



The Printer Working Group

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White Paper

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## IPP 3D Printing Extensions 0.1 (3D)

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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-20150729.docx>

<http://ftp.pwg.org/pub/pwg/ipp/ws/wd-sweet-ipp3d-20150729.pdf>

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## 136 1. Introduction

137 This white paper defines an extension to the Internet Printing Protocol (IPP) that supports  
138 printing of physical objects by Additive Manufacturing devices such as three-dimensional  
139 (3D) printers. The attributes and values defined in this document have been prototyped  
140 using the CUPS software [CUPS].

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

146 [This document also addresses common Cloud-based issues by extending the IPP Shared  
147 Infrastructure Extensions \[PWG5100.18\], although how such services are provisioned or  
148 managed is out of scope.](#)

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

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## 153 2. Terminology

### 154 2.1 Terms Used in This Document

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

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

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

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

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

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

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

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

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

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## 175 **2.2 Acronyms and Organizations**

176 *CNC*: Computer Numerical Control

177 *DLP*: Digital Light Processing

178 *FDM*: Fused Deposition Modeling

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

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

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

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

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

184 *SDL*: Selective Deposition Lamination

185 *SL*: Stereo Lithography

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

187

## 189 3. Rationale for IPP 3D Printing Extensions

190 Existing specifications define the following:

- 191 1. IPP/2.0 Second Edition [PWG5100.12] defines version 2.0, 2.1, and 2.2 of the  
192 Internet Printing Protocol which defines a standard operating and data model,  
193 interface protocol, and extension mechanism to support traditional Printers;
- 194 2. IPP Everywhere [PWG5100.14] defines a profile of existing IPP specifications,  
195 standard Job Template attributes, and standard document formats;
- 196 3. [IPP Shared Infrastructure Extensions \(INFRA\) \[PWG5100.18\] defines an](#)  
197 [interface for printing through shared services based in infrastructure such as](#)  
198 [Cloud servers;](#)
- 199 4. The Standard Specification for Additive Manufacturing File Format (AMF)  
200 Version 1.1 [ISO52915] defines an XML schema and file format for describing  
201 3D objects with one or more materials;
- 202 5. The SLC File Specification [STLFORMAT] defines a file format ([commonly](#)  
203 [called "STL files"](#)) for describing 3D object with a single material;
- 204 6. [.....](#)

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

### 208 3.1 Use Cases

#### 209 3.1.1 Print a 3D Object

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

#### 213 [3.1.2 Print a 3D Object Using Loaded Materials](#)

214 [Jane is viewing a 3D object and wishes to print it. After initiating a print action, she selects](#)  
215 [a 3D printer on the network that has the material\(s\) she wishes to use, specifies additional](#)  
216 [print settings, and submits the object for printing.](#)

#### 217 [3.1.3 Print a 3D Object with Multiple Materials](#)

218 [Jane wants to print a multi-material object on a single-material Printer. Jane uses software](#)  
219 [on her Client device to create Document data that instructs the Printer to pause printing](#)  
220 [and provide status information at specific layers so that she can change materials at the](#)  
221 [Printer and resume printing with the new material.](#)

**Deleted:** The Interchangeable Variable Block Data Format for Positioning, Contouring, and Contouring/Positioning Numerically Controlled Machines [RS274D] defines the "G-code" format that is commonly used by 3D printers; a [\[5\]](#)



### 227 [3.1.4 View a 3D Object During Printing](#)

228 [Jane has submitted a 3D print Job that will take 4 hours to complete. She can visually](#)  
229 [monitor the progress of the Job through a web page provided by the Printer.](#)

## 230 **3.2 Exceptions**

### 231 **3.2.1 Clogged Extruder**

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

### 235 **3.2.2 Extruder Temperature Out of Range**

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

### 240 [3.2.3 Extruder Head Movement Issues](#)

241 [While printing a 3D object, the extruder head movement becomes irregular. The Printer](#)  
242 [stops printing and sets the corresponding state reason to allow Jane's Client device to](#)  
243 [discover the issue and display an appropriate alert.](#)

### 244 **3.2.4 Filament Feed Jam**

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

### 248 [3.2.5 Filament Feed Skip](#)

249 [While printing a 3D object, the filament extrusion rate is insufficient to maintain proper](#)  
250 [printing. The printer stops printing and sets the corresponding state reason to allow Jane's](#)  
251 [Client device to discover the issue and display an appropriate alert.](#)

### 252 **3.2.6 Material Empty**

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

### 256 [3.2.7 Material Adhesion Issues](#)

257 [While printing a 3D object, the printed object releases from the build platform or the current](#)  
258 [layer is not adhering to the previous one. The printer stops printing and sets the](#)  
259 [corresponding state reason to allow Jane's Client device to discover the issue and display](#)  
260 [an appropriate alert.](#)

### 261 **3.2.8 Print Bed Temperature Out of Range**

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

### 265 [3.2.9 Print Bed Not Clear](#)

266 [When starting to print a 3D object, the Printer detects that the build platform is not](#)  
267 [empty/clear. The Printer stops printing and sets the corresponding state reason to allow](#)  
268 [Jane's Client device to discover the issue and display an appropriate alert. The Printer](#)  
269 [starts printing once the build platform is cleared.](#)

## 270 **3.3 Out of Scope**

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

- 272 1. Definition of new file formats; and
- 273 2. Support for Subtractive Manufacturing technologies such as CNC milling
- 274 machines.

## 275 **3.4 Design Requirements**

276 The design requirements for this document are:

- 277 1. Define attributes and values to describe supported and loaded (ready) materials
- 278 used for FDM; and
- 279 2. Define attributes and values to describe FDM printer capabilities and state

280 The design recommendations for this document are:

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

282

283 **4. Technical Solutions/Approaches**

284 Current 3D printers offer limited connectivity and status monitoring capabilities. Many  
 285 printers simply [read printer-ready](#) files from SD memory cards, with all interaction and  
 286 status monitoring happening at the printer's console.

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

Deleted: [S3G]  
 Deleted: , and this interface does offer an improved printing experience from the host device

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

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

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299 **4.1 High-Level Model**

300 IPP [RFC2911] and the IETF Printer MIB [RFC3805] already define a comprehensive  
 301 model for the operation and data elements of a typical 2D printer. The IPP Job processing  
 302 model matches how 3D printers process Jobs and Documents. However, more types of  
 303 subunits are used in a 3D printer, requiring additions to the model and state values. Table  
 304 1 lists the subunits of 3D printers for different technologies.

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

Subunit	Technology
Build Platforms	All
Cameras	All
Cutters	SDL
Doors	All
Fans	FDM
Input Trays	SDL
Lamps	DLP
Lasers	Laser Sintering, SL
Marker Supplies	All
Markers (or Extruders)	Many
Media Path	SDL
Motors	All
Reservoirs	DLP, Laser Sintering, SL

**312 4.1.1 Build Platforms**

313 Build Platforms hold the printed object. The platform [typically](#) moves up or down during  
314 printing as layers are applied, [although in some cases it moves along all three axis](#).

**315 4.1.2 Cameras**

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

**318 4.1.3 Cutters**

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

**321 4.1.4 Fans**

322 Fans are used to cool printed material and maintain proper extruder [and material](#)  
323 [temperatures](#).

**324 4.1.5 Lamps**

325 Lamps are used by DLP printers to provide an ultraviolet light source for curing the liquid  
326 material while printing a layer. [Lamps are also used to illuminate the Build Platforms](#).

**327 4.1.6 Lasers**

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

**330 4.1.7 Markers (or Extruders)**

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

**334 4.1.8 Motors**

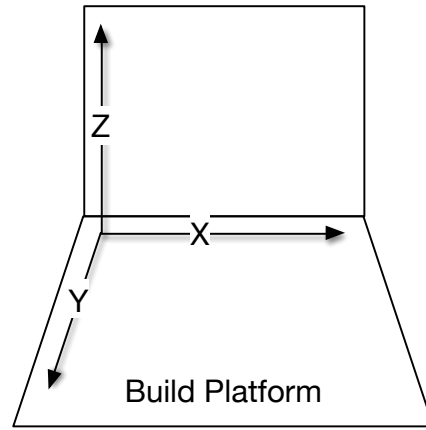
335 Motors are used to move the Build Platforms and (in some cases) move the Markers.

**336 4.1.9 Reservoirs**

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

## 338 4.2 Coordinate System

339 3D printers operate in three dimensions and thus have three axis of movement. [Figure 1](#)  
340 [shows the coordinate system where the](#) X axis represents the width of the object, the Y  
341 axis represents the depth of the object, and the Z axis represents the height of the object.



342  
343 [Figure 1 - Typical Build Platform Coordinate System](#)

344 [Filament usage by extrusion Printers is sometimes also modeled as an additional "E" axis,](#)  
345 [e.g., E1 for the first filament, E2 for the second filament, etc.](#)

## 346 4.3 Cloud-Based Printing

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

352 [Snapshots of camera video can be uploaded as JPEG image resources using HTTP PUT](#)  
353 [requests from the Proxy to the Infrastructure Printer. Such resources need to be updated](#)  
354 [in an atomic fashion to allow Clients to safely poll for updates to the camera video.](#)

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## 356 5. New Attributes

### 357 5.1 Job Template Attributes

#### 358 5.1.1 materials-col (1setOf collection)

359 This Job Template attribute defines the materials to be used for the Job. [When specified,](#)  
 360 [the Printer validates the requested materials both when the Job is created and when it](#)  
 361 [enters the 'processing' state. If the requested materials are not loaded, the 'material-](#)  
 362 [needed' keyword is added to the Printer's "printer-state-reasons" values and the Job is](#)  
 363 [placed in the 'processing-stopped' state.](#)

364 [The Client typically supplies "materials-col" values matching those returned in the](#)  
 365 ["materials-col-database" \(section 5.2.1\) or "materials-col-ready" \(section 5.2.3\) Printer](#)  
 366 [Description attributes.](#)

##### 367 5.1.1.1 material-color (type2 keyword)

368 This member attribute provides a PWG media color value representing the color of the  
 369 material.

##### 370 5.1.1.2 material-key (keyword)

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

##### 373 5.1.1.3 material-name (name(MAX))

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

##### 375 5.1.1.4 material-type (type2 keyword)

376 This member attribute specifies the type of material. [The keyword consists of a material](#)  
 377 [name \('abs', 'pla', etc.\) and form \('filament', 'liquid', 'powder', etc.\) separated by an](#)  
 378 [underscore.](#) Values include:

379 'abs\_filament': Acrylonitrile Butadiene Styrene (ABS) filament.

380 'chocolate\_powder': Chocolate powder.

381 'gold\_powder': Gold (metal) powder.

382 'photopolymer-resin\_liquid': Photopolymer (liquid) resin.

383 'pla\_filament': Polylactic Acid (PLA) filament.

384 ['pla-conductive\\_filament': Conductive PLA filament.](#)

Deleted: [\[Editor's note: probably want a figure for this\]](#)

Deleted: s

Deleted: <#>material-diameter (integer)

... [6]

389 'pla-flexible\_filament': Flexible PLA filament.

390 'silver\_powder': Silver (metal) powder.

391 **[Editor's note: This list needs to be expanded significantly...]**

392 **5.1.1.5 material-use (type2 keyword)**

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

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

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

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

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

398

399 **5.1.2 print-fill-density (integer(0:100))**

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

401 **5.1.3 print-fill-thickness (integer(0:MAX))**

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

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

406 **5.1.4 print-layer-thickness (integer(0:MAX))**

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

409 **5.1.5 print-rafts (type2 keyword)**

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

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

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

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

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

Deleted: <#>filament-retraction-distance (integer(0:... [7])

- Deleted: -N
- Deleted: Nth
- Deleted: , where N is an integer from 1 to the number of materials
- Deleted: -N
- Deleted: Nth
- Deleted: , where N is an integer from 1 to the number of materials
- Deleted: -N
- Deleted: Nth
- Deleted: , where N is an integer from 1 to the number of materials

430 'standard': Print [brims](#), [rafts](#), [and/or skirts](#) using implementation-defined default  
431 parameters.

#### 432 **5.1.6 print-shell-thickness (integer(0:MAX))**

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

#### 435 **5.1.7 print-speed (integer(1:MAX))**

436 [This Job Template attribute specifies the printing speed in nanometers per second.](#)

#### 437 **5.1.8 print-supports (type2 keyword)**

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

440 'none': Do not print supports.

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

442 'material': Print supports using the '[support](#)' material [specified](#) for the Job.

#### 443 **5.1.9 printer-bed-temperature (integer | no-value)**

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

#### 446 **5.1.10 printer-chamber-temperature (integer | no-value)**

447 [This Job Template attribute specifies the desired print chamber temperature in degrees](#)  
448 [Celsius. The 'no-value' value is used to disable temperature control in the print chamber.](#)

#### 449 **5.1.11 printer-fan-speed (integer(0:100))**

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

### 452 **5.2 Printer Description Attributes**

#### 453 **5.2.1 materials-col-database (1setOf collection)**

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

**Deleted:** 'material-N': Print rafts using the Nth material, where N is an integer from 1 to the number of materials for the Job. .

**Deleted:** -N

**Deleted:** Nth

**Deleted:** , where N is an integer from 1 to the number of materials



#### 464 **5.2.2 materials-col-default (1setOf collection)**

465 This Printer Description attribute lists the default materials that will be used if the  
466 "materials-col" Job Template attribute is not specified.

#### 467 **5.2.3 materials-col-ready (1setOf collection)**

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

#### 470 **5.2.4 materials-col-supported (1setOf type2 keyword)**

471 This Printer Description attribute lists the "materials-col" member attributes that are  
472 supported by the Printer.

#### 473 **5.2.5 material-type-supported (1setOf type2 keyword)**

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

#### 475 **5.2.6 material-use-supported (1setOf type2 keyword)**

476 [This Printer Description attribute lists the supported "material-use" values for the Printer.](#)

#### 477 **5.2.7 print-fill-density-default (integer(0:100))**

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

#### 479 **5.2.8 print-fill-thickness-default (integer(0:MAX))**

480 This Printer Description attribute specifies the default "print-fill-thickness" value in  
481 nanometers.

#### 482 **5.2.9 print-fill-thickness-supported (1setOf (integer(0:MAX) | 483 rangeOfInteger(0:MAX)))**

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

#### 486 **5.2.10 print-layer-order (type1 keyword)**

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

#### 489 **5.2.11 print-layer-thickness-default (integer(0:MAX))**

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

Deleted: <#>material-diameter-supported (1setOf (integer | rangeOfInteger)) - ... [8]

Deleted:

496 **5.2.12 print-layer-thickness-supported (1setOf (integer(0:MAX) |**  
497 **rangeOfInteger(0:MAX)))**

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

500 **5.2.13 print-rafts-default (type2 keyword)**

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

502 **5.2.14 print-rafts-supported (1setOf type2 keyword)**

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

504 **5.2.15 print-shell-thickness-default (integer(0:MAX))**

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

507 **5.2.16 print-shell-thickness-supported (1setOf (integer(0:MAX) |**  
508 **rangeOfInteger(0:MAX)))**

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

511 **5.2.17 print-speed-default (integer(1:MAX))**

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

514 **5.2.18 print-speed-supported (1setOf (integer(1:MAX) | rangeOfInteger(1:MAX)))**

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

517 **5.2.19 print-supports-default (type2 keyword)**

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

519 **5.2.20 print-supports-supported (1setOf type2 keyword)**

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

521 **5.2.21 printer-accuracy-supported (collection)**

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

Moved (insertion) [1]

### 525 **5.2.22 printer-bed-temperature-default (integer | no-value)**

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

### 528 **5.2.23 printer-bed-temperature-supported (1setOf (integer | rangeOfInteger))**

529 This Printer Description attribute lists the supported "printer-bed-temperature" values (or  
530 ranges of values) in degrees Celsius.

### 531 **5.2.24 printer-camera-image-uri (1setOf uri)**

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

### 536 **5.2.25 printer-chamber-temperature-default (integer | no-value)**

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

### 539 **5.2.26 printer-chamber-temperature-supported (1setOf (integer | rangeOfInteger))**

540 This Printer Description attribute lists the supported "printer-chamber-temperature" values  
541 (or ranges of values) in degrees Celsius.

### 542 **5.2.27 printer-fan-speed-default (integer(0:MAX))**

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

### 544 **5.2.28 printer-fan-speed-supported (boolean)**

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

### 547 **5.2.29 printer-head-temperature-supported (1setOf integer | rangeOfInteger)**

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

### 550 **5.2.30 printer-volume-supported (collection)**

551 This Printer Description attribute specifies the maximum build volume supported by the  
552 Printer. The "x-dimension (integer(1:MAX))", "y-dimension (integer(1:MAX))", and "z-  
553 dimension (integer(1:MAX))" member attributes specify the size in millimeters along each  
554 axis.

Deleted: <#>filament-retraction-distance-supported  
(1setOf (integer(0:MAX) | rangeOfInteger(0:MAX))) - ... [9]

Moved up [1]: <#>printer-accuracy-supported  
(collection) - ... [10]

## 561 5.3 Printer Status Attributes

### 562 5.3.1 printer-bed-temperature-current (integer | no-value)

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

### 565 [5.3.2 printer-chamber-temperature-current \(integer | no-value\)](#)

566 [This Printer Status attribute provides the current print chamber temperature in degrees](#)  
567 [Celsius. If the print chamber is not temperature controlled, the 'no-value' value is returned.](#)

### 568 5.3.3 printer-fan-speed-current (integer(0:100))

569 This Printer Status attribute provides the current fan speed in percent.

### 570 5.3.4 printer-head-temperature-current (1setOf (integer | no-value))

571 This Printer Status attribute provides the current extruder head temperatures in degrees  
572 Celsius. The 'no-value' value is returned when the extruder head is not temperature  
573 controlled. [\[Editor's note: Do we need this if we are not specifying material temperature?\]](#)

## 574 5.4 Other Potential Attributes

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

- 577 1. Initial layer thickness in nanometers
- 578 2. Initial layer line width in percent
- 579 3. Dual extrusion overlap in nanometers
- 580 4. Travel speed in nanometers per second
- 581 5. Bottom layer speed in nanometers per second
- 582 6. Infill speed in nanometers per second
- 583 7. Outer shell speed in nanometers per second
- 584 8. Inner shell speed in nanometers per second
- 585 9. Minimum layer time in seconds or milliseconds

## 586 6. New Values for Existing Attributes

### 587 6.1 ipp-features-supported (1setOf type2 keyword)

588 This document [suggests \(but does not register\)](#) the new value 'ipp-3d'.

Deleted: defines

**590 6.2 printer-state-reasons (1setOf type2 keyword)**

591 This document [suggests \(but does not register\)](#) the following new values:

Deleted: defines

- 592 'camera-failure': A camera is no longer working.
- 593 'cutter-at-eol': A cutter has reached its end-of-life and will need to be replaced soon.
- 594 'cutter-failure': A cutter has failed.
- 595 'cutter-near-eol': A cutter is near its end-of-life and may need to be replaced soon.
- 596 'extruder-failure': An extruder has failed and requires maintenance or replacement.
- 597 'extruder-jam': An extruder is jammed or clogged.
- 598 'fan-failure': A fan has failed.
- 599 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.
- 600 'lamp-failure': A lamp has failed.
- 601 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.
- 602 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.
- 603 'laser-failure': A laser has failed.
- 604 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.
- 605 'material-empty': One or more build materials have been exhausted.
- 606 'material-low': One or more build materials may need replenishment soon.
- 607 'material-needed': One or more build materials need to be loaded for a processing  
608 Job.
- 609 'motor-failure': A motor has failed.
- 610 'reservoir-empty': One or more reservoirs are empty.
- 611 'reservoir-low': One or more reservoirs are almost empty.
- 612 'reservoir-needed': One or more reservoirs are empty but need to be filled for a  
613 processing Job.

## 615 7. Object Definition Languages (ODLs)

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

### 618 7.1 Additive Manufacturing Format (AMF)

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

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

627 The suggested (but not registered) MIME media type is [model/amf](#).

Deleted: 'application

### 628 7.2 Standard Tessellation Language (STL)

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

631

Deleted: <#>G-Code .

## 634 8. Internationalization Considerations

635 For interoperability and basic support for multiple languages, conforming implementations  
636 MUST support:

- 637 5. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)  
638 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 639 6. The Unicode Format for Network Interchange [RFC5198] which requires  
640 transmission of well-formed UTF-8 strings and recommends transmission of  
641 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

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

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

649 [Implementations of this document SHOULD conform to the following standards on](#)  
650 [processing of human-readable Unicode text strings, see:](#)

651 [Unicode Bidirectional Algorithm \[UAX9\] – left-to-right, right-to-left, and vertical](#)

652 [Unicode Line Breaking Algorithm \[UAX14\] – character classes and wrapping](#)

653 [Unicode Normalization Forms \[UAX15\] – especially NFC for \[RFC5198\]](#)

654 [Unicode Text Segmentation \[UAX29\] – grapheme clusters, words, sentences](#)

655 [Unicode Identifier and Pattern Syntax \[UAX31\] – identifier use and normalization](#)

656 [Unicode Character Encoding Model \[UTR17\] – multi-layer character model](#)

657 [Unicode in XML and other Markup Languages \[UTR20\] – XML usage](#)

658 [Unicode Character Property Model \[UTR23\] – character properties](#)

659 [Unicode Conformance Model \[UTR33\] – Unicode conformance basis+](#)

660 [Unicode Collation Algorithm \[UTS10\] – sorting](#)

661 [Unicode Locale Data Markup Language \[UTS35\] – locale databases](#)

## 662 9. Security Considerations

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

665 [Implementations of this specification SHOULD conform to the following standards on](#)  
 666 [processing of human-readable Unicode text strings. see:](#)

667 [Unicode Security Mechanisms \[UTS39\] – detecting and avoiding security attacks](#)

668 [Unicode Security FAQ \[UNISECFAQ\] – common Unicode security issues](#)

669 [Editor's note: the rest is TBD but will include explosions, fires, and other physical risks that  
 670 have been documented in the news and various documents and studies]

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**Deleted:** TBD

**758 12. Change History****759 12.1 July 29, 2015**

- 760 [1. Dropped all references to X3G and G-code.](#)
- 761 [2. Reworked materials-col to specify materials but not temperatures and other](#)
- 762 [physical properties](#)
- 763 [3. Added "material-use" member attribute to assign materials to specific uses.](#)
- 764 [4. Supports and rafts pick materials based on "material-use" values and not](#)
- 765 [indices.](#)
- 766 [5. Added reference to IPP INFRA](#)
- 767 [6. Added printer-camera-image-uri Printer Description attribute.](#)

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**768 12.2 April 13, 2015**

- 769 [1. Updated front matter to incorporate new IEEE-ISTO boilerplate for a contributed](#)
- 770 [white paper.](#)

**771 12.3 April 5, 2015**

- 772 [1. Updated front matter to remove IEEE-ISTO boilerplate.](#)
- 773 [2. Fixed various typos](#)
- 774 [3. Clarified that SLC files are commonly known as STL files.](#)
- 775 [4. Clarified that S3G is a binary version of G-code with a standard packet format.](#)
- 776 [5. Added use case for printing with loaded materials](#)
- 777 [6. Added use case for multi-material printing on a single material printer.](#)
- 778 [7. Added use case for monitoring print progress visually with a web cam.](#)
- 779 [8. Added exception for "skipping" \(insufficient material flow/feed\)](#)
- 780 [9. Added exception for adhesion issues](#)
- 781 [10. Added exception for build plate being full.](#)
- 782 [11. Added exception for head movement issues.](#)
- 783 [12. Added figure showing the typical coordinate system.](#)
- 784 [13. Expanded Job Template and Printer Description details, added comments for](#)
- 785 [discussion.](#)
- 786 [14. Added new Unicode considerations and references.](#)

**787 12.4 January 23, 2015**

788 Initial revision.

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For additional information regarding the Printer Working Group visit:

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## **About the Internet Printing Protocol Workgroup**

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

For additional information regarding IPP visit:

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

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

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Table 1 - An Example Table ..... 4

The Interchangeable Variable Block Data Format for Positioning, Contouring, and Contouring/Positioning Numerically Controlled Machines [RS274D] defines the "G-code" format that is commonly used by 3D printers; and The S3G protocol [S3G] defines a simple network protocol and file format for controlling 3D printers.

### **material-diameter (integer)**

This member attribute provides the diameter of the printed material in nanometers. This attribute is only applicable for Printers that extrude their material.

### **material-feed-rate (integer)**

This member attribute provides the material feed rate in nanometers per second. This attribute is only applicable for Printers that extrude their material.

[Editor's note: Some feedback indicates that we might want to specify feed rate using volume...]

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### **filament-retraction-distance (integer(0:MAX))**

This member attribute specifies the filament retraction distance in nanometers. This attribute is only applicable to FDM Printers.

### **filament-retraction-speed (integer(0:MAX))**

This member attribute specifies the filament retraction speed in nanometers per second. This attribute is only applicable to FDM Printers.

### **extruder-temperature (integer | rangeOfInteger)**

This member attribute specifies the desired extruder temperature (or range of temperatures) in degrees Celsius. This attribute is only applicable to Printers that extrude their material.

### **print-speed (integer(1:MAX))**

This member attribute specifies the print speed in nanometers per second.

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

This Printer Description attribute lists the supported diameters (or ranges of diameters) of extruded material in nanometers.

### **material-feed-rate-supported (1setOf (integer | rangeOfInteger))**

This Printer Description attribute lists the supported feed rates (or ranges of feed rates) in nanometers per second.

[Editor's note: Some feedback indicates that we might want to specify feed rate using volume...]

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**filament-retraction-distance-supported (1setOf (integer(0:MAX) | rangeOfInteger(0:MAX)))**

This Printer Description attribute specifies the supported "filament-retraction-distance" values (or ranges of values) in nanometers.

**filament-speed-supported (1setof (integer(0:MAX) | rangeOfInteger(0:MAX)))**

This Printer Description attribute specifies the supported "filament-speed" values (or ranges of values) in nanometers per second.

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

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

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

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

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- [RS274D] "Interchangeable Variable Block Data Format for Positioning, Contouring, and Contouring/Positioning Numerically Controlled Machines", EIA Standard RS-274-D, February 1979
- [S3G] Makerbot Industries, "S3G protocol (formerly RepRap Generation 3 Protocol Specification", <https://github.com/makerbot/s3g/blob/master/doc/s3gProtocol.md>

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