'material-empty': One or more build materials have been exhausted.
- 1082 'material-low': One or more build materials may need replenishment soon.
- 1083 'material-needed': One or more build materials need to be loaded for a processing
- 1084 Job.
- 1085 'motor-failure': A motor has failed.
- 1086

## 1087 **10. Conformance Requirements**

### 1088 **10.1 Printer Conformance Requirements**

1089 In order for a Printer to claim conformance to this specification, a Printer MUST support:

- 1090 1. The required discovery protocols in section 5;
- 1091 2. The required transports and resource paths in section 6.1;
- 1092 3. The required HTTP features in section 6.2;
- 1093 4. The required IPP operations in section 6.3;
- 1094 5. The required IPP attributes in sections 6.4 through 6.9;
- 1095 6. The required document formats in section 7;
- 1096 7. The additional values defined in section 9;
- 1097 8. The internationalization considerations in section 11; and
- 1098 9. The security considerations in section 12.

### 1099 **10.2 Client Conformance Requirements**

1100 In order for a Client to claim conformance to this specification, a Client MUST support:

- 1101 1. The required discovery protocols in section 5;
- 1102 2. The required transports and resource paths in section 6.1;
- 1103 3. The required HTTP features in section 6.2;
- 1104 4. The required IPP operations in section 6.3;
- 1105 5. The required IPP attributes in sections 6.4 through 6.9;
- 1106 6. The required document formats in section 7;
- 1107 7. The additional values defined in section 9;
- 1108 8. The internationalization considerations in section 11; and
- 1109 9. The security considerations in section 12.

1110



## 1111 **11. Internationalization Considerations**

1112 For interoperability and basic support for multiple languages, conforming implementations  
1113 MUST support:

- 1114 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)  
1115 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 1116 2. The Unicode Format for Network Interchange [RFC5198] which requires  
1117 transmission of well-formed UTF-8 strings and recommends transmission of  
1118 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1119 Unicode NFC is defined as the result of performing Canonical Decomposition (into base  
1120 characters and combining marks) followed by Canonical Composition (into canonical  
1121 composed characters wherever Unicode has assigned them).

1122 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and  
1123 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in  
1124 IPP Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8  
1125 URIs now 'hidden').

1126 Implementations of this specification SHOULD conform to the following standards on  
1127 processing of human-readable Unicode text strings, see:

1128 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical

1129 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping

1130 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]

1131 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences

1132 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization

1133 Unicode Character Encoding Model [UTR17] – multi-layer character model

1134 Unicode in XML and other Markup Languages [UTR20] – XML usage

1135 Unicode Character Property Model [UTR23] – character properties

1136 Unicode Conformance Model [UTR33] – Unicode conformance basis+

1137 Unicode Collation Algorithm [UTS10] – sorting

1138 Unicode Locale Data Markup Language [UTS35] – locale databases

## 1139 **12. Security Considerations**

1140 In addition to the security considerations described in the IPP/1.1: Model and Semantics  
1141 [RFC8011], the following sub-sections describe issues that are unique to 3D printing.

1142 Implementations of this specification SHOULD conform to the following standards on  
1143 processing of human-readable Unicode text strings, see:

1144       Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1145       Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

### 1146 **12.1 Confidentiality**

1147 Clients and Printers MUST provide confidentiality of data in transit using either an interface  
1148 providing physical security such as USB or using TLS encryption [RFC5246] over  
1149 unsecured/network connections,

### 1150 **12.2 Access Control**

1151 Because of the potential for abuse and misuse, Printers SHOULD provide access control  
1152 mechanisms including lists of allowed Clients, authentication, and authorization to site  
1153 defined policies.

### 1154 **12.3 Physical Safety**

1155 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such  
1156 as protective gates, covers, or interlocks.

### 1157 **12.4 Material Safety**

1158 Printers MUST restrict usage and combination of materials to those that can be safely  
1159 printed. Access controls (section 12.2) MAY be used to allow authorized End Users to  
1160 experiment with untested materials or combinations, but only when such materials or  
1161 combinations can reasonably be expected to not pose a safety risk.

### 1162 **12.5 Temperature Control**

1163 Printers MUST validate values provided by Clients and limit material, extruder, build  
1164 platform, and print chamber temperatures within designed limits to prevent unsafe  
1165 operating conditions, damage to the hardware, hazardous emissions, explosions, and/or  
1166 fires.

1167

## 1168 13. IANA and PWG Considerations

### 1169 13.1 Attribute Registrations

1170 The attributes defined in this specification will be published by IANA according to the  
1171 procedures in IPP/1.1 Model and Semantics [RFC8011] section 7.2 in the following file:

1172 <http://www.iana.org/assignments/ipp-registrations>

1173 The registry entries will contain the following information:

1174 Job Status attributes:	Reference
1175 -----	-----
1176 materials-col-actual (1setOf collection)	[PWG5100.NN]
1177 < member attributes are the same as materials-col >	[PWG5100.NN]
1178 multiple-object-handling-actual (type2 keyword)	[PWG5100.NN]
1179 print-accuracy-actual (collection)	[PWG5100.NN]
1180 < member attributes are the same as print-accuracy >	[PWG5100.NN]
1181 print-objects-actual (1setOf collection)	[PWG5100.NN]
1182 < member attributes are the same as print-objects >	[PWG5100.NN]
1183 print-rafts-actual (1setOf type2 keyword)	[PWG5100.NN]
1184 print-supports-actual (1setOf type2 keyword)	[PWG5100.NN]
1185 printer-bed-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.NN]
1186	
1187 Job Template attributes:	Reference
1188 -----	-----
1189 materials-col (1setOf collection)	[PWG5100.NN]
1190 material-amount (integer(0:MAX))	[PWG5100.NN]
1191 material-amount-units (type2 keyword)	[PWG5100.NN]
1192 material-color (type2 keyword)	[PWG5100.NN]
1193 material-diameter (integer(0:MAX))	[PWG5100.NN]
1194 material-diameter-tolerance (integer(0:MAX))	[PWG5100.NN]
1195 material-fill-density (integer(0:100))	[PWG5100.NN]
1196 material-key (keyword)	[PWG5100.NN]
1197 material-name (name(MAX))	[PWG5100.NN]
1198 material-purpose (1setOf type2 keyword)	[PWG5100.NN]
1199 material-rate (integer(1:MAX))	[PWG5100.NN]
1200 material-rate-units (type2 keyword)	[PWG5100.NN]
1201 material-shell-thickness (integer(0:MAX))	[PWG5100.NN]
1202 material-temperature (integer(-273:MAX)   rangeOfInteger(-273:MAX))	[PWG5100.NN]
1203	
1204 material-type (type2 keyword   name(MAX))	[PWG5100.NN]
1205 multiple-object-handling (type2 keyword)	[PWG5100.NN]
1206 print-accuracy (collection)	[PWG5100.NN]
1207 accuracy-units (type2 keyword)	[PWG5100.NN]
1208 x-accuracy (integer(0:MAX))	[PWG5100.NN]
1209 y-accuracy (integer(0:MAX))	[PWG5100.NN]
1210 z-accuracy (integer(0:MAX))	[PWG5100.NN]
1211 print-objects (1setOf collection)	[PWG5100.NN]
1212 document-number (integer(1:MAX))	[PWG5100.NN]
1213 object-offset (collection)	[PWG5100.NN]
1214 x-offset (integer(0:MAX))	[PWG5100.NN]
1215 y-offset (integer(0:MAX))	[PWG5100.NN]

1216	z-offset (integer(0:MAX))	[PWG5100.NN]
1217	object-size (collection)	[PWG5100.NN]
1218	x-dimension (integer(1:MAX))	[PWG5100.NN]
1219	y-dimension (integer(1:MAX))	[PWG5100.NN]
1220	z-dimension (integer(1:MAX))	[PWG5100.NN]
1221	object-uuid (uri)	[PWG5100.NN]
1222	print-rafts (type2 keyword)	[PWG5100.NN]
1223	print-supports (type2 keyword)	[PWG5100.NN]
1224	printer-bed-temperature (integer(-273:MAX))	[PWG5100.NN]
1225		
1226	Printer Description attributes:	Reference
1227	-----	-----
1228	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.NN]
1229	material-amount-units-supported (1setOf type2 keyword)	[PWG5100.NN]
1230	material-diameter-supported (1setOf (integer(0:MAX)	
1231	rangeOfInteger(0:MAX)))	[PWG5100.NN]
1232	material-purpose-supported (1setOf type2 keyword)	[PWG5100.NN]
1233	material-rate-supported (1setOf (integer(1:MAX)   rangeOfInteger(1:MAX)))	
1234		[PWG5100.NN]
1235	material-rate-units-supported (1setOf type2 keyword)	[PWG5100.NN]
1236	material-shell-thickness-supported (1setOf (integer(0:MAX)	
1237	rangeOfInteger(0:MAX)))	[PWG5100.NN]
1238	material-temperature-supported (1setOf (integer(-273:MAX)	
1239	rangeOfInteger(-273:MAX)))	[PWG5100.NN]
1240	material-type-supported (1setOf type2 keyword)	[PWG5100.NN]
1241	materials-col-database (1setOf collection)	[PWG5100.NN]
1242	< member attributes are the same as materials-col >	[PWG5100.NN]
1243	materials-col-default (1setOf collection)	[PWG5100.NN]
1244	< member attributes are the same as materials-col >	[PWG5100.NN]
1245	materials-col-ready (1setOf collection)	[PWG5100.NN]
1246	< member attributes are the same as materials-col >	[PWG5100.NN]
1247	materials-col-supported (1setOf type2 keyword)	[PWG5100.NN]
1248	max-materials-col-supported (integer(1:MAX))	[PWG5100.NN]
1249	multiple-object-handling-default (type2 keyword)	[PWG5100.NN]
1250	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.NN]
1251	pdf-features-supported (1setOf type2 keyword)	[PWG5100.NN]
1252	print-accuracy-supported (collection)	[PWG5100.NN]
1253	< member attributes are the same as print-accuracy >	[PWG5100.NN]
1254	print-objects-supported (1setOf type2 keyword)	[PWG5100.NN]
1255	print-rafts-default (type2 keyword)	[PWG5100.NN]
1256	print-rafts-supported (1setOf type2 keyword)	[PWG5100.NN]
1257	print-supports-default (type2 keyword)	[PWG5100.NN]
1258	print-supports-supported (1setOf type2 keyword)	[PWG5100.NN]
1259	printer-bed-temperature-default (integer(-273:MAX))	[PWG5100.NN]
1260	printer-bed-temperature-supported (1setOf (integer(-273:MAX)	
1261	rangeOfInteger(-273:MAX)))	[PWG5100.NN]
1262	printer-camera-image-uri (1setOf uri)	[PWG5100.NN]
1263	printer-volume-supported (collection)	[PWG5100.NN]
1264	x-dimension (integer(1:MAX))	[PWG5100.NN]
1265	y-dimension (integer(1:MAX))	[PWG5100.NN]
1266	z-dimension (integer(1:MAX))	[PWG5100.NN]

## 1267 13.2 Attribute Value Registrations

1268 The attributes defined in this specification will be published by IANA according to the  
1269 procedures in IPP/1.1 Model and Semantics [RFC8011] section 7.1 in the following file:

1270 <http://www.iana.org/assignments/ipp-registrations>

1271 The registry entries will contain the following information:

1272	Attributes (attribute syntax)	Reference
1273	Keyword Attribute Value	
1274	-----	-----
1275	accuracy-units (type2 keyword)	[PWG5100.NN]
1276	mm	[PWG5100.NN]
1277	nm	[PWG5100.NN]
1278	um	[PWG5100.NN]
1279	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.NN]
1280	< any accuracy-units values >	[PWG5100.NN]
1281	ipp-features-supported (1setOf type2 keyword)	[PWG5100.13]
1282	ipp-3d	[PWG5100.NN]
1283	material-amount-units (type2 keyword)	[PWG5100.NN]
1284	g	[PWG5100.NN]
1285	kg	[PWG5100.NN]
1286	l	[PWG5100.NN]
1287	m	[PWG5100.NN]
1288	ml	[PWG5100.NN]
1289	mm	[PWG5100.NN]
1290	material-color (type2 keyword)	[PWG5100.NN]
1291	< any "media" color name >	[PWG5100.NN]
1292	material-purpose (1setOf type2 keyword)	[PWG5100.NN]
1293	all	[PWG5100.NN]
1294	in-fill	[PWG5100.NN]
1295	raft	[PWG5100.NN]
1296	shell	[PWG5100.NN]
1297	support	[PWG5100.NN]
1298	material-rate-units (type2 keyword)	[PWG5100.NN]
1299	mg_second	[PWG5100.NN]
1300	ml_second	[PWG5100.NN]
1301	mm_second	[PWG5100.NN]
1302	material-type (type2 keyword)	[PWG5100.NN]
1303	abs	[PWG5100.NN]
1304	abs-carbon-fiber	[PWG5100.NN]
1305	abs-carbon-nanotube	[PWG5100.NN]
1306	chocolate	[PWG5100.NN]
1307	gold	[PWG5100.NN]
1308	nylon	[PWG5100.NN]
1309	pet	[PWG5100.NN]
1310	photopolymer	[PWG5100.NN]
1311	pla	[PWG5100.NN]
1312	pla-conductive	[PWG5100.NN]
1313	pla-dissolvable	[PWG5100.NN]
1314	pla-flexible	[PWG5100.NN]
1315	pla-magnetic	[PWG5100.NN]
1316	pla-steel	[PWG5100.NN]
1317	pla-stone	[PWG5100.NN]

1318	pla-wood	[PWG5100.NN]
1319	polycarbonate	[PWG5100.NN]
1320	silver	[PWG5100.NN]
1321	titanium	[PWG5100.NN]
1322	wax	[PWG5100.NN]
1323	materials-col-supported (1setOf type2 keyword)	[PWG5100.NN]
1324	< any materials-col member attribute name >	[PWG5100.NN]
1325	multiple-object-handling (type2 keyword)	[PWG5100.NN]
1326	auto	[PWG5100.NN]
1327	best-fit	[PWG5100.NN]
1328	best-quality	[PWG5100.NN]
1329	best-speed	[PWG5100.NN]
1330	one-at-a-time	[PWG5100.NN]
1331	pdf-features-supported (1setOf type2 keyword)	[PWG5100.NN]
1332	prc	[PWG5100.NN]
1333	u3d	[PWG5100.NN]
1334	print-objects-supported (1setOf type2 keyword)	[PWG5100.NN]
1335	< any print-objects member attribute name >	[PWG5100.NN]
1336	print-rafts (type2 keyword)	[PWG5100.NN]
1337	brim	[PWG5100.NN]
1338	none	[PWG5100.NN]
1339	raft	[PWG5100.NN]
1340	skirt	[PWG5100.NN]
1341	standard	[PWG5100.NN]
1342	print-supports (type2 keyword)	[PWG5100.NN]
1343	material	[PWG5100.NN]
1344	none	[PWG5100.NN]
1345	standard	[PWG5100.NN]
1346	printer-state-reasons (1setOf type2 keyword)	[RFC8011]
1347	camera-failure	[PWG5100.NN]
1348	chamber-cooling	[PWG5100.NN]
1349	chamber-heating	[PWG5100.NN]
1350	chamber-temperature-high	[PWG5100.NN]
1351	chamber-temperature-low	[PWG5100.NN]
1352	extruder-cooling	[PWG5100.NN]
1353	extruder-failure	[PWG5100.NN]
1354	extruder-heating	[PWG5100.NN]
1355	extruder-jam	[PWG5100.NN]
1356	extruder-temperature-high	[PWG5100.NN]
1357	extruder-temperature-low	[PWG5100.NN]
1358	fan-failure	[PWG5100.NN]
1359	lamp-at-eol	[PWG5100.NN]
1360	lamp-failure	[PWG5100.NN]
1361	lamp-near-eol	[PWG5100.NN]
1362	laser-at-eol	[PWG5100.NN]
1363	laser-failure	[PWG5100.NN]
1364	laser-near-eol	[PWG5100.NN]
1365	material-empty	[PWG5100.NN]
1366	material-low	[PWG5100.NN]
1367	material-needed	[PWG5100.NN]
1368	motor-failure	[PWG5100.NN]

### 1369 13.3 Service Type Registration

1370 The DNS-SD service type defined in this specification will be published by IANA according  
1371 to the procedures in Internet Assigned Numbers Authority (IANA) Procedures for the  
1372 Management of the Service Name and Transport Protocol Port Number Registry  
1373 [BCP165].

1374 The registration template is as follows:

1375       Service Name: ipp3d  
1376  
1377       Transport Protocol(s): tcp  
1378  
1379       Assignee/Contact: Michael Sweet, msweet@apple.com  
1380  
1381       Description: 3D Print services (3D printers) using the Internet Printing  
1382       Protocol over HTTPS.  
1383  
1384       Reference: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-5100.NN.pdf)  
1385       5100.NN.pdf  
1386  
1387       Port Number:  
1388  
1389       Service Code:  
1390  
1391       Known Unauthorized Uses:  
1392  
1393       Assignment Notes: Change controller is The Printer Working Group, c/o The  
1394       IEEE Industry Standards and Technology Organization, 445 Hoes Lane,  
1395       Piscataway, NJ 08854, USA

### 1396 13.4 MIME Media Type Registration

1397 The MIME media type defined in this specification will be published by IANA according to  
1398 the procedures in Media Type Specifications and Registration Procedures [BCP13].

1399 The registration template is as follows:

1400       Type name: model  
1401  
1402       Subtype name: 3mf  
1403  
1404       Required parameters: N/A  
1405  
1406       Optional parameters: N/A  
1407  
1408       Encoding considerations: binary  
1409  
1410       Security considerations: 3MF files can be very large, particularly after  
1411       decompression, which could fill a filesystem and cause a denial of service  
1412       or system failure. This media type does not employ any sort of active or  
1413       executable content. Neither privacy nor integrity protection is provided  
1414       by the media type itself; if these protections are needed they must be

1415 implemented externally. Authentication, access control, and  
1416 privacy/integrity are normally handled by the Internet Printing Protocol,  
1417 Hyper-Text Transport Protocol, and Transport Layer Security.  
1418  
1419 Interoperability considerations:  
1420  
1421 Published specification: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-5100.NN.pdf)  
1422 [YYYYMMDD-5100.NN.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-5100.NN.pdf)  
1423  
1424 Applications that use this media type: 3D modeling and slicing software  
1425  
1426 Fragment identifier considerations:  
1427  
1428 Additional information:  
1429  
1430 Deprecated alias names for this type: N/A  
1431  
1432 Magic number(s): N/A  
1433  
1434 File extension(s): 3mf  
1435  
1436 Macintosh file type code(s): N/A  
1437  
1438 Person & email address to contact for further information: Michael Sweet,  
1439 [msweet@apple.com](mailto:msweet@apple.com)  
1440  
1441 Intended usage: COMMON  
1442  
1443 Restrictions on usage: N/A  
1444  
1445 Author/Change controller: The Printer Working Group, c/o The IEEE Industry  
1446 Standards and Technology Organization, 445 Hoes Lane, Piscataway, NJ  
1447 08854, USA  
1448  
1449 Provisional registration? (standards tree only): No

## 1450 13.5 Semantic Model Registrations

1451 The IPP attributes, values, and operations defined in this specification and listed in the  
1452 preceding sections will be added to the PWG Semantic Model XML schema using the  
1453 method defined in section 21 of [PWG5108.07].  
1454



## 1455 14. References

### 1456 14.1 Normative References

- 1457 [3MF] "3D Manufacturing Format Core Specification & Reference Guide  
1458 v1.0", [http://www.3mf.io/wp-](http://www.3mf.io/wp-content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf)  
1459 [content/uploads/2015/04/3MFcoreSpec\\_1.0.1.pdf](http://www.3mf.io/wp-content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf)
- 1460 [BONJOUR] Apple Inc., "Bonjour Printing Specification Version 1.2", July 2013,  
1461 <http://developer.apple.com/bonjour/>
- 1462 [ECMA363] "Universal 3D File Format", ECMA-363
- 1463 [IPP-USB] "IPP USB Specification",  
1464 [http://www.usb.org/developers/devclass\\_docs](http://www.usb.org/developers/devclass_docs)
- 1465 [ISO10646] "Information technology -- Universal Coded Character Set (UCS)",  
1466 ISO/IEC 10646:2011
- 1467 [ISO14739] "Document management -- 3D use of Product Representation  
1468 Compact (PRC) format -- Part 1: PRC 10001", ISO 14739-1:2014
- 1469 [ISO32000] "Document management — Portable document format — Part 1: PDF  
1470 1.7", ISO 32000-1:2008
- 1471 [ISO52915] "Standard Specification for Additive Manufacturing File Format (AMF)  
1472 Version 1.1", ISO/ASTM 52915:2013
- 1473 [JFIF] E. Hamilton, "JPEG File Interchange Format Version 1.02",  
1474 September 1992, <http://www.w3.org/Graphics/JPEG/jif3.pdf>
- 1475 [PWG5100.5] D. Carney, T. Hastings, P. Zehler, "IPP: Document Object", PWG  
1476 5100.5-2003, October 2003, [http://ftp.pwg.org/pub/pwg/candidates/cs-](http://ftp.pwg.org/pub/pwg/candidates/cs-ippdocobject10-20031031-5100.5.pdf)  
1477 [ippdocobject10-20031031-5100.5.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippdocobject10-20031031-5100.5.pdf)
- 1478 [PWG5100.11] T. Hastings, D. Fullman, "IPP Job and Printer Extensions - Set 2  
1479 (JPS2)", PWG 5100.11-2010, October 2010,  
1480 [http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-20101030-5100.11.pdf)  
1481 [20101030-5100.11.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-20101030-5100.11.pdf)
- 1482 [PWG5100.12] M. Sweet, I. McDonald, "IPP Version 2.0, 2.1, and 2.2", PWG  
1483 5100.12-2015, October 2015,  
1484 <http://ftp.pwg.org/pub/pwg/standards/std-ipp20-20151030-5100.12.pdf>
- 1485 [PWG5100.13] M. Sweet, I. McDonald, "IPP Job and Printer Extensions - Set 3  
1486 (JPS3)", PWG 5100.13-2012, July 2012,

- 1487 <http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext3v10-20120727-5100.13.pdf>  
1488
- 1489 [PWG5100.14] M. Sweet, I. McDonald, A. Mitchell, J. Hutchings, "IPP Everywhere",  
1490 PWG 5100.14-2013, January 2013,  
1491 <http://ftp.pwg.org/pub/pwg/candidates/cs-ippeve10-20130128-5100.14.pdf>  
1492
- 1493 [PWG5100.18] M. Sweet, I. McDonald, "IPP Shared Infrastructure Extensions  
1494 (INFRA)", PWG 5100.18-2015, June 2015,  
1495 <http://ftp.pwg.org/pub/pwg/candidates/cs-ippinfra10-20150619-5100.18.pdf>  
1496
- 1497 [PWG5108.01] W. Wagner, P. Zehler, "MFD Model and Common Semantics", PWG  
1498 5108.01-2011, April 2011, <http://ftp.pwg.org/pub/pwg/candidates/cs-sm20-mfdmodel10-20110415-5108.1.pdf>  
1499
- 1500 [PWG5108.07] P. Zehler, "PWG Print Job Ticket and Associated Capabilities Version  
1501 1.0 (PJT)", PWG 5108.07-2012, August 2012,  
1502 <http://ftp.pwg.org/pub/pwg/candidates/cs-sm20-pjt10-20120801-5108.07.pdf>  
1503
- 1504 [RFC2083] T. Boutell, "PNG (Portable Network Graphics) Specification Version  
1505 1.0", RFC 2083, March 1997, <http://tools.ietf.org/html/rfc2083>
- 1506 [RFC2119] S. Bradner, "Key words for use in RFCs to Indicate Requirement  
1507 Levels", RFC 2119/BCP 14, March 1997,  
1508 <http://tools.ietf.org/html/rfc2119>
- 1509 [RFC2136] P. Vixie, S. Thomson, Y. Rekhter, J. Bound, "Dynamic Updates in the  
1510 Domain Name System (DNS UPDATE)", RFC 2136, April 1997,  
1511 <http://tools.ietf.org/html/rfc2136>
- 1512 [\[RFC3510\]](http://tools.ietf.org/html/rfc3510) R. Herriot, I. McDonald, "Internet Printing Protocol/1.1: IPP URL  
1513 Scheme", RFC 3510, April 2003, <http://tools.ietf.org/html/rfc3510>
- 1514 [RFC3805] R. Bergman, H. Lewis, I. McDonald, "Printer MIB v2", RFC 3805, June  
1515 2004, <http://tools.ietf.org/html/rfc3805>
- 1516 [RFC3806] R. Bergman, H. Lewis, I. McDonald, "Printer Finishing MIB", RFC  
1517 3806, June 2004, <http://tools.ietf.org/html/rfc3806>
- 1518 [\[RFC4122\]](http://tools.ietf.org/html/rfc4122) P. Leach, M. Mealling, R. Salz, "A Universally Unique Identifier  
1519 (UUID) URN Namespace", RFC 4122, July 2005,  
1520 <http://tools.ietf.org/html/rfc4122>

- 1521 [\[RFC4510\]](#) [Zeilenga, K., Ed., "Lightweight Directory Access Protocol \(LDAP\):](#)  
1522 [Technical Specification Road Map", RFC 4510, June 2006,](#)  
1523 <http://tools.ietf.org/html/rfc4510>
- 1524 [RFC5198] J. Klensin, M. Padlipsky, "Unicode Format for Network Interchange",  
1525 RFC 5198, March 2008, <http://tools.ietf.org/html/rfc5198>
- 1526 [RFC5246] T.Dierks, E. Rescorla, "Transport Layer Security 1.2", RFC 5246,  
1527 August 2008, <http://tools.ietf.org/html/rfc5246>
- 1528 [RFC6762] S. Cheshire, M. Krochmal, "Multicast DNS", RFC 6762, February  
1529 2013, <http://tools.ietf.org/html/rfc6762>
- 1530 [RFC6763] S. Cheshire, M. Krochmal, "DNS-Based Service Discovery", RFC  
1531 6763, February 2013, <http://tools.ietf.org/html/rfc6763>
- 1532 [\[RFC7230\]](#) [R. Fielding, J. Reschke, "Hypertext Transfer Protocol \(HTTP/1.1\):](#)  
1533 [Message Syntax and Routing", RFC 7230, June 2014,](#)  
1534 <http://tools.ietf.org/html/rfc7230>
- 1535 [\[RFC7232\]](#) [R. Fielding, J. Reschke, "Hypertext Transfer Protocol \(HTTP/1.1\):](#)  
1536 [Conditional Requests", RFC 7232, June 2014,](#)  
1537 <http://tools.ietf.org/html/rfc7232>
- 1538 [\[RFC7234\]](#) [R. Fielding, M. Nottingham, J. Reschke, "Hypertext Transfer Protocol](#)  
1539 [\(HTTP/1.1\): Caching", RFC 7234, June 2014,](#)  
1540 <http://tools.ietf.org/html/rfc7234>
- 1541 [RFC7472] I. McDonald, M. Sweet, "IPP over HTTPS Transport Binding and 'ipps'  
1542 URI Scheme", RFC 7472, March 2015,  
1543 <http://tools.ietf.org/html/rfc7472>
- 1544 [RFC7612] P. Flemming, I. McDonald, "Lightweight Directory Access Protocol  
1545 (LDAP): Schema for Printer Services", RFC 7612, June 2015,  
1546 <http://tools.ietf.org/html/rfc7612>
- 1547 [RFC8011] M. Sweet, I. McDonald, "Internet Printing Protocol/1.1: Model and  
1548 Semantics", RFC 8011, December 2016,  
1549 <http://tools.ietf.org/html/rfc8011>
- 1550 [STD63] F. Yergeau, "UTF-8, a transformation format of ISO 10646", RFC  
1551 3629/STD 63, November 2003, <http://tools.ietf.org/html/rfc3629>
- 1552 [UAX9] Unicode Consortium, "Unicode Bidirectional Algorithm", UAX#9, June  
1553 2014,  
1554 <http://www.unicode.org/reports/tr9/tr9-31.html>

- 1555 [UAX14] Unicode Consortium, “Unicode Line Breaking Algorithm”, UAX#14,  
1556 June 2014,  
1557 <http://www.unicode.org/reports/tr14/tr14-33.html>
- 1558 [UAX15] Unicode Consortium, “Normalization Forms”, UAX#15, June 2014,  
1559 <http://www.unicode.org/reports/tr15/tr15-41.html>
- 1560 [UAX29] Unicode Consortium, “Unicode Text Segmentation”, UAX#29, June  
1561 2014,  
1562 <http://www.unicode.org/reports/tr29/tr29-25.html>
- 1563 [UAX31] Unicode Consortium, “Unicode Identifier and Pattern Syntax”,  
1564 UAX#31, June 2014,  
1565 <http://www.unicode.org/reports/tr31/tr31-21.html>
- 1566 [UNICODE] Unicode Consortium, "Unicode Standard", Version 9.0.0, June 2016,  
1567 <http://www.unicode.org/versions/Unicode9.0.0/>
- 1568 [UTS10] Unicode Consortium, “Unicode Collation Algorithm”, UTS#10, June  
1569 2014,  
1570 <http://www.unicode.org/reports/tr10/tr10-30.html>
- 1571 [UTS35] Unicode Consortium, “Unicode Locale Data Markup Language”,  
1572 UTS#35, September 2014,  
1573 <http://www.unicode.org/reports/tr35/tr35-37/tr35.html>
- 1574 [UTS39] Unicode Consortium, “Unicode Security Mechanisms”, UTS#39,  
1575 September 2014,  
1576 <http://www.unicode.org/reports/tr39/tr39-9.html>

## 1577 14.2 Informative References

- 1578 [BCP13] N. Freed, J. Klensin, T. Hansen, "Media Type Specifications and  
1579 Registration Procedures", BCP 13, RFC 6838,  
1580 <http://tools.ietf.org/html/rfc6838>
- 1581 [BCP165] M. Cotton, L. Eggert, J. Touch, M. Westerlund, S. Cheshire, "Internet  
1582 Assigned Numbers Authority (IANA) Procedures for the Management  
1583 of the Service Name and Transport Protocol Port Number Registry",  
1584 BCP 165, RFC 6335, <http://tools.ietf.org/html/rfc6335>
- 1585 [IPPSAMPLE] "ISTO-PWG IPP Sample Code Repository",  
1586 <https://github.com/istopwg/ippsample>
- 1587 [RFC3196] T. Hastings, C. Manros, P. Zehler, C. Kugler, H. Holst, "Internet  
1588 Printing Protocol/1.1: Implementer's Guide", RFC 3196, November  
1589 2001, <http://tools.ietf.org/html/rfc3196>

- 1590 [STLFORMAT] 3D Systems, Inc., "SLC File Specification", 1994
- 1591 [UNISECFAQ] Unicode Consortium "Unicode Security FAQ", November 2013,  
1592 <http://www.unicode.org/faq/security.html>
- 1593 [UTR17] Unicode Consortium "Unicode Character Encoding Model", UTR#17,  
1594 November 2008,  
1595 <http://www.unicode.org/reports/tr17/tr17-7.html>
- 1596 [UTR20] Unicode Consortium "Unicode in XML and other Markup Languages",  
1597 UTR#20, January 2013,  
1598 <http://www.unicode.org/reports/tr20/tr20-9.html>
- 1599 [UTR23] Unicode Consortium "Unicode Character Property Model", UTR#23,  
1600 November 2008,  
1601 <http://www.unicode.org/reports/tr23/tr23-9.html>
- 1602 [UTR33] Unicode Consortium "Unicode Conformance Model", UTR#33,  
1603 November 2008,  
1604 <http://www.unicode.org/reports/tr33/tr33-5.html>

## 1605 **15. Author's Address**

1606 Primary author:

1607 Michael Sweet  
1608 Apple Inc.  
1609 1 Infinite Loop  
1610 MS 111-HOMC  
1611 Cupertino, CA 95014  
1612 msweet@apple.com

1613 The authors would also like to thank the following individuals for their contributions to this  
1614 standard:

1615 Olliver Schinagl, Ultimaker B.V.  
1616 Michael Scrutton, Adobe Systems  
1617 Emmet Lalish, Microsoft Corporation  
1618

## 1619 **16. Object Definition Languages (ODLs)**

1620 This section provides information on several commonly used ODLs with either existing  
1621 (registered) or suggested MIME media types.

### 1622 **16.1 3D Manufacturing Format (3MF)**

1623 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that  
1624 provides geometry, material, and texture information necessary to support a wide variety of  
1625 3D printers. Materials can be named and composed within the geometry, facilitating  
1626 multiple material support in coordination with a Job Ticket.

1627 The registered MIME media type for the original Microsoft published specification is  
1628 "application/vnd.ms-3mfdocument". The suggested (but not registered) MIME media type  
1629 for the 3MF Consortium's published specification is "model/3mf".

### 1630 **16.2 Additive Manufacturing Format (AMF)**

1631 AMF [ISO52915] is a relatively new format that was designed as a replacement for the  
1632 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-  
1633 available specification, but has several advantages over STL including:

- 1634 1. Shared vertices which eliminates holes and other breaks in the surface  
1635 geometry of objects,
- 1636 2. Specification of multiple materials in a single file,
- 1637 3. Curved surfaces can be specified, and
- 1638 4. Coordinates use explicit units for proper output dimensions.

1639 The suggested (but not registered) MIME media type is 'model/amf'.

### 1640 **16.3 Portable Document Format (PDF)**

1641 PDF [ISO32000] is widely supported for 2D printing and has two 3D formats that are used  
1642 to embed 3D objects - PRC [ISO14739-1] and U3D [ECMA363]. The registered MIME  
1643 media type for PDF is "application/pdf".

1644 [For discussion: define a "model/pdf" MIME media type for PDFs containing 3D content?]

### 1645 **16.4 Standard Tessellation Language (STL)**

1646 STL [STLFORMAT] is widely supported by existing client software. The registered MIME  
1647 media type is 'application/sla'.

1648

## 1649 **17. Design Choices**

1650 This section documents some of the design choices that were made during the  
1651 development of this specification.

### 1652 **17.1 Units for Length Values**

1653 The default unit for most length values is hundredths of millimeters (1/2540th of an inch),  
1654 matching the units for 2D printing and providing a range of 0.01mm to 21.47km. This was  
1655 determined to be sufficient for the class of printers this specification targets.

### 1656 **17.2 Units for Thickness Values**

1657 The default unit for most thickness values is nanometers, which provides a range of  
1658 0.000001mm to 2.147m. This was determined to be sufficient for the class of printers this  
1659 specification targets.

### 1660 **17.3 Use of Celsius for Temperatures**

1661 The various integer attributes for temperature use degrees Celsius. This was done  
1662 because most existing printers and materials are specified using degrees Celsius. There is  
1663 no advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to  
1664 perform additional unit conversions could cause safety issues. All temperature attributes  
1665 use a range of -273 (absolute zero) to MAX (2147483647 - significantly hotter than our  
1666 sun) to allow flexibility.

### 1667 **17.4 Explicit Units for Other Values**

1668 Some attributes have a companion "xxx-units" attribute that specifies an explicit unit for the  
1669 given measurement(s). The initial list of unit values for each attribute has been limited to  
1670 those necessary for current printers and technologies at the time of writing of this  
1671 specification in order to minimize interoperability issues.

### 1672 **17.5 Intent vs. Process**

1673 The IPP Model [RFC8011], and more generally the PWG Semantic Model [PWG5108.1],  
1674 have long focused on Job Tickets specifying "what" is wanted for the printed output vs.  
1675 "how" that output is produced. This focus has served IPP well and allowed it to be used  
1676 with wildly different printing technologies.

1677 During the development of this specification, attributes that define a specific process or  
1678 technological parameter have been introduced and later replaced by intent-based  
1679 alternatives that allow an implementation to select suitable process-based parameters at

1680 print time, preserving the intrinsic value of such parameters without burdening the Client or  
1681 End User with such things.

1682 At the same time, some process parameters are needed for things like material  
1683 specification. For example, a particular brand of PLA may require a higher melting  
1684 temperature - this information might only be known to the End User, so the "materials-col"  
1685 collection contains an member attribute to convey this process-specific parameter. The  
1686 Printer advertises whether temperature is a valid material property in the "materials-col-  
1687 supported" Printer Description attribute.

1688 Finally, IPP does not prohibit the definition or use of process-based Job Template  
1689 attributes for specific implementations. Such extension attributes can be listed in the "job-  
1690 creation-attributes-supported" Printer Description attribute to notify Clients of their  
1691 existence.

## 1692 **17.6 Choosing a Required Document Format**

1693 One of the design consideration of this specification is to choose an open, freely available  
1694 file format for use as required document format. Having a required document format  
1695 makes interoperability significantly easier, and using an open and freely available format  
1696 allows developers of "consumer" printers to support IPP 3D. Several formats were  
1697 considered, including STL, AMF, PDF, and 3MF.

1698 While STL is a widely-implemented, open, and freely available file format, it lacks support  
1699 for multiple materials and colors/textures, and has technical issues that cause "holes" in  
1700 generated models.

1701 While AMF supports multiple materials and does not have the "holes" issue, it is not freely  
1702 available nor widely-implemented.

1703 PDF is the most capable 3D format but is not freely available and has the interoperability  
1704 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-  
1705 features-supported" Printer Description attribute (section 8.3.17) allows Clients to  
1706 determine whether a 3D PDF file can be printed by the Printer.

1707 3MF is open and freely available, supports multiple materials and color/textures, does not  
1708 have the "holes" issue of STL, and has a freely available open source implementation that  
1709 supports both creation and consumption of 3MF files.  
1710



## 1711 **18. Change History**

### 1712 **18.1 January 10, 2017**

- 1713 1. MS1: Added "max-materials-col-supported" to Table 5 (required Printer  
1714 Description attributes)

### 1715 **18.2 December 13, 2016**

- 1716 1. MS1: Added "max-materials-col-supported" Printer Description attribute.  
1717 2. MS2: Added "material-diameter-tolerance" member attribute for "materials-col".  
1718 3. MS3: Removed "job-constraints-supported" and "job-resolvers-supported"  
1719 attributes from table 5 (not all printers have constraints).  
1720 4. SK1, SK2: Reworded section 1 introduction.  
1721 5. SK3, SK4: Add 3D PDF and 3MF to organizations, make all URLs hyperlinks  
1722 6. SK6: Added references to PDF, U3D, and PRC specs in section 3.  
1723 7. SK8: Added Discovery and related terms from IPP Everywhere specification.  
1724 8. SK9: Fixed formatting between table 2 and section 5.1.3.  
1725 9. SK10: Added LDAP OID in section 5.2.  
1726 10. Global: Updated references to RFC 2911 to RFC 8011  
1727 11. Section 14.1: Added missing references  
1728 12. Table 9 and section 8.2: Add missing -actual attributes and fix references.  
1729 13. SK16: Fixed "model/3mf" spelling mistakes.

### 1730 **18.3 November 14, 2016**

- 1731 1. Status: Stable  
1732 2. Added "color-supported" as a required Printer Description attribute.

### 1733 **18.4 August 24, 2016**

- 1734 1. Section 5.1.2: "over DNS-SD"  
1735 2. Section 6.4: Dropped document-password from required operation attributes  
1736 3. Section 6.5: Dropped document-password-supported from required Printer  
1737 Description attributes, fixed section reference for material-shell-thickness, fixed  
1738 note 1 reference for link-local addresses.  
1739 4. Section 6.7: Fixed section references.  
1740 5. Section 8.1: Updated print-accuracy -supported attributes.  
1741 6. Section 8.1.3: Broke up print-accuracy member attributes into subsections.  
1742 7. Section 8.1.4: Added table listing member attributes.  
1743 8. Sections 8.1.4.x: Added syntax to each of the sub-member attributes.  
1744 9. Section 8.2: Reworked as table listing the member attributes.  
1745 10. Section 8.3.18: Reworded as the best supported "print-accuracy" value.  
1746 11. Section 8.3.27: Broke up member attributes into subsections.

1747 12. Section 17.3: Mentioned the range for temperature values.

## 1748 **18.5 August 16, 2016**

- 1749 1. Section 1: Added informative reference to IPP sample code.
- 1750 2. Section 6.2: Fixed reference to HTTP/1.1 spec.
- 1751 3. Section 6.2.2: "camera image" instead of "ICC profile".
- 1752 4. Table 5: Added missing print-accuracy-default attribute, fix link-local rule to point
- 1753 to PWG5100.14.
- 1754 5. Table 6: Add missing reference for printer-camera-image-uri attribute, drop note
- 1755 3.
- 1756 6. Section 8.1.1.4: Use nanometers for material-diameter, just like material-shell-
- 1757 thickness.
- 1758 7. Section 8.1.1.10: Added '\_sec' to material-rate-units values.
- 1759 8. Section 8.1.3: Added accuracy-units member attribute.
- 1760 9. Section 8.3.x: Added missing print-accuracy-default attribute.
- 1761 10. Section 8.3.x: Added accuracy-units-supported attribute.
- 1762 11. Section 8.3.6: Fix reference to "material-shell-thickness" member attribute.
- 1763 12. Section 8.3.11: Required.
- 1764 13. Section 8.3.13: List required values.
- 1765 14. Section 10.x: Fix spelling of "attribute" and section reference for document
- 1766 formats.
- 1767 15. Section 13: Updated registration information.
- 1768 16. Section 14.1: Updated Unicode reference to v9.0.0.
- 1769 17. Section 14.2: Added informative reference to IPP sample code.
- 1770 18. Section 17: Update and talk about length, thickness, and explicit unit attribute
- 1771 values.

## 1772 **18.6 July 14, 2016**

- 1773 1. Updated with conformance requirements.
- 1774 2. Added a new Protocol Binding section that outlines the core IPP and HTTP
- 1775 requirements.
- 1776 3. Section 8.1.x: Made materials-col, print-rafts, and print-supports REQUIRED,
- 1777 print-objects and multiple-object-handling CONDITIONALLY REQUIRED for
- 1778 PDF printers, added printer-bed-temperature and made it CONDITIONALLY
- 1779 REQUIRED for printers with a temperature-controlled build platform.
- 1780 4. Table 3: The supported values for print-accuracy are in print-accuracy-
- 1781 supported, not x/y/z-accuracy-supported.
- 1782 5. Section 8.1.4: Changed print-accuracy to use hundredths of millimeters for the
- 1783 units, with 0 being <0.01mm.
- 1784 6. Section 8.2: The -actual attributes are all Job Status (read-only)
- 1785 7. Section 8.3.16: Changed to use hundredths of millimeters for units.
- 1786 8. Section 8.3.x: Add printer-bed-temperature-default and -supported.

**1787 18.7 April 30, 2016**

- 1788 1. Status: Prototype
- 1789 2. Section 3.1.x: Added a new use case for tool printing where precision is needed.
- 1790 3. Section 3.3 and 3.4: Updated list of design requirements and out-of-scope items
- 1791 based on April 2016 F2F discussions.
- 1792 4. New Section 5 for transport and resource path requirements.
- 1793 5. Section 6.1: No longer reference Bonjour Printing spec, but instead define
- 1794 everything here. Service type is now "\_ipp3d.\_tcp".
- 1795 6. Section 6.2: FILL in LDAP information.
- 1796 7. Section 8.1: Drop print-quality-details, add print-accuracy, make print-objects a
- 1797 1setOf collection
- 1798 8. Section 8.1.1: Add material-fill-density and material-shell-thickness member
- 1799 attributes
- 1800 9. Section 8.1.3: Change to 1setOf collection and define member attributes for
- 1801 dimensions, offset, UUID, and document number.
- 1802 10. Section 8.2: Add print-objects-actual
- 1803 11. Section 8.3: Add material-thickness-supported, print-accuracy-supported, and
- 1804 drop print-quality-details-xxx
- 1805 12. Section 8.3.17: print-objects-supported is now a 1setOf type2 keyword
- 1806 13. Section 8.3.23: Dimensions are in hundredths of millimeters
- 1807 14. Section 10: Filled in conformance requirements
- 1808 15. Section 12.1: Talk about confidentiality
- 1809 16. Section 13: Filled in IANA considerations
- 1810 17. Section 17: Talk about use of PWG units (hundredths of millimeters) and
- 1811 nanometers.

**1812 18.8 April 20, 2016**

- 1813 1. Section 4.2: Add note that not all subunits are exposed, input tray/roll, trimmers
- 1814 are All.
- 1815 2. Section 4.3: Update Figure 2
- 1816 3. Section 4.6: Fix section reference
- 1817 4. Section 5: Drop SLP
- 1818 5. Section 5.1: Update to use \_ipp3d.\_tcp, define TXT record
- 1819 6. Section 5.2: Drop SLP
- 1820 7. Section 7.1.4: Clarify keyword value definitions.

**1821 18.9 March 3, 2016**

- 1822 1. Added background on choice of 3MF vs. PDF.
- 1823 2. Added PDF to list of ODLs.
- 1824 3. Added pdf-features-supported attribute.

**1825 18.10 February 17, 2016**

- 1826 1. Global: "Document" instead of "document".
- 1827 2. Added discovery protocols and document formats sections, with requirements.
- 1828 3. Section 1: Reworded, added discovery and standard ODL discussion.
- 1829 4. Section 1.1: Dropped
- 1830 5. Section 4.2: Reworked subunits to be abstract views necessary for maintenance
- 1831 and status monitoring, entirely matching up with the Printer and Finisher MIBs
- 1832 6. Section 4.3: Replace Figure 2 with a depiction of the build volume, explain IPP
- 1833 coordinate system for build volume
- 1834 7. Section 4.4: Reword and drop mention of temperatures as intent.
- 1835 8. Section 5.1.x: Drop all of the process attributes (thickness, fill percent, speed,
- 1836 temperatures), add new print-quality-details attribute
- 1837 9. Section 5.1.1: Reference materials-col-supported, materials-col.material-name is
- 1838 enough in job ticket to use existing -database or -ready.
- 1839 10. Section 5.1.2: Added multiple-object-handling attribute
- 1840 11. Section 5.1.1.10: Clarified this is the printing temperature.
- 1841 12. Section 5.1.1.11: Dropped "filament", "powder", etc., talk about localization of
- 1842 values, and make "keyword | name".
- 1843 13. Section 5.3.x: Drop all of the process attributes, add new multiple-object-
- 1844 handling-xxx and print-quality-details-xxx attributes
- 1845 14. Section 5.4.x: Dropped
- 1846 15. Section 11.x: Updated references, moved STL to informative section, added
- 1847 PDF 1.7 (ISO 32000)
- 1848 16. Section 14.3: Added section on process vs intent

**1849 18.11 February 1, 2016**

- 1850 1. Updated front matter for working draft
- 1851 2. Fixed one remaining use of "white paper"

**1852 18.12 January 28, 2016**

- 1853 1. Updated to working draft template.
- 1854 2. Fixed document URLs.
- 1855 3. Global: "white paper" changed to "specification" as needed.
- 1856 4. Abstract: "this specification", extension to IPP Everywhere as well.
- 1857 5. Section 4: "3D Print Service Model", remove old intro text
- 1858 6. Dropped tables 1-3, instead just say "same as 2D print service" and mention that
- 1859 certain Job Template attributes such as "media" are not applicable to most 3D
- 1860 printers.
- 1861 7. Table 4: Added section references, reordered so that all RFC 3805 subunits are
- 1862 listed first.
- 1863 8. Section 4.x: Reword in places now that this is a specification.
- 1864 9. Section 5: Added subunit collection attributes

- 1865 10. Section 6: Add registration (instead of just suggestion)  
1866 11. Added Section 14 on design choices

### 1867 **18.13 November 16, 2015**

- 1868 1. Section 1: Fix typos  
1869 2. Section 3: Updated rationale to talk about 3MF instead of AMF and STL  
1870 3. Section 4: Added new subsection on the 3D Print Service and the operations  
1871 and attributes that are used.  
1872 4. Section 4.3: Added Chambers to list of subunits since we are providing access  
1873 to the temperature.  
1874 5. Section 5.1.1: Added table listing all member attributes.  
1875 6. Section 5.1.1.x: Added sections on material-amount, material-amount-units,  
1876 material-diameter, material-rate, material-rate-units  
1877 7. Section 5.1.1.x: Renamed "material-use" to "material-purpose" to avoid  
1878 confusion with "material-amount-xxx".  
1879 8. Section 5.3: Add new materials-col member attribute -supported attributes  
1880 9. Section 7.1: Note existing MS 3DMF MIME media type  
1881 10. Global: printer-bed-xxx -> printer-platform-xxx  
1882 11. Global: Add range for all temperature attributes (-273:MAX)

### 1883 **18.14 October 29, 2015**

- 1884 1. Greatly expanded the discussion of how current solutions work and the IPP  
1885 model  
1886 2. Added discussion points for amount of material used  
1887 3. Added materials-col-actual Job Description attribute  
1888 4. Added 3MF description and reference  
1889 5. Fixed link to IPP Everywhere in references

### 1890 **18.15 August 12, 2015**

- 1891 1. Dropped "0.1" from the title  
1892 2. Various typographical changes  
1893 3. Section 2.2: Added ODL acronym  
1894 4. Table 1: Added reference column  
1895 5. Figure 1: Updated figure to show Z increasing downward (direction of build  
1896 platform movement)  
1897 6. Section 4.x: Added sub-section on output intent.  
1898 7. Section 5.1: Added table listing Job Template and corresponding -default and -  
1899 supported attributes.  
1900 8. Section 5.1.1.4: Added more types of filament, solid wax, and clarification on the  
1901 names used for material type keywords.  
1902 9. Section 5.1.1.5: Made material-use 1setOf, added 'all' value.

- 1903 10. Updated printer-bed-temperature-supported and printer-chamber-temperature-  
1904 supported to allow 'no-value' values.  
1905 11. Section 9.x: Added subsections on specific 3D printing security considerations.

1906 **18.16 July 29, 2015**

- 1907 1. Dropped all references to X3G and G-code.  
1908 2. Reworked materials-col to specify materials but not temperatures and other  
1909 physical properties  
1910 3. Added “material-use” member attribute to assign materials to specific uses.  
1911 4. Supports and rafts pick materials based on “material-use” values and not  
1912 indices.  
1913 5. Added reference to IPP INFRA  
1914 6. Added printer-camera-image-uri Printer Description attribute.

1915 **18.17 April 13, 2015**

- 1916 1. Updated front matter to incorporate new IEEE-ISTO boilerplate for a contributed  
1917 white paper.

1918 **18.18 April 5, 2015**

- 1919 1. Updated front matter to remove IEEE-ISTO boilerplate.  
1920 2. Fixed various typos  
1921 3. Clarified that SLC files are commonly known as STL files.  
1922 4. Clarified that S3G is a binary version of G-code with a standard packet format.  
1923 5. Added use case for printing with loaded materials  
1924 6. Added use case for multi-material printing on a single material printer.  
1925 7. Added use case for monitoring print progress visually with a web cam.  
1926 8. Added exception for "skipping" (insufficient material flow/feed)  
1927 9. Added exception for adhesion issues  
1928 10. Added exception for build plate being full.  
1929 11. Added exception for head movement issues.  
1930 12. Added figure showing the typical coordinate system.  
1931 13. Expanded Job Template and Printer Description details, added comments for  
1932 discussion.  
1933 14. Added new Unicode considerations and references.

1934 **18.19 January 23, 2015**

- 1935 Initial revision.