



The Printer Working Group

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White Paper

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IPP 3D Printing Extensions (3D)

Status: Interim

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

This document is a White Paper. For a definition of a "White Paper", see:

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

This document is available electronically at:

<http://ftp.pwg.org/pub/pwg/ipp/ws/wd-sweet-ipp3d-20151116.docx>

<http://ftp.pwg.org/pub/pwg/ipp/ws/wd-sweet-ipp3d-20151116.pdf>

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Table of Contents

13

14 1. Introduction..... 6

15 1.1 Previous Solutions 6

16 2. Terminology..... 7

17 2.1 3D Printing Terminology 7

18 2.2 Acronyms and Organizations..... 7

19 3. Rationale for IPP 3D Printing Extensions 9

20 3.1 Use Cases 9

21 3.1.1 Print a 3D Object..... 9

22 3.1.2 Print a 3D Object Using Loaded Materials 9

23 3.1.3 Print a 3D Object with Multiple Materials 9

24 3.1.4 View a 3D Object During Printing..... 9

25 3.2 Exceptions 10

26 3.2.1 Clogged Extruder 10

27 3.2.2 Extruder Temperature Out of Range..... 10

28 3.2.3 Extruder Head Movement Issues 10

29 3.2.4 Filament Feed Jam 10

30 3.2.5 Filament Feed Skip 10

31 3.2.6 Material Empty 10

32 3.2.7 Material Adhesion Issues 10

33 3.2.8 Print Bed Temperature Out of Range 11

34 3.2.9 Print Bed Not Clear 11

35 3.3 Out of Scope 11

36 3.4 Design Requirements 11

37 4. Technical Solutions/Approaches 12

38 4.1 High-Level Model..... 12

39 4.2 3D Print Service 14

40 4.3 3D Printer Subunits..... 18

41 4.3.1 Build Platforms 19

42 4.3.2 Cameras..... 19

43 4.3.3 Chambers..... 19

44 4.3.4 Cutters 19

45 4.3.5 Fans 19

46 4.3.6 Lamps 19

47 4.3.7 Lasers 19

48 4.3.8 Markers (or Extruders) 19

49 4.3.9 Motors 20

50 4.3.10 Reservoirs 20

51 4.4 3D Printer Coordinate System 20

52 4.5 Output Intent and Job Processing 21

53 4.6 Job Spooling 21

54 4.7 Cloud-Based Printing 21

55 5. New Attributes 22

56 5.1 Job Template Attributes 22

57 5.1.1 materials-col (1setOf collection)..... 23

58 5.1.2 print-fill-density (integer(0:100)) 26

59 5.1.3 print-fill-thickness (integer(0:MAX)) 26

60 5.1.4 print-layer-thickness (integer(0:MAX)) 26

61 5.1.5 print-rafts (type2 keyword) 26

62 5.1.6 print-shell-thickness (integer(0:MAX)) 26

63 5.1.7 print-speed (integer(1:MAX)) 26

64 5.1.8 print-supports (type2 keyword) 26

65 5.1.9 printer-chamber-temperature (integer(-273:MAX) | no-value) 27

66 5.1.10 printer-fan-speed (integer(0:100)) 27

67 5.1.11 printer-platform-temperature (integer(-273:MAX) | no-value) 27

68 5.2 Job Description Attributes 27

69 5.2.1 materials-col-actual (1setOf collection) 27

70 5.3 Printer Description Attributes 27

71 5.3.1 material-amount-units-supported (1setOf type2 keyword) 27

72 5.3.2 material-diameter-supported (1setOf (integer | rangeOfInteger)) 27

73 5.3.3 material-purpose-supported (1setOf type2 keyword) 27

74 5.3.4 material-rate-supported (1setOf (integer | rangeOfInteger)) 27

75 5.3.5 material-rate-units-supported (1setOf type2 keyword) 28

76 5.3.6 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-

77 273:MAX))) 28

78 5.3.7 material-type-supported (1setOf type2 keyword) 28

79 5.3.8 materials-col-database (1setOf collection) 28

80 5.3.9 materials-col-default (1setOf collection) 28

81 5.3.10 materials-col-ready (1setOf collection) 28

82 5.3.11 materials-col-supported (1setOf type2 keyword) 28

83 5.3.12 print-fill-density-default (integer(0:100)) 28

84 5.3.13 print-fill-thickness-default (integer(0:MAX)) 28

85 5.3.14 print-fill-thickness-supported (1setOf (integer(0:MAX) |

86 rangeOfInteger(0:MAX))) 29

87 5.3.15 print-layer-order (type1 keyword) 29

88 5.3.16 print-layer-thickness-default (integer(0:MAX)) 29

89 5.3.17 print-layer-thickness-supported (1setOf (integer(0:MAX) |

90 rangeOfInteger(0:MAX))) 29

91 5.3.18 print-rafts-default (type2 keyword) 29

92 5.3.19 print-rafts-supported (1setOf type2 keyword) 29

93 5.3.20 print-shell-thickness-default (integer(0:MAX)) 29

94 5.3.21 print-shell-thickness-supported (1setOf (integer(0:MAX) |

95 rangeOfInteger(0:MAX))) 29

96 5.3.22 print-speed-default (integer(1:MAX)) 29

97 5.3.23 print-speed-supported (1setOf (integer(1:MAX) | rangeOfInteger(1:MAX))) 30

98 5.3.24 print-supports-default (type2 keyword) 30

99 5.3.25 print-supports-supported (1setOf type2 keyword) 30

100 5.3.26 printer-accuracy-supported (collection) 30

101 5.3.27 printer-camera-image-uri (1setOf uri) 30

102 5.3.28 printer-chamber-temperature-default (integer(-273:MAX) | no-value) 30

103 5.3.29 printer-chamber-temperature-supported (1setOf (integer(-273:MAX) |

104 rangeOfInteger(-273:MAX)) | no-value) 30

105 5.3.30 printer-fan-speed-default (integer(0:MAX)) 30

106 5.3.31 printer-fan-speed-supported (boolean) 30

107 5.3.32 printer-platform-temperature-default (integer(-273:MAX) | no-value) 31

108 5.3.33 printer-platform-temperature-supported (1setOf (integer(-273:MAX) |

109 rangeOfInteger(-273:MAX)) | no-value) 31

110 5.3.34 printer-volume-supported (collection) 31

111 5.4 Printer Status Attributes 31

112 5.4.1 printer-chamber-temperature-current (integer | no-value) 31

113 5.4.2 printer-fan-speed-current (integer(0:100)) 31

114 5.4.3 printer-head-temperature-current (1setOf (integer | no-value)) 31

115 5.4.4 printer-platform-temperature-current (integer(-273:MAX) | no-value) 31

116 6. New Values for Existing Attributes 32

117 6.1 ipp-features-supported (1setOf type2 keyword) 32

118 6.2 printer-state-reasons (1setOf type2 keyword) 32

119 7. Object Definition Languages (ODLs) 33

120 7.1 3D Manufacturing Format (3MF) 33

121 7.2 Additive Manufacturing Format (AMF) 33

122 7.3 Standard Tessellation Language (STL) 34

123 8. Internationalization Considerations 34

124 9. Security Considerations 35

125 9.1 Access Control 35

126 9.2 Physical Safety 35

127 9.3 Material Safety 35

128 9.4 Temperature Control 35

129 10. References 36

130 11. Author's Address 38

131 12. Change History 39

132 12.1 November 16, 2015 39

133 12.2 October 29, 2015 39

134 12.3 August 12, 2015 39

135 12.4 July 29, 2015 40

136 12.5 April 13, 2015 40

137 12.6 April 5, 2015 40

138 12.7 January 23, 2015 40

List of Figures

142 Figure 1 - Generalized IPP Model (RFC 2911) 13

143 Figure 2 - Typical Build Platform Coordinate System 20

List of Tables

147 Table 1 - 3D Printer Subunits 18

Deleted: 1. Introduction - 6 - [1]

Deleted: Figure 1 - Typical Build Platform Coordinate System - 10 -

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155 1. Introduction

156 This white paper defines an extension to the Internet Printing Protocol (IPP) that supports
157 printing of physical objects by Additive Manufacturing devices such as three-dimensional
158 (3D) printers. The attributes and values defined in this document have been prototyped
159 using the CUPS software [CUPS].

160 The primary focus of this document is on popular Fused Deposition Modeling (FDM)
161 devices that melt and extrude ABS and/or PLA filaments in layers to produce a physical,
162 3D object. However, the same attributes can be used for other types of 3D printers that
163 use different methods and materials such as Laser Sintering of powdered materials and
164 curing of liquids using ultraviolet light.

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

168 This document does not address the larger issue of choosing a common Object Definition
169 Language (ODL) for interoperability, however there are suggested MIME media type
170 names listed in section 7, for several formats in common use as well as strategies for
171 mapping material definitions in the Job Ticket to the ODL content.

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172 1.1 Previous Solutions

173 3D printers are commonly bundled with so-called "slicer" software that converts ODL files
174 into a suitable low-level format (G-code, etc.) for the printer. The file produced by the slicer
175 software is then copied to a SD memory card and inserted in a slot on the printer where it
176 can be selected for printing. Some printers also support job submission via USB interface,
177 and third-party Cloud solutions often use the USB interface to print jobs received through
178 the Cloud.

179 Unfortunately, the USB serial protocol used for 3D printers does not support identification
180 of 3D printers or their capabilities, nor is there a single standard protocol in use during job
181 submission or processing (printing). This combined with the use of printer-specific file
182 formats makes direct printing infeasible outside the narrow range of computers supported
183 by the manufacturer, an issue that has plagued 2D printing for years and that the PWG
184 IPP workgroup has helped to mitigate through projects such as IPP Everywhere.

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188 2. Terminology

189 2.1 3D Printing Terminology

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

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

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

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

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

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

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

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

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

208 2.2 Acronyms and Organizations

209 *CNC*: Computer Numerical Control

210 *DLP*: Digital Light Processing

211 *FDM*: Fused Deposition Modeling

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

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

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

215 *ODL*: Object Definition Language

Deleted: Terms Used in This Document

Field Code Changed

- 217 *PWG*: Printer Working Group, <http://www.pwg.org/>
- 218 *SD*: SD Card Association, <http://www.sdcard.org/>
- 219 *SDL*: Selective Deposition Lamination
- 220 *SL*: Stereo Lithography
- 221 *USB*: Universal Serial Bus, <http://www.usb.org/>
- 222

223 3. Rationale for IPP 3D Printing Extensions

224 Existing specifications define the following:

- 225 1. IPP/2.0 Second Edition [PWG5100.12] defines version 2.0, 2.1, and 2.2 of the
226 Internet Printing Protocol which defines a standard operating and data model,
227 interface protocol, and extension mechanism to support traditional Printers;
- 228 2. IPP Everywhere [PWG5100.14] defines a profile of existing IPP specifications,
229 standard Job Template attributes, and standard document formats;
- 230 3. IPP Shared Infrastructure Extensions (INFRA) [PWG5100.18] defines an
231 interface for printing through shared services based in infrastructure such as
232 Cloud servers;
- 233 4. [The 3D Manufacturing Format Core Specification & Reference Guide v1.0 \[3MF\]](#)
234 [defines an XML schema and file format for describing 3D objects with one or](#)
235 [more materials.](#)

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

239 3.1 Use Cases

240 3.1.1 Print a 3D Object

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

244 3.1.2 Print a 3D Object Using Loaded Materials

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

248 3.1.3 Print a 3D Object with Multiple Materials

249 Jane wants to print a multi-material object on a single-material Printer. Jane uses software
250 on her Client device to create Document data that instructs the Printer to pause printing
251 and provide status information at specific layers so that she can change materials at the
252 Printer and resume printing with the new material.

253 3.1.4 View a 3D Object During Printing

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

Deleted: The Standard Specification for Additive Manufacturing File Format (AMF) Version 1.1 [ISO52915] defines an XML schema and file format for describing 3D objects with one or more materials; and . [2]

261 **3.2 Exceptions**

262 **3.2.1 Clogged Extruder**

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

266 **3.2.2 Extruder Temperature Out of Range**

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

271 **3.2.3 Extruder Head Movement Issues**

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

275 **3.2.4 Filament Feed Jam**

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

279 **3.2.5 Filament Feed Skip**

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

283 **3.2.6 Material Empty**

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

287 **3.2.7 Material Adhesion Issues**

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

292 3.2.8 Print Bed Temperature Out of Range

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

296 3.2.9 Print Bed Not Clear

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

301 3.3 Out of Scope

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

- 303 1. Definition of new file formats; and
- 304 2. Support for Subtractive Manufacturing technologies such as CNC milling
305 machines.

306 3.4 Design Requirements

307 The design requirements for this document are:

- 308 3. Define attributes and values to describe supported and loaded (ready) materials
309 used for FDM; and
- 310 4. Define attributes and values to describe FDM printer capabilities and state

311 The design recommendations for this document are:

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

313

314 4. Technical Solutions/Approaches

315 Current 3D printers offer limited connectivity and status monitoring capabilities. Many
316 printers simply read printer-ready files from SD memory cards, with all interaction and
317 status monitoring happening at the printer's console.

318 Makerbot Industries uses a proprietary protocol and file format that generalizes some
319 aspects of the interface between a host device and 3D printer. However, this solution is
320 highly specific to FDM printing and does not offer any spooling or security functionality.

321 Various other proprietary protocols and interfaces are also in use, typically based on the
322 USB serial protocol class for direct connection to a host device. And there are a number of
323 Cloud-based solutions emerging that utilize a proxy device that communicates with the
324 Cloud and 3D printer.

325 Given that the 3D printing industry and technologies are still undergoing a great deal of
326 change and development, certain aspects of 3D printing may be difficult or infeasible to
327 standardize. However, a stable, reliable, and secure interface between host device (IPP
328 Client) and 3D printer (IPP Printer) can be defined today in a way that allows for future
329 changes to be incorporated without difficulty.

330 4.1 High-Level Model

331 The IPP/1.1 Model and Semantics [RFC2911], the IETF Printer MIB [RFC3805], and the
332 IETF Finisher MIB [RFC3806] already define a comprehensive model for the operation and
333 data elements of a typical 2D printer. Figure 1 shows the generalized IPP model. The IPP
334 Server provides the external network interface for IPP Clients, while the Print Service
335 manages and processes Jobs and communicates with the Output Device(s) and their sub-
336 units.

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

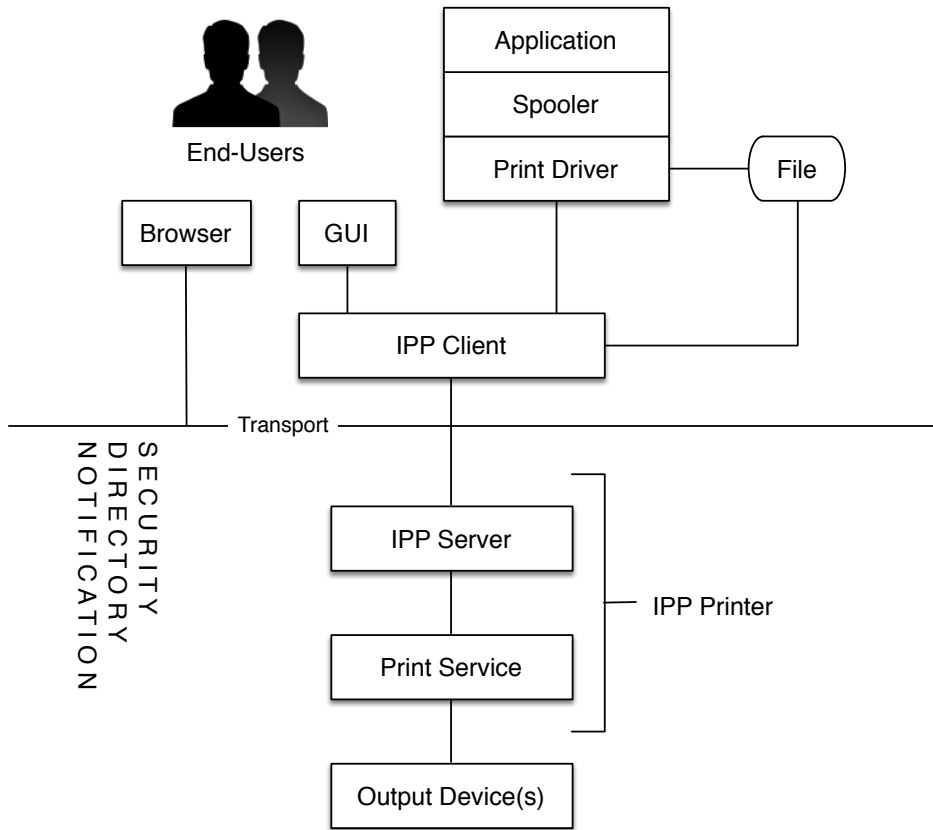
343 The IPP Printer object contains zero or more Job objects and is responsible for managing,
344 scheduling, and processing Jobs. It also provides the current state of the Output Device(s)
345 and communicates with them as needed.

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

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

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

357



358

359

Figure 1 - Generalized IPP Model (RFC 2911)

4.2 3D Print Service

3D printing uses a variation of the traditional Print service that maintains state and capability information specific to 3D printing. Table 1 lists the operations that are used by the 3D Print service. Table 2 lists additional operations that are used by Cloud-based services. And Table 3 lists the various attributes that are used by all 3D Print services.

Table 1 - 3D Print Service Operations

Code	Operation Name	Reference
0x0004	Validate-Job	RFC 2911
0x0005	Create-Job	RFC 2911
0x0006	Send-Document	RFC 2911
0x0007	Send-URI	RFC 2911
0x0008	Cancel-Job	RFC 2911
0x0009	Get-Job-Attributes	RFC 2911
0x000A	Get-Jobs	RFC 2911
0x000B	Get-Printer-Attributes	RFC 2911
0x000C	Hold-Job	RFC 2911
0x000D	Release-Job	RFC 2911
0x0010	Pause-Printer	RFC 2911
0x0011	Resume-Printer	RFC 2911
0x0013	Set-Printer-Attributes	RFC 3380
0x0014	Set-Job-Attributes	RFC 3380
0x0015	Get-Printer-Supported-Values	RFC 3380
0x0016	Create-Printer-Subscriptions	RFC 3995
0x0017	Create-Job-Subscriptions	RFC 3995
0x0018	Get-Subscription-Attributes	RFC 3995
0x0019	Get-Subscriptions	RFC 3995
0x001A	Renew-Subscription	RFC 3995
0x001B	Cancel-Subscription	RFC 3995
0x001C	Get-Notifications	RFC 3996
0x0022	Enable-Printer	RFC 3998
0x0023	Disable-Printer	RFC 3998
0x0024	Pause-Printer-After-Current-Job	RFC 3998
0x0025	Hold-New-Jobs	RFC 3998
0x0026	Release-Held-New-Jobs	RFC 3998
0x002D	Cancel-Current-Job	RFC 3998
0x0038	Cancel-Jobs	PWG 5100.11
0x0039	Cancel-My-Jobs	PWG 5100.11
0x003A	Resubmit-Job	PWG 5100.11
0x003B	Close-Job	PWG 5100.11
0x003C	Identify-Printer	PWG 5100.13

Table 2 - Additional Cloud-Based 3D Print Service Operations

Code	Operation Name	Reference
0x003F	Acknowledge-Document	PWG 5100.18
0x0040	Acknowledge-Identify-Printer	PWG 5100.18
0x0041	Acknowledge-Job	PWG 5100.18
0x0042	Fetch-Document	PWG 5100.18
0x0043	Fetch-Job	PWG 5100.18
0x0044	Get-Output-Device-Attributes	PWG 5100.18
0x0045	Update-Active-Jobs	PWG 5100.18
0x0046	Deregister-Output-Device	PWG 5100.18
0x0047	Update-Document-Status	PWG 5100.18
0x0048	Update-Job-Status	PWG 5100.18
0x0049	Update-Output-Device-Attributes	PWG 5100.18

Table 3 - 3D Print Service Attributes

Attribute Name	Object	Reference
attributes-charset	All/operation	RFC 2911
attributes-natural-language	All/operation	RFC 2911
charset-configured	Printer	RFC 2911
charset-supported	Printer	RFC 2911
compression	operation	RFC 2911
compression-supported	Printer	RFC 2911
document-format	Document/operation	RFC 2911
document-format-default	Printer	RFC 2911
document-format-supported	Printer	RFC 2911
document-name	Job/Document/ operation	RFC 2911
generated-natural-language-supported	Printer	RFC 2911
ipp-attribute-fidelity	operation	RFC 2911
ipp-features-supported	Printer	PWG 5100.13
ipp-versions-supported	Printer	RFC 2911
job-id	Job	RFC 2911
job-name	Job/operation	RFC 2911
job-originating-user-name	Job	RFC 2911
job-printer-up-time	Job	RFC 2911
job-state	Job	RFC 2911
job-state-reasons	Job	RFC 2911
job-state-message	Job	RFC 2911
limit	operation	RFC 2911
my-jobs	operation	RFC 2911
natural-language-configured	Printer	RFC 2911
operations-supported	Printer	RFC 2911
pdl-override-supported	Printer	RFC 2911
pdl-override-guaranteed-supported	Printer	IANA

Attribute Name	Object	Reference
printer-is-accepting-jobs	Printer	RFC 2911
printer-name	Printer	RFC 2911
printer-state	Printer	RFC 2911
printer-state-message	Printer	RFC 2911
printer-state-reasons	Printer	RFC 2911
printer-current-time	Printer	RFC 2911
printer-up-time	Printer	RFC 2911
printer-uri	operation	RFC 2911
printer-uri-supported	Printer	RFC 2911
queued-job-count	Printer	RFC 2911
requested-attributes	operation	RFC 2911
requesting-user-name	operation	RFC 2911
date-time-at-completed	Job	RFC 2911
date-time-at-creation	Job	RFC 2911
date-time-at-processing	Job	RFC 2911
time-at-completed	Job	RFC 2911
time-at-creation	Job	RFC 2911
time-at-processing	Job	RFC 2911
uri-authentication-supported	Printer	RFC 2911
uri-security-supported	Printer	RFC 2911
printer-xri-supported	Printer	RFC 3380
which-jobs	operation	RFC 2911
print-quality	Job	RFC 2911
print-quality-default	Job	RFC 2911
print-quality-supported	Job	RFC 2911
color-supported	Printer	RFC 2911
copies	Job	RFC 2911
copies-default	Printer	RFC 2911
copies-supported	Printer	RFC 2911
finishings	Job	RFC 2911
finishings-supported	Printer	RFC 2911
finishings-default	Printer	RFC 2911
job-creation-attributes-supported	Printer	PWG 5100.11
printer-alert	Printer	PWG 5100.9
printer-alert-description	Printer	PWG 5100.9
printer-info	Printer	RFC 2911
printer-location	Printer	RFC 2911
printer-geo-location	Printer	PWG 5100.13
printer-make-and-model	Printer	RFC 2911
printer-more-info	Printer	RFC 2911
status-message	operation	RFC 2911
ippget-event-life	Printer	RFC 3996
job-hold-until	Job	RFC 2911
job-hold-until-supported	Printer	RFC 2911
job-hold-until-default	Printer	RFC 2911

Attribute Name	Object	Reference
job-ids	operation	PWG 5100.11
job-ids-supported	Printer	PWG 5100.11
job-priority	Job	RFC 2911
job-priority-default	Printer	RFC 2911
job-priority-supported	Printer	RFC 2911
job-settable-attributes-supported	Printer	RFC 3380
printer-settable-attributes-supported	Printer	RFC 3380
last-document	operation	RFC 2911
multiple-operation-time-out	Printer	RFC 2911
multiple-operation-time-out-action	Printer	PWG 5100.13
notify-charset	Subscription	RFC 3995
notify-events	Subscription	RFC 3995
notify-events-default	Printer	RFC 3995
notify-events-supported	Printer	RFC 3995
notify-get-interval	operation	RFC 3996
notify-job-id	Subscription	RFC 3995
notify-lease-duration	Subscription	RFC 3995
notify-lease-duration-default	Printer	RFC 3995
notify-lease-duration-supported	Printer	RFC 3995
notify-lease-expiration-time	Subscription	RFC 3995
notify-max-events-supported	Printer	RFC 3995
notify-natural-language	Subscription	RFC 3995
notify-printer-up-time	Subscription	RFC 3995
notify-printer-uri	Subscription	RFC 3995
notify-pull-method	Subscription	RFC 3995
notify-pull-method-supported	Printer	RFC 3995
notify-sequence-number	Subscription	RFC 3995
notify-sequence-numbers	operation	RFC 3995
notify-status-code	operation	RFC 3995
notify-subscribed-event	Subscription	RFC 3995
notify-subscriber-user-name	Subscription	RFC 3995
notify-subscription-id	Subscription	RFC 3995
notify-subscriptions-ids	operation	RFC 3996
notify-text	Subscription	RFC 3995
notify-time-interval	Subscription	RFC 3995
notify-user-data	Subscription	RFC 3995
notify-wait	operation	RFC 3996
output-device-supported	Printer	RFC 2911
output-device-assigned	Job	RFC 3998
printer-state-change-date-time	Printer	RFC 3995
printer-state-change-time	Printer	RFC 3995
printer-config-change-date-time	Printer	PWG 5100.13
printer-config-change-time	Printer	PWG 5100.13
which-jobs-supported	Printer	PWG 5100.11
printer-get-attributes-supported	Printer	PWG 5100.13

Attribute Name	Object	Reference
printer-icons	Printer	PWG 5100.13
printer-organization	Printer	PWG 5100.13
printer-organizational-unit	Printer	PWG 5100.13
printer-uuid	Printer	PWG 5100.13
job-uuid	Job	PWG 5100.13
notify-subscription-uuid	Subscription	PWG 5100.13
printer-mandatory-job-attributes	Printer	PWG 5100.13
printer-supply	Printer	PWG 5100.13
printer-supply-description	Printer	PWG 5100.13
printer-supply-info-uri	Printer	PWG 5100.13
compression-accepted	operation	PWG 5100.17
document-format-accepted	operation	PWG 5100.17
document-number	operation	PWG 5100.5
document-preprocessed	operation	PWG 5100.18
document-uri	operation	RFC 2911
fetch-status-code	operation	PWG 5100.18
fetch-status-message	operation	PWG 5100.18
first-index	operation	PWG 5100.13
identify-actions	operation	PWG 5100.13
identify-actions-default	Printer	PWG 5100.13
identify-actions-supported	Printer	PWG 5100.13
output-device-job-states	operation	PWG 5100.18
output-device-uuid	operation	PWG 5100.18
printer-static-resource-directory-uri	Printer	PWG 5100.18
printer-static-resource-k-octets-supported	Printer	PWG 5100.18
printer-static-resource-k-octets-free	Printer	PWG 5100.18

371 **4.3 3D Printer Subunits**

372 [Table 4](#) lists the subunits of 3D printers for different technologies.

373 **Table 4.- 3D Printer Subunits**

Subunit	Technology	Reference
Build Platforms	All	<none>
Cameras	All	<none>
Chamber	All	<none>
Cutters	SDL	RFC 3806
Doors	All	RFC 3805
Fans	FDM	<none>
Input Trays	SDL	RFC 3805
Lamps	DLP	<none>
Lasers	Laser Sintering, SL	<none>
Marker Supplies	All	RFC 3805
Markers (or Extruders)	Many	RFC 3805

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Subunit	Technology	Reference
Media Path	SDL	RFC 3805
Motors	All	<none>
Reservoirs	DLP, Laser Sintering, SL	<none>

376 4.3.1 Build Platforms

377 Build Platforms hold the printed object. The platform typically moves up or down during
378 printing as layers are applied, although in some cases it moves along all three axis.

379 4.3.2 Cameras

380 Cameras typically show the Build Platforms, offering a visual progress/status reporting for
381 remote users.

382 4.3.3 Chambers

383 [Chambers are the volumes containing the objects being printed. Chambers are sometimes](#)
384 [temperature controlled and/or have doors that provide access to the printed objects.](#)

385 4.3.4 Cutters

386 Cutters are used to trim support material on printed objects and/or remove regions of
387 media that are not part of the final printed object.

388 4.3.5 Fans

389 Fans are used to cool printed material and maintain proper extruder and material
390 temperatures.

391 4.3.6 Lamps

392 Lamps are used by DLP printers to provide an ultraviolet light source for curing the liquid
393 material while printing a layer. Lamps are also used to illuminate the Build Platforms.

394 4.3.7 Lasers

395 Lasers are used by Laser Sintering and Stereo Lithography (SL) printers to fuse powdered
396 material or cure liquid material while printing a layer.

397 4.3.8 Markers (or Extruders)

398 Markers can be traditional subunits where an image is printed on sheets of paper (SDL),
399 extruders that place material onto the Build Platform or previous layer, or projectors that
400 display an inverse image on the surface of a liquid material (DLP).

401 4.3.9 Motors

402 Motors are used to move the Build Platforms and (in some cases) move the Markers.

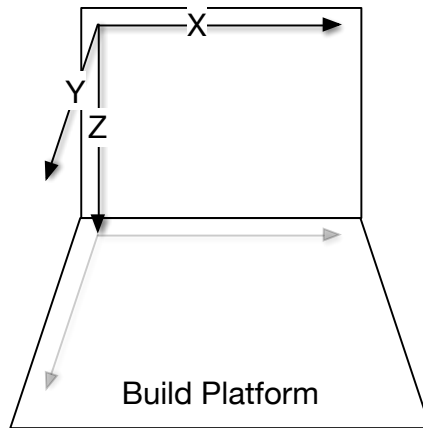
403 4.3.10 Reservoirs

404 Reservoirs hold liquid or powdered material used to create the printed object.

405 4.4 3D Printer Coordinate System

406 3D printers operate in three dimensions and thus have three axis of movement. Figure 2
407 shows a typical coordinate system where the X axis represents the width of the object, the
408 Y axis represents the depth of the object, and the Z axis represents the height of the
409 object. Note that, depending on the technology used, the Z axis may move in the opposite
410 direction, or the extruder may move independently with a stationary build platform.

411



412

413 **Figure 2 - Typical Build Platform Coordinate System**

414 Filament usage by extrusion Printers is sometimes also modeled as an additional "E" axis,
415 e.g., E1 for the first filament, E2 for the second filament, etc.

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

420 **4.5 Output Intent and Job Processing**

421 As with 2D printing, the focus of 3D printing using IPP is specification of output intent and
422 not for process or device control. Clients can specify general material selections (“red
423 PLA”, “brown wood PLA”, “clear ABS”, etc.), print speed and quality, build platform and
424 chamber temperatures, and whether supports and rafts should be printed. Printers then
425 use the implementation specific device control and (ordered) processes to satisfy the
426 Client-supplied output intent when processing the Job.

427 Also as with 2D printing, 3D Printers process Jobs using one or more interpreters. 2D
428 printing typically involves rasterization of the document data while 3D printing involves
429 geometric transformations, addition of support geometry, and slicing (laying) of the
430 object(s) in the document data so that they can be printed.

431 **4.6 Job Spooling**

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

435 **4.7 Cloud-Based Printing**

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

441 Snapshots of camera video can be uploaded as JPEG image resources using HTTP PUT
442 requests from the Proxy to the Infrastructure Printer. Such resources need to be updated
443 in an atomic fashion to allow Clients to safely poll for updates to the camera video.
444

445 **5. New Attributes**

446 **5.1 Job Template Attributes**

447 [Table 5](#) lists the Job Template attributes and their corresponding “-default” and “-
448 supported” attributes.

449 **Table 5 - Job Template Attributes**

Job Template	Printer: Default	Printer: Supported
materials-col (collection)	materials-col-default (1setOf collection)	materials-col-database (1setOf collection) materials-col-ready (1setOf collection) materials-col-supported (1setOf type2 keyword)
print-fill-density (integer(0:100))	print-fill-density-default (integer(0:100))	<none>
print-fill-thickness (integer(0:MAX))	print-fill-thickness-default (integer(0:MAX))	print-fill-thickness-supported (1setOf (integer(0:MAX) rangeOfInteger(0:MAX)))
print-layer-thickness (integer(0:MAX))	print-layer-thickness-default (integer(0:MAX))	print-layer-thickness-supported (1setOf (integer(0:MAX) rangeOfInteger(0:MAX)))
print-rafts (type2 keyword)	print-rafts-default (type2 keyword)	print-rafts-supported (1setOf type2 keyword)
print-shell-thickness (integer(0:MAX))	print-shell-thickness-default (integer(0:MAX))	print-shell-thickness-supported (1setOf (integer(0:MAX) rangeOfInteger(0:MAX)))
print-speed (integer(1:MAX))	print-speed-default (integer(1:MAX))	print-speed-supported (1setOf (integer(1:MAX) rangeOfInteger(1:MAX)))
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)
printer-chamber-temperature (integer no-value)	printer-chamber-temperature-default (integer no-value)	printer-chamber-temperature-supported (1setOf (integer rangeOfInteger) no-value)
printer-fan-speed (integer(0:100))	printer-fan-speed-default (integer(0:100))	printer-fan-speed-supported (boolean)

Deleted: Table 2

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452 **5.1.1 materials-col (1setOf collection)**

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

458 The Client typically supplies "materials-col" values matching those returned in the
 459 "materials-col-database" (section 5.3.1) or "materials-col-ready" (section 5.3.10) Printer
 460 Description attributes. Table 6 lists the member attributes.

461 **Table 6 - "materials-col" Member Attributes**

Member Attribute	Printer: Supported Values
material-amount	N/A
material-amount-units	material-amount-units-supported
material-color	N/A
material-diameter	material-diameter-supported
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-temperate	material-temperature-supported
material-type	material-type-supported

462 **5.1.1.1 material-amount (integer(0:MAX) | unknown)**

463 This member attribute provides the estimated amount of material that is available
 464 ("materials-col-database" and "materials-col-ready" values), the estimated amount of
 465 material that is required ("materials-col" values), or the actual amount of material that has
 466 been used ("materials-col-actual" values).

467 **5.1.1.2 material-amount-units (type2 keyword)**

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

469 'g': Value is mass in grams.

470 'kg': Value is mass in kilograms.

471 'l': Value is volume in liters.

472 'm': Value is length in meters.

Deleted: 5.2.1

Deleted: 5.2.3

475 'ml': Value is volume in milliliters.

476 'mm': Value is length in millimeters.

477 **5.1.1.3 material-color (type2 keyword)**

478 This member attribute provides a PWG media color value representing the color of the
479 material.

480 material-diameter (integer(1:MAX))

481 This member attribute provides the diameter of the filament in nanometers and is only
482 used for filament materials.

483 **5.1.1.4 material-key (keyword)**

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

486 **5.1.1.5 material-name (name(MAX))**

487 This member attribute provides a localized name of the material.

488 **5.1.1.6 material-purpose (1setOf type2 keyword)**

489 This member attribute specifies what the material will be used for. Values include:

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

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

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

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

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

495 **5.1.1.7 material-rate (integer(1:MAX))**

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

498 **5.1.1.8 material-rate-units (type2 keyword)**

499 This member attribute provides the units for the "material-rate" member attribute. Values
500 include:

501 'mg': Value is milligrams per second.

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Deleted: [Discuss proposal for new member attributes to describe material requirements/consumption: material-length-mm (integer(0:MAX)), material-mass-g (integer(0:MAX)), and material-volume-ml (integer(0:MAX))] -

\$07 ['ml': Value is milliliters per second.](#)
\$08 ['mm': Value is millimeters per second.](#)
\$09 **[5.1.1.9 material-temperature \(integer\(-273:MAX\) | rangeOfInteger\(-273:MAX\)\)](#)**
\$10 [This member attribute specifies the temperature \(or range of temperatures\) for the material](#)
\$11 [in degrees Celsius.](#)

512 **5.1.1.10 material-type (type2 keyword)**

513 This member attribute specifies the type of material. The keyword consists of a material
514 name ('abs', 'pla', 'pla-flexible', etc.) and form ('filament', 'liquid', 'powder', etc.) separated
515 by an underscore. Material names and forms cannot contain the underscore (_) character,
516 which is reserved as a separator in the keyword value. Values include:

517 'abs_filament': Acrylonitrile Butadiene Styrene (ABS) filament.
518 'abs-carbon-fiber_filament': ABS filament reinforced with carbon fibers.
519 'abs-carbon-nanotube_filament': ABS filament reinforced with carbon nanotubes.
520 'chocolate_powder': Chocolate powder.
521 'gold_powder': Gold (metal) powder.
522 'nylon_filament': Nylon filament.
523 'pet_filament': Polyethylene terephthalate (PET) filament.
524 'photopolymer-resin_liquid': Photopolymer (liquid) resin.
525 'pla_filament': Polylactic Acid (PLA) filament.
526 'pla-conductive_filament': Conductive PLA filament.
527 'pla-dissolvable_filament': Dissolvable PLA filament.
528 'pla-flexible_filament': Flexible PLA filament.
529 'pla-magnetic_filament': PLA with embedded iron particles.
530 'pla-steel-filament': PLA with embedded steel particles.
531 'pla-stone_filament': PLA filament with embedded stone chips.
532 'pla-wood_filament': PLA filament with embedded wood fibers.
533 'polycarbonate_filament': Polycarbonate filament.

534 'silver_powder': Silver (metal) powder.

535 'titanium_powder': Titanium (metal) powder.

536 'wax_solid': Solid wax.

537 **5.1.2 print-fill-density (integer(0:100))**

538 This Job Template attribute specifies the in-fill density of interior regions in percent.

539 **5.1.3 print-fill-thickness (integer(0:MAX))**

540 This Job Template attribute specifies the thickness of any in-fill walls in nanometers, with 0
541 representing the thinnest possible walls.

542 **5.1.4 print-layer-thickness (integer(0:MAX))**

543 This Job Template attribute specifies the thickness of each layer in nanometers, with 0
544 representing the thinnest possible layers.

545 **5.1.5 print-rafts (type2 keyword)**

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

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

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

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

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

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

554 **5.1.6 print-shell-thickness (integer(0:MAX))**

555 This Job Template attribute specifies the thickness of exterior walls in nanometers, with 0
556 representing the thinnest possible wall.

557 **5.1.7 print-speed (integer(1:MAX))**

558 This Job Template attribute specifies the printing speed in nanometers per second.

559 **5.1.8 print-supports (type2 keyword)**

560 This Job Template attribute specifies whether to print supports under the object. Values
561 include:

Deleted: <#>material-use (1setOf type2 keyword) [3]

Deleted: [Editor's note: One comment requested speed/layer thickness attributes for in-fill, shells, and supports.] .

566 'none': Do not print supports.

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

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

569 **5.1.9 printer-chamber-temperature (integer(-273:MAX) | no-value)**

Deleted: <#>printer-bed-temperature (integer | no-v... [4]

570 This Job Template attribute specifies the desired print chamber temperature in degrees
571 Celsius. The 'no-value' value is used to disable temperature control in the print chamber.

572 **5.1.10 printer-fan-speed (integer(0:100))**

573 This Job Template attribute specifies the desired fan speed in percent of maximum. A
574 value of 0 turns the fans off during printing.

575 **5.1.11 printer-platform-temperature (integer(-273:MAX) | no-value)**

576 This Job Template attribute specifies the desired Build Platform temperature in degrees
577 Celsius. The 'no-value' value is used to disable temperature control on the Build Platform.

578 **5.2 Job Description Attributes**

579 **5.2.1 materials-col-actual (1setOf collection)**

580 This Job Description attribute provides a receipt of the actual material(s) used for the Job.

581 **5.3 Printer Description Attributes**

582 **5.3.1 material-amount-units-supported (1setOf type2 keyword)**

583 This Printer Description attribute lists the supported "material-amount-units" values for the
584 Printer.

585 **5.3.2 material-diameter-supported (1setOf (integer | rangeOfInteger))**

586 This Printer Description attribute lists the supported "material-diameter" values for the
587 Printer.

588 **5.3.3 material-purpose-supported (1setOf type2 keyword)**

589 This Printer Description attribute lists the supported "material-purpose" values for the
590 Printer.

591 **5.3.4 material-rate-supported (1setOf (integer | rangeOfInteger))**

592 This Printer Description attribute lists the supported "material-rate" values for the Printer.

\$95 **5.3.5 material-rate-units-supported (1setOf type2 keyword)**

\$96 This Printer Description attribute lists the supported "material-rate-units" values for the
 \$97 Printer.

\$98 **5.3.6 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-**
 \$99 **273:MAX)))**

\$100 This Printer Description attribute specifies the supported "material-temperature" values (or
 \$101 ranges of values) in degrees Celsius.

\$102 **5.3.7 material-type-supported (1setOf type2 keyword)**

\$103 This Printer Description attribute lists the supported "material-type" values for the Printer.

\$104 **5.3.8 materials-col-database (1setOf collection)**

\$105 This Printer Description attribute lists the pre-configured materials for the Printer. Each
 \$106 value contains the corresponding "materials-col" member attributes and will typically reflect
 \$107 vendor and site ("third party") materials that are supported by the Printer.

\$108 **5.3.9 materials-col-default (1setOf collection)**

\$109 This Printer Description attribute lists the default materials that will be used if the
 \$110 "materials-col" Job Template attribute is not specified.

\$111 **5.3.10 materials-col-ready (1setOf collection)**

\$112 This Printer Description attribute lists the materials that have been loaded into the Printer.
 \$113 Each value contains the corresponding "materials-col" member attributes.

\$114 **5.3.11 materials-col-supported (1setOf type2 keyword)**

\$115 This Printer Description attribute lists the "materials-col" member attributes that are
 \$116 supported by the Printer.

\$117 **5.3.12 print-fill-density-default (integer(0:100))**

\$118 This Printer Description attribute specifies the default "print-fill-density" value in percent.

\$119 **5.3.13 print-fill-thickness-default (integer(0:MAX))**

\$120 This Printer Description attribute specifies the default "print-fill-thickness" value in
 \$121 nanometers.

Deleted: <#>material-type-supported (1setOf type2
 keyword) .

... [5]

625 **5.3.14 print-fill-thickness-supported (1setOf (integer(0:MAX) |**
626 **rangeOfInteger(0:MAX)))**

627 This Printer Description attribute lists the supported "print-fill-thickness" values (or ranges
628 of values) in nanometers.

629 **5.3.15 print-layer-order (type1 keyword)**

630 This Printer Description attribute specifies the order of layers when printing, either 'top-to-
631 bottom' or 'bottom-to-top'.

632 **5.3.16 print-layer-thickness-default (integer(0:MAX))**

633 This Printer Description attribute specifies the default "print-layer-thickness" value in
634 nanometers.

635 **5.3.17 print-layer-thickness-supported (1setOf (integer(0:MAX) |**
636 **rangeOfInteger(0:MAX)))**

637 This Printer Description attribute lists the supported values (or ranges of values) for the
638 "print-layer-thickness" Job Template attribute.

639 **5.3.18 print-rafts-default (type2 keyword)**

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

641 **5.3.19 print-rafts-supported (1setOf type2 keyword)**

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

643 **5.3.20 print-shell-thickness-default (integer(0:MAX))**

644 This Printer Description attribute specifies the default "print-shell-thickness" value in
645 nanometers.

646 **5.3.21 print-shell-thickness-supported (1setOf (integer(0:MAX) |**
647 **rangeOfInteger(0:MAX)))**

648 This Printer Description attribute lists the supported "print-shell-thickness" values (or
649 ranges of values) in nanometers.

650 **5.3.22 print-speed-default (integer(1:MAX))**

651 This Printer Description attribute lists the default "print-speed" value in nanometers per
652 second.

653 **5.3.23 print-speed-supported (1setOf (integer(1:MAX) | rangeOfInteger(1:MAX)))**

654 This Printer Description attribute lists the supported "print-speed" values (or ranges of
655 values) in nanometers per second.

656 **5.3.24 print-supports-default (type2 keyword)**

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

658 **5.3.25 print-supports-supported (1setOf type2 keyword)**

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

660 **5.3.26 printer-accuracy-supported (collection)**

661 This Printer Description attribute specifies the absolute accuracy of the Printer. The "x-
662 accuracy (integer(1:MAX))", "y-accuracy (integer(1:MAX))", and "z-accuracy
663 (integer(1:MAX))" member attributes specify the accuracy in nanometers along each axis.

664 **5.3.27 printer-camera-image-uri (1setOf uri)**

665 This Printer Description attribute lists the URIs for one or more resident camera snapshots.
666 Each URI corresponds to a separate resident camera. The images referenced by each
667 URI can change at any time so it is up to the Client to periodically poll for changes and for
668 the Printer to atomically update the images so that Clients can safely do so.

669 **5.3.28 printer-chamber-temperature-default (integer(-273:MAX) | no-value)**

670 This Printer Description attribute specifies the default "printer-chamber-temperature" value
671 in degrees Celsius.

672 **5.3.29 printer-chamber-temperature-supported (1setOf (integer(-273:MAX) |
673 rangeOfInteger(-273:MAX) | no-value)**

674 This Printer Description attribute lists the supported "printer-chamber-temperature" values
675 (or ranges of values) in degrees Celsius. The out-of-band 'no-value' value specifies that
676 the Printer does not offer temperature control of the print chamber.

677 **5.3.30 printer-fan-speed-default (integer(0:MAX))**

678 This Printer Description attribute specifies the default "printer-fan-speed" value in percent.

679 **5.3.31 printer-fan-speed-supported (boolean)**

680 This Printer Description attribute specifies whether the "printer-fan-speed" Job Template
681 attribute is supported.

Deleted: <#>printer-bed-temperature-default (integer | no-value) . [61]

685 **5.3.32 printer-platform-temperature-default (integer(-273:MAX) | no-value)**
 686 This Printer Description attribute specifies the default "printer-platform-temperature" value
 687 in degrees Celsius.

Deleted: <#>printer-head-temperature-supported (1setOf (integer | rangeOfInteger)) - ... [7]

688 **5.3.33 printer-platform-temperature-supported (1setOf (integer(-273:MAX) |**
 689 **rangeOfInteger(-273:MAX)) | no-value)**
 690 This Printer Description attribute lists the supported "printer-platform-temperature" values
 691 (or ranges of values) in degrees Celsius. The out-of-band 'no-value' value specifies that
 692 the Printer does not offer temperature control of the Build Platform.

693 **5.3.34 printer-volume-supported (collection)**
 694 This Printer Description attribute specifies the maximum build volume supported by the
 695 Printer. The "x-dimension (integer(1:MAX))", "y-dimension (integer(1:MAX))", and "z-
 696 dimension (integer(1:MAX))" member attributes specify the size in millimeters along each
 697 axis.

698 **5.4 Printer Status Attributes**

699 Editor's note: May be useful to change these to pairs of printer-xxx and printer-xxx-
 700 description attributes, like we do for printer-alert, printer-input-tray, printer-output-tray,
 701 printer-supply, etc. That will also provide a mapping to potential MIB extensions...

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702 **5.4.1 printer-chamber-temperature-current (integer | no-value)**
 703 This Printer Status attribute provides the current print chamber temperature in degrees
 704 Celsius. If the print chamber is not temperature controlled, the 'no-value' value is returned.

Comment [MRS1]: How about a top-level subunit status attribute? Or just break these out for future SNMP Printer MIB subunit groups?
 Deleted: <#>printer-bed-temperature-current (integer | no-value) - ... [8]

705 **5.4.2 printer-fan-speed-current (integer(0:100))**
 706 This Printer Status attribute provides the current fan speed in percent.

707 **5.4.3 printer-head-temperature-current (1setOf (integer | no-value))**
 708 This Printer Status attribute provides the current extruder head temperatures in degrees
 709 Celsius. The 'no-value' value is returned when the extruder head is not temperature
 710 controlled.

Deleted: [Editor's note: Do we need this if we are not specifying material temperature?]

711 **5.4.4 printer-platform-temperature-current (integer(-273:MAX) | no-value)**
 712 This Printer Status attribute provides the current Build Platform temperature in degrees
 713 Celsius. If the Build Platform is not temperature controlled, the 'no-value' value is returned.

Formatted: IEEEStd Paragraph
 Deleted: - ... [9]

724 6. New Values for Existing Attributes

725 6.1 ipp-features-supported (1setOf type2 keyword)

726 This document suggests (but does not register) the new value 'ipp-3d'.

727 6.2 printer-state-reasons (1setOf type2 keyword)

728 This document suggests (but does not register) the following new values:

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

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

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

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

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

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

735 'cutter-failure': A cutter has failed.

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

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

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

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

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

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

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

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

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

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

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

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

748 'laser-failure': A laser has failed.
749 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.
750 'material-empty': One or more build materials have been exhausted.
751 'material-low': One or more build materials may need replenishment soon.
752 'material-needed': One or more build materials need to be loaded for a processing
753 Job.
754 'motor-failure': A motor has failed.
755 'reservoir-empty': One or more reservoirs are empty.
756 'reservoir-low': One or more reservoirs are almost empty.
757 'reservoir-needed': One or more reservoirs are empty but need to be filled for a
758 processing Job.
759 **[Editor's Note: Additional keywords may be needed, for discussion]**

760 **7. Object Definition Languages (ODLs)**

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

763 **7.1 3D Manufacturing Format (3MF)**

764 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that
765 provides geometry, material, and texture information necessary to support a wide variety of
766 3D printers. Materials can be named and composed within the geometry, facilitating
767 multiple material support in coordination with a Job Ticket.

768 The [registered MIME media type for the original Microsoft published specification is](#)
769 ["application/vnd.ms-3mfdocument"](#). The suggested (but not registered) MIME media type
770 [for the 3MF Consortium's published specification](#) is "model/3mf".

771 **7.2 Additive Manufacturing Format (AMF)**

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

- 775 1. Shared vertices which eliminates holes and other breaks in the surface
776 geometry of objects,

- 777 2. Specification of multiple materials in a single file,
778 3. Curved surfaces can be specified, and
779 4. Coordinates use explicit units for proper output dimensions.

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

781 **7.3 Standard Tessellation Language (STL)**

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

784 **8. Internationalization Considerations**

785 For interoperability and basic support for multiple languages, conforming implementations
786 MUST support:

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

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

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

799 Implementations of this document SHOULD conform to the following standards on
800 processing of human-readable Unicode text strings, see:

- 801 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical
802 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping
803 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]
804 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences
805 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization
806 Unicode Character Encoding Model [UTR17] – multi-layer character model
807 Unicode in XML and other Markup Languages [UTR20] – XML usage

- 808 Unicode Character Property Model [UTR23] – character properties
- 809 Unicode Conformance Model [UTR33] – Unicode conformance basis+
- 810 Unicode Collation Algorithm [UTS10] – sorting
- 811 Unicode Locale Data Markup Language [UTS35] – locale databases

812 **9. Security Considerations**

813 In addition to the security considerations described in the IPP/1.1: Model and Semantics
814 [RFC2911], the following sub-sections describe issues that are unique to 3D printing.

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

- 817 Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks
- 818 Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

819 **9.1 Access Control**

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

823 **9.2 Physical Safety**

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

826 **9.3 Material Safety**

827 Printers MUST restrict usage and combination of materials to those that can be safely
828 printed. Access controls (section 9.1) MAY be used to allow authorized users to
829 experiment with untested materials or combinations, but only when such materials or
830 combinations can reasonably be expected to not pose a safety risk.

831 **9.4 Temperature Control**

832 Printers MUST validate temperature and fan speed values provided by Clients and limit
833 material, extruder, build platform, and print chamber temperatures within designed limits to
834 prevent unsafe operating conditions, damage to the hardware, explosions, and/or fires.

835 **10. References**

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838 [content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf](http://www.3mf.io/wp-content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf)

839 [ISO10646] "Information technology -- Universal Coded Character Set (UCS)",
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841 [ISO52915] "Standard Specification for Additive Manufacturing File Format (AMF)
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Field Code Changed

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923 standard:

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925 12. Change History

926 12.1 November 16, 2015

- 927 [1. Section 1: Fix typos](#)
- 928 [2. Section 3: Updated rationale to talk about 3MF instead of AMF and STL](#)
- 929 [3. Section 4: Added new subsection on the 3D Print Service and the operations](#)
- 930 [and attributes that are used.](#)
- 931 [4. Section 4.3: Added Chambers to list of subunits since we are providing access](#)
- 932 [to the temperature.](#)
- 933 [5. Section 5.1.1: Added table listing all member attributes.](#)
- 934 [6. Section 5.1.1.x: Added sections on material-amount, material-amount-units,](#)
- 935 [material-diameter, material-rate, material-rate-units](#)
- 936 [7. Section 5.1.1.x: Renamed "material-use" to "material-purpose" to avoid](#)
- 937 [confusion with "material-amount-xxx".](#)
- 938 [8. Section 5.3: Add new materials-col member attribute -supported attributes](#)
- 939 [9. Section 7.1: Note existing MS 3DMF MIME media type](#)
- 940 [10.Global: printer-bed-xxx -> printer-platform-xxx](#)
- 941 [11.Global: Add range for all temperature attributes \(-273:MAX\)](#)

942 12.2 October 29, 2015

- 943 1. Greatly expanded the discussion of how current solutions work and the IPP
- 944 model
- 945 2. Added discussion points for amount of material used
- 946 3. Added materials-col-actual Job Description attribute
- 947 4. Added 3MF description and reference
- 948 5. Fixed link to IPP Everywhere in references

949 12.3 August 12, 2015

- 950 1. Dropped "0.1" from the title
- 951 2. Various typographical changes
- 952 3. Section 2.2: Added ODL acronym
- 953 4. Table 1: Added reference column
- 954 5. Figure 1: Updated figure to show Z increasing downward (direction of build
- 955 platform movement)
- 956 6. Section 4.x: Added sub-section on output intent.
- 957 7. Section 5.1: Added table listing Job Template and corresponding -default and -
- 958 supported attributes.
- 959 8. Section 5.1.1.4: Added more types of filament, solid wax, and clarification on the
- 960 names used for material type keywords.
- 961 9. Section 5.1.1.5: Made material-use 1setOf, added 'all' value.
- 962 10. Updated printer-bed-temperature-supported and printer-chamber-temperature-
- 963 supported to allow 'no-value' values.

964 11. Section 9.x: Added subsections on specific 3D printing security considerations.

965 **12.4 July 29, 2015**

- 966 1. Dropped all references to X3G and G-code.
967 2. Reworked materials-col to specify materials but not temperatures and other
968 physical properties
969 3. Added "material-use" member attribute to assign materials to specific uses.
970 4. Supports and rafts pick materials based on "material-use" values and not
971 indices.
972 5. Added reference to IPP INFRA
973 6. Added printer-camera-image-uri Printer Description attribute.

974 **12.5 April 13, 2015**

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

977 **12.6 April 5, 2015**

- 978 1. Updated front matter to remove IEEE-ISTO boilerplate.
979 2. Fixed various typos
980 3. Clarified that SLC files are commonly known as STL files.
981 4. Clarified that S3G is a binary version of G-code with a standard packet format.
982 5. Added use case for printing with loaded materials
983 6. Added use case for multi-material printing on a single material printer.
984 7. Added use case for monitoring print progress visually with a web cam.
985 8. Added exception for "skipping" (insufficient material flow/feed)
986 9. Added exception for adhesion issues
987 10. Added exception for build plate being full.
988 11. Added exception for head movement issues.
989 12. Added figure showing the typical coordinate system.
990 13. Expanded Job Template and Printer Description details, added comments for
991 discussion.
992 14. Added new Unicode considerations and references.

993 **12.7 January 23, 2015**

994 Initial revision.

1. Introduction 6
2. Terminology 6
2.1 Conformance Terminology 6
2.2 Other Terminology 7
2.3 Acronyms and Organizations 7
3. Requirements 8
3.1 Rationale for Title of Document 8
3.2 Use Cases 8
3.3 Exceptions 8
3.4 Out of Scope 8
3.5 Design Requirements 8
4. First Specification Section 8
5. Conformance Requirements 9
6. Internationalization Considerations 9
7. Security Considerations 9
8. IANA Considerations 9
9. References 9
9.1 Normative References 9
9.2 Informative References 9
10. Authors' Addresses 9
11. Change History 11
11.1 Month, DD, YYYY 11

The Standard Specification for Additive Manufacturing File Format (AMF) Version 1.1 [ISO52915] defines an XML schema and file format for describing 3D objects with one or more materials; and The SLC File Specification [STLFORMAT] defines a file format (commonly called "STL files") for describing 3D object with a single material

material-use (1setOf type2 keyword)

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

- 'all': The material will be used for all parts of the printed object.
'in-fill': The material will be used to fill the interior of the printed object.
'raft': The material will be used to print a raft under the printed object.
'shell': The material will be used for the surface of the printed object.
'support': The material will be used to support the printed object.

printer-bed-temperature (integer | no-value)

This Job Template attribute specifies the desired Build Platform temperature in degrees Celsius. The 'no-value' value is used to disable temperature control on the Build Platform.

material-type-supported (1setOf type2 keyword)

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

material-use-supported (1setOf type2 keyword)

This Printer Description attribute lists the supported "material-use" values for the Printer.

printer-bed-temperature-default (integer | no-value)

This Printer Description attribute specifies the default "printer-bed-temperature" value in degrees Celsius.

printer-bed-temperature-supported (1setOf (integer | rangeOfInteger) | no-value)

This Printer Description attribute lists the supported "printer-bed-temperature" values (or ranges of values) in degrees Celsius. The out-of-band 'no-value' value specifies that the Printer does not offer temperature control of the build platform.

printer-head-temperature-supported (1setOf (integer | rangeOfInteger))

This Printer Description attribute specifies the supported "printer-head-temperature" values (or ranges of values) in degrees Celsius.

1.1.1**printer-bed-temperature-current (integer | no-value)**

This Printer Status attribute provides the current Build Platform temperature in degrees Celsius. If the Build Platform is not temperature controlled, the 'no-value' value is returned.

Other Potential Attributes

Based on existing 3D printer software, the following parameters could also be candidates for standardization:

- Initial layer thickness in nanometers
- Initial layer line width in percent
- Dual extrusion overlap in nanometers
- Travel speed in nanometers per second
- Bottom layer speed in nanometers per second
- Infill speed in nanometers per second
- Outer shell speed in nanometers per second
- Inner shell speed in nanometers per second
- Minimum layer time in seconds or milliseconds