



The Printer Working Group

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## IPP 3D Printing Extensions (3D)

Status: Interim

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

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

This document is available electronically at:

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

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## 181 1. Introduction

182 This white paper defines an extension to the Internet Printing Protocol (IPP) that supports  
183 printing of physical objects by Additive Manufacturing devices such as three-dimensional  
184 (3D) printers. The attributes and values defined in this document have been prototyped  
185 using the CUPS software [CUPS].

186 The primary focus of this document is on popular Fused Deposition Modeling (FDM)  
187 devices that melt and extrude ABS and/or PLA filaments in layers to produce a physical,  
188 3D object. However, the same attributes can be used for other types of 3D printers that  
189 use different methods and materials such as Laser Sintering of powdered materials and  
190 curing of liquids using ultraviolet light.

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

194 This document does not address the larger issue of choosing a common Object Definition  
195 Language (ODL) for interoperability, however there are suggested MIME media type  
196 names listed in section 13, for several formats in common use as well as strategies for  
197 mapping material definitions in the Job Ticket to the ODL content.

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### 198 1.1 Previous Solutions

199 3D printers are commonly bundled with so-called "slicer" software that converts ODL files  
200 into a suitable low-level format (G-code, etc.) for the printer. The file produced by the slicer  
201 software is then copied to a SD memory card and inserted in a slot on the printer where it  
202 can be selected for printing. Some printers also support job submission via USB interface,  
203 and third-party Cloud solutions often use the USB interface to print jobs received through  
204 the Cloud.

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

211

## 213 2. Terminology

### 214 2.1 Conformance Terminology

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

### 220 2.2 Printing Terminology

221 Normative definitions and semantics of printing terms are imported from IETF Printer MIB  
222 v2 [RFC3805], IETF Finisher MIB [RFC3806], and IETF Internet Printing Protocol/1.1:  
223 Model and Semantics [RFC2911].

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

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

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

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

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

### 235 2.3 Protocol Role Terminology

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

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

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



## 243 2.4 3D Printing Terminology

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

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

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

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

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

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

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

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

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

## 262 2.5 Acronyms and Organizations

263 *CNC*: Computer Numerical Control

264 *DLP*: Digital Light Processing

265 *FDM*: Fused Deposition Modeling

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

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

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

269 *ODL*: Object Definition Language

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

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

Field Code Changed

272 *SDL*: Selective Deposition Lamination

273 *SL*: Stereo Lithography

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

275

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

277 Existing specifications define the following:

- 278 1. IPP/2.0 Second Edition [PWG5100.12] defines version 2.0, 2.1, and 2.2 of the  
279 Internet Printing Protocol which defines a standard operating and data model,  
280 interface protocol, and extension mechanism to support traditional Printers;
- 281 2. IPP Everywhere [PWG5100.14] defines a profile of existing IPP specifications,  
282 standard Job Template attributes, and standard document formats;
- 283 3. IPP Shared Infrastructure Extensions (INFRA) [PWG5100.18] defines an  
284 interface for printing through shared services based in infrastructure such as  
285 Cloud servers;
- 286 4. The 3D Manufacturing Format Core Specification & Reference Guide v1.0 [3MF]  
287 defines an XML schema and file format for describing 3D objects with one or  
288 more materials.

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

### 292 **3.1 Use Cases**

#### 293 **3.1.1 Print a 3D Object**

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

#### 297 **3.1.2 Print a 3D Object Using Loaded Materials**

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

#### 301 **3.1.3 Print a 3D Object with Multiple Materials**

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

#### 306 **3.1.4 View a 3D Object During Printing**

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

**309 3.2 Exceptions****310 3.2.1 Clogged Extruder**

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

**314 3.2.2 Extruder Temperature Out of Range**

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

**319 3.2.3 Extruder Head Movement Issues**

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

**323 3.2.4 Filament Feed Jam**

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

**327 3.2.5 Filament Feed Skip**

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

**331 3.2.6 Material Empty**

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

**335 3.2.7 Material Adhesion Issues**

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

340 **3.2.8 Print Bed Temperature Out of Range**

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

344 **3.2.9 Print Bed Not Clear**

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

349 **3.3 Out of Scope**

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

- 351 1. Definition of new file formats; and  
352 2. Support for Subtractive Manufacturing technologies such as CNC milling  
353 machines.

354 **3.4 Design Requirements**

355 The design requirements for this document are:

- 356 1. Define attributes and values to describe supported and loaded (ready) materials  
357 used for FDM; and  
358 2. Define attributes and values to describe FDM printer capabilities and state

359 The design recommendations for this document are:

- 360 1. Support 3D printing technologies other than FDM  
361

## 362 4. 3D Print Service Model

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

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

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

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

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

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

389

Deleted: Technical Solutions/Approaches

Deleted: Current 3D printers offer limited connectivity and status monitoring capabilities. Many printers simply read printer-ready files from SD memory cards, with all interaction and status monitoring happening at the printer's console [2]

Deleted: IPP

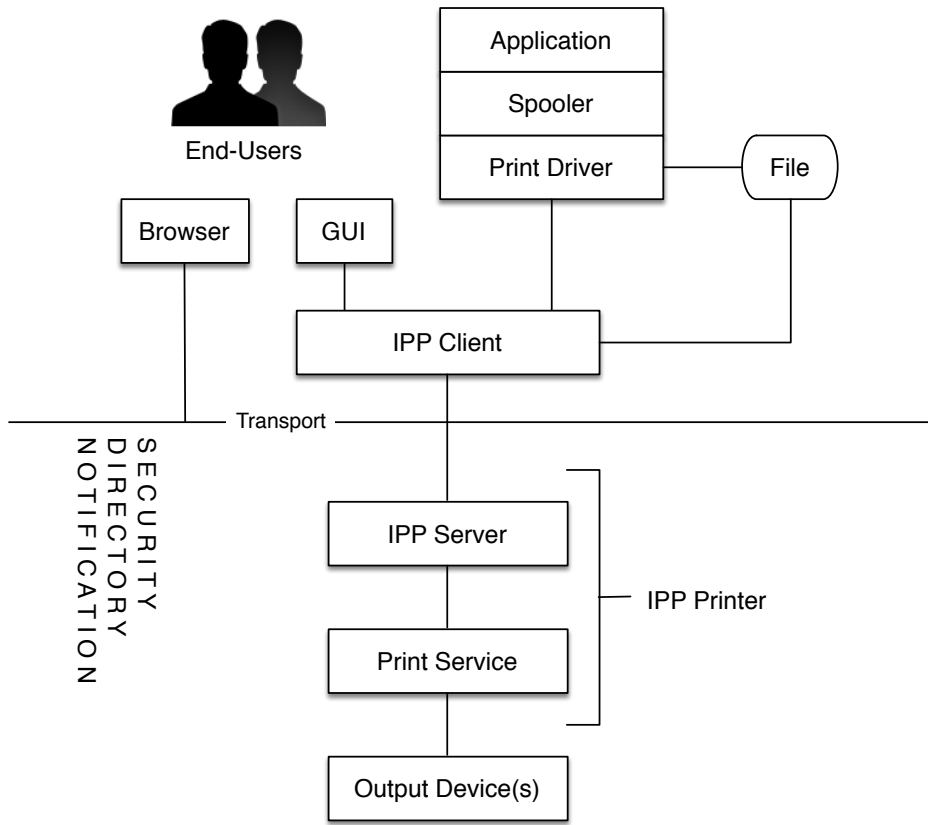


Figure 1 - Generalized IPP Model (RFC 2911)

397

398

399

400 4.1 3D Print Service

401 3D printing uses a variation of the traditional Print service that maintains state and
402 capability information specific to 3D printing. The 3D Print service supports all of the same
403 operations of the Print service described in [RFC2911] except for the Print-Job and Print-
404 URI operations which are compound operations that are not used in newer IPP services.
405 Similarly, the 3D Print service uses a superset of the Print service attributes except where
406 such attributes are not applicable, for example the "media" attributes for a 3D printer that
407 does not use media sheets. Attributes specific to the 3D Print Service are defined in
408 section 5.

Deleted: 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.

412 4.2 3D Printer Subunits

413 Table 1 lists the subunits of 3D printers for different technologies.

414 Table 1 - 3D Printer Subunits

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Subunit	Technology	Reference
Cutters	SDL	RFC 3806
Doors	All	RFC 3805
Input Trays	SDL	RFC 3805
Marker Supplies	All	RFC 3805
Markers (or Extruders)	Many	RFC 3805
Media Path	SDL	RFC 3805
Build Platforms	All	Section 4.2.1
Cameras	All	Section 4.2.2
Chamber	All	Section 4.2.3
Fans	FDM	Section 4.2.5
Lamps	DLP	Section 4.2.6
Lasers	Laser Sintering, SL	Section 4.2.7
Motors	All	Section 4.2.9
Reservoirs	DLP, Laser Sintering, SL	Section 4.2.10

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415 4.2.1 Build Platforms

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

418 4.2.2 Cameras

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



436 **4.2.3 Chambers**

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

439 **4.2.4 Cutters**

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

442 **4.2.5 Fans**

443 Fans are used to cool printed material and maintain proper extruder and material  
444 temperatures.

445 **4.2.6 Lamps**

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

448 **4.2.7 Lasers**

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

451 **4.2.8 Markers (or Extruders)**

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

455 **4.2.9 Motors**

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

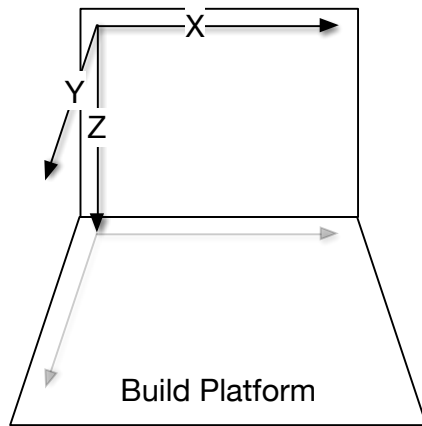
457 **4.2.10 Reservoirs**

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

459 **4.3 3D Printer Coordinate System**

460 3D printers operate in three dimensions and thus have three axis of movement. Figure 2  
461 shows a typical coordinate system where the X axis represents the width of the object, the  
462 Y axis represents the depth of the object, and the Z axis represents the height of the  
463 object. Note that, depending on the technology used, the Z axis may move in the opposite  
464 direction, or the extruder may move independently with a stationary build platform.

465



466

467

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

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

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

#### 474 **4.4 Output Intent and Job Processing**

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

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

#### 485 **4.5 Job Spooling**

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

489 **4.6 Cloud-Based Printing**

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

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494 Snapshots of camera video are uploaded as JPEG image resources using HTTP PUT  
495 requests from the Proxy to the Infrastructure Printer. Such resources MUST be updated in  
496 an atomic fashion to allow Clients to safely poll for updates to the camera video.  
497

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502 **5. New Attributes**503 **5.1 Job Template Attributes**

504 Table 2 lists the Job Template attributes and their corresponding “-default” and “-  
505 supported” attributes.

506 **Table 2 - Job Template Attributes**

<b>Job Template</b>	<b>Printer: Default</b>	<b>Printer: Supported</b>
materials-col (collection)	materials-col-default (1setOf collection)	materials-col-database (1setOf collection) materials-col-ready (1setOf collection) materials-col-supported (1setOf type2 keyword)
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)

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508 **5.1.1 materials-col (1setOf collection)**

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

514 The Client typically supplies "materials-col" values matching those returned in the  
\$15 "materials-col-database" (section 5.3.1) or "materials-col-ready" (section 5.3.10) Printer  
\$16 Description attributes. Table 3 lists the member attributes.

\$17 **Table 3 - "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

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- Deleted: 5.2.3
- Deleted: Table 6
- Deleted: 6

518 **5.1.1.1 material-amount (integer(0:MAX) | unknown)**

519 This member attribute provides the estimated amount of material that is available  
520 ("materials-col-database" and "materials-col-ready" values), the estimated amount of  
521 material that is required ("materials-col" values), or the actual amount of material that has  
522 been used ("materials-col-actual" values).

523 **5.1.1.2 material-amount-units (type2 keyword)**

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

- 525 'g': Value is mass in grams.
- 526 'kg': Value is mass in kilograms.
- 527 'l': Value is volume in liters.
- 528 'm': Value is length in meters.

533 'ml': Value is volume in milliliters.

534 'mm': Value is length in millimeters.

535 **5.1.1.3 material-color (type2 keyword)**

536 This member attribute provides a PWG media color [\[PWG5101.1\]](#) value representing the  
537 color of the material.

538 **5.1.1.4 material-diameter (integer(1:MAX))**

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

541 **5.1.1.5 material-key (keyword)**

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

544 **5.1.1.6 material-name (name(MAX))**

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

546 **5.1.1.7 material-purpose (1setOf type2 keyword)**

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

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

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

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

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

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

553 **5.1.1.8 material-rate (integer(1:MAX))**

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

556 **5.1.1.9 material-rate-units (type2 keyword)**

557 This member attribute provides the units for the "material-rate" member attribute. Values  
558 include:

559 'mg': Value is milligrams per second.

560 'ml': Value is milliliters per second.

561 'mm': Value is millimeters per second.

562 **5.1.1.10 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))**

563 This member attribute specifies the temperature (or range of temperatures) for the material  
564 in degrees Celsius.

565 **5.1.1.11 material-type (type2 keyword)**

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

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

571 'abs-carbon-fiber\_filament': ABS filament reinforced with carbon fibers.

572 'abs-carbon-nanotube\_filament': ABS filament reinforced with carbon nanotubes.

573 'chocolate\_powder': Chocolate powder.

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

575 'nylon\_filament': Nylon filament.

576 'pet\_filament': Polyethylene terephthalate (PET) filament.

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

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

579 'pla-conductive\_filament': Conductive PLA filament.

580 'pla-dissolvable\_filament': Dissolvable PLA filament.

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

582 'pla-magnetic\_filament': PLA with embedded iron particles.

583 'pla-steel-filament': PLA with embedded steel particles.

584 'pla-stone\_filament': PLA filament with embedded stone chips.

585 'pla-wood\_filament': PLA filament with embedded wood fibers.

586 'polycarbonate\_filament': Polycarbonate filament.

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

588 'titanium\_powder': Titanium (metal) powder.

589 'wax\_solid': Solid wax.

#### 590 **5.1.2 print-fill-density (integer(0:100))**

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

#### 592 **5.1.3 print-fill-thickness (integer(0:MAX))**

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

#### 595 **5.1.4 print-layer-thickness (integer(0:MAX))**

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

#### 598 **5.1.5 print-rafts (type2 keyword)**

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

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

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

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

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

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

#### 607 **5.1.6 print-shell-thickness (integer(0:MAX))**

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

#### 610 **5.1.7 print-speed (integer(1:MAX))**

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

#### 612 **5.1.8 print-supports (type2 keyword)**

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



615 'none': Do not print supports.

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

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

618 **5.1.9 printer-chamber-temperature (integer(-273:MAX) | no-value)**

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

621 **5.1.10 printer-fan-speed (integer(0:100))**

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

624 **5.1.11 printer-platform-temperature (integer(-273:MAX) | no-value)**

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

627 **5.2 Job Description Attributes**

628 **5.2.1 materials-col-actual (1setOf collection)**

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

630 **5.3 Printer Description Attributes**

631 **5.3.1 material-amount-units-supported (1setOf type2 keyword)**

632 This Printer Description attribute lists the supported "material-amount-units" values for the  
633 Printer.

634 **5.3.2 material-diameter-supported (1setOf (integer | rangeOfInteger))**

635 This Printer Description attribute lists the supported "material-diameter" values for the  
636 Printer.

637 **5.3.3 material-purpose-supported (1setOf type2 keyword)**

638 This Printer Description attribute lists the supported "material-purpose" values for the  
639 Printer.

640 **5.3.4 material-rate-supported (1setOf (integer | rangeOfInteger))**

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

**642 5.3.5 material-rate-units-supported (1setOf type2 keyword)**

643 This Printer Description attribute lists the supported "material-rate-units" values for the  
644 Printer.

**645 5.3.6 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-  
646 273:MAX)))**

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

**649 5.3.7 material-type-supported (1setOf type2 keyword)**

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

**651 5.3.8 materials-col-database (1setOf collection)**

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

**655 5.3.9 materials-col-default (1setOf collection)**

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

**658 5.3.10 materials-col-ready (1setOf collection)**

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

**661 5.3.11 materials-col-supported (1setOf type2 keyword)**

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

**664 5.3.12 print-fill-density-default (integer(0:100))**

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

**666 5.3.13 print-fill-thickness-default (integer(0:MAX))**

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

669 **5.3.14 print-fill-thickness-supported (1setOf (integer(0:MAX) |**  
670 **rangeOfInteger(0:MAX)))**

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

673 **5.3.15 print-layer-order (type1 keyword)**

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

676 **5.3.16 print-layer-thickness-default (integer(0:MAX))**

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

679 **5.3.17 print-layer-thickness-supported (1setOf (integer(0:MAX) |**  
680 **rangeOfInteger(0:MAX)))**

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

683 **5.3.18 print-rafts-default (type2 keyword)**

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

685 **5.3.19 print-rafts-supported (1setOf type2 keyword)**

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

687 **5.3.20 print-shell-thickness-default (integer(0:MAX))**

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

690 **5.3.21 print-shell-thickness-supported (1setOf (integer(0:MAX) |**  
691 **rangeOfInteger(0:MAX)))**

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

694 **5.3.22 print-speed-default (integer(1:MAX))**

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

**697 5.3.23 print-speed-supported (1setOf (integer(1:MAX) | rangeOfInteger(1:MAX)))**

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

**700 5.3.24 print-supports-default (type2 keyword)**

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

**702 5.3.25 print-supports-supported (1setOf type2 keyword)**

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

**704 5.3.26 printer-accuracy-supported (collection)**

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

**708 5.3.27 printer-camera-image-uri (1setOf uri)**

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

**713 5.3.28 printer-chamber-temperature-default (integer(-273:MAX) | no-value)**

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

**716 5.3.29 printer-chamber-temperature-supported (1setOf (integer(-273:MAX) |  
717 rangeOfInteger(-273:MAX)) | no-value)**

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

**721 5.3.30 printer-fan-speed-default (integer(0:MAX))**

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

**723 5.3.31 printer-fan-speed-supported (boolean)**

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

**726 5.3.32 printer-platform-temperature-default (integer(-273:MAX) | no-value)**

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

**729 5.3.33 printer-platform-temperature-supported (1setOf (integer(-273:MAX) |  
730 rangeOfInteger(-273:MAX)) | no-value)**

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

**734 5.3.34 printer-volume-supported (collection)**

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

**739 5.4 Printer Status Attributes****740 5.4.1 printer-camera (1setOf collection)**

741 This Printer Status attribute provides current information about the camera sub-units, if  
742 any, of the Printer. Each of the member attributes are modeled using the common Printer  
743 MIB v2 [RFC3805] sub-unit properties.

**744 5.4.1.1 camera-info (text(127))**

745 This REQUIRED member attribute provides a localized description of the camera sub-unit.

**746 5.4.1.2 camera-info-uri (uri)**

747 This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page  
748 providing additional information about the camera sub-unit.

**749 5.4.1.3 camera-name (name(127))**

750 This REQUIRED member attribute provides a unique name for the camera sub-unit.

**751 5.4.1.4 camera-state (type1 enum)**

752 This REQUIRED member attribute provides the overall state of the camera sub-unit.  
753 Values are:

754 '3' ('idle'): The camera sub-unit is available and either idle or in standby mode.

755 '4' ('processing'): The camera sub-unit is available and either active or busy.

756 '5' ('stopped'): The camera sub-unit is unavailable.

#### 757 **5.4.1.5 camera-state-reasons (1setOf type2 keyword)**

758 This CONDITIONALLY REQUIRED member attribute provides details concerning the  
 759 camera sub-unit state. Printers with more than one camera sub-unit MUST support this  
 760 member attribute. Values include:

761 'camera-failure': The camera is no longer working.

#### 762 **5.4.2 printer-chamber (1setOf collection)**

763 This Printer Status attribute provides current information about the chamber sub-units, if  
 764 any, of the Printer. Each of the member attributes are modeled using the common Printer  
 765 MIB v2 [RFC3805] sub-unit properties.

##### 766 **5.4.2.1 chamber-info (text(127))**

767 This REQUIRED member attribute provides a localized description of the chamber sub-  
 768 unit.

##### 769 **5.4.2.2 chamber-info-uri (uri)**

770 This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page  
 771 providing additional information about the chamber sub-unit.

##### 772 **5.4.2.3 chamber-name (name(127))**

773 This REQUIRED member attribute provides a unique name for the chamber sub-unit.

##### 774 **5.4.2.4 chamber-state (type1 enum)**

775 This REQUIRED member attribute provides the overall state of the chamber sub-unit.  
 776 Values are:

777 '3' ('idle'): The chamber sub-unit is available and either idle or in standby mode.

778 '4' ('processing'): The chamber sub-unit is available and either active or busy.

779 '5' ('stopped'): The chamber sub-unit is unavailable.

##### 780 **5.4.2.5 chamber-state-reasons (1setOf type2 keyword)**

781 This CONDITIONALLY REQUIRED member attribute provides details concerning the  
 782 chamber sub-unit state. Printers with more than one chamber sub-unit MUST support this  
 783 member attribute. Values include:

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

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

**Deleted:** -

791 'chamber-heating': The chamber is being heated.

792 'chamber-temperature-high': The temperature of the chamber is high.

793 'chamber-temperature-low': The temperature of the chamber is low.

#### 794 5.4.2.6 **chamber-temperature (integer(-273:MAX) | no-value)**

795 This **REQUIRED** member attribute provides the current print chamber temperature in  
796 degrees Celsius. If the print chamber is not temperature controlled, the 'no-value' value is  
797 returned.

Deleted: -current

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#### 798 5.4.3 **printer-cutter (1setOf collection)**

799 This Printer Status attribute provides current information about the cutter sub-units, if any,  
800 of the Printer. Each of the member attributes are modeled using the common Printer MIB  
801 v2 [RFC3805] sub-unit properties.

##### 802 5.4.3.1 **cutter-info (text(127))**

803 This REQUIRED member attribute provides a localized description of the cutter sub-unit.

##### 804 5.4.3.2 **cutter-info-uri (uri)**

805 This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page  
806 providing additional information about the cutter sub-unit.

##### 807 5.4.3.3 **cutter-name (name(127))**

808 This REQUIRED member attribute provides a unique name for the cutter sub-unit.

##### 809 5.4.3.4 **cutter-state (type1 enum)**

810 This REQUIRED member attribute provides the overall state of the cutter sub-unit. Values  
811 are:

812 '3' ('idle'): The cutter sub-unit is available and either idle or in standby mode.

813 '4' ('processing'): The cutter sub-unit is available and either active or busy.

814 '5' ('stopped'): The cutter sub-unit is unavailable.

##### 815 5.4.3.5 **cutter-state-reasons (1setOf type2 keyword)**

816 This CONDITIONALLY REQUIRED member attribute provides details concerning the  
817 cutter sub-unit state. Printers with more than one cutter sub-unit MUST support this  
818 member attribute. Values include:

§21 'cutter-at-eol': The cutter has reached its end-of-life and will need to be replaced  
§22 soon.

§23 'cutter-failure': The cutter has failed.

§24 'cutter-near-eol': The cutter is near its end-of-life and may need to be replaced soon.

#### §25 **5.4.4 printer-extruder (1setOf collection)**

§26 This Printer Status attribute provides current information about the extruder sub-units, if  
§27 any, of the Printer. Each of the member attributes are modeled using the common Printer  
§28 MIB v2 [RFC3805] sub-unit properties.

##### §29 **5.4.4.1 extruder-info (text(127))**

§30 This REQUIRED member attribute provides a localized description of the extruder sub-  
§31 unit.

##### §32 **5.4.4.2 extruder-info-uri (uri)**

§33 This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page  
§34 providing additional information about the extruder sub-unit.

##### §35 **5.4.4.3 extruder-name (name(127))**

§36 This REQUIRED member attribute provides a unique name for the extruder sub-unit.

##### §37 **5.4.4.4 extruder-state (type1 enum)**

§38 This REQUIRED member attribute provides the overall state of the extruder sub-unit.  
§39 Values are:

§40 '3' ('idle'): The extruder sub-unit is available and either idle or in standby mode.

§41 '4' ('processing'): The extruder sub-unit is available and either active or busy.

§42 '5' ('stopped'): The extruder sub-unit is unavailable.

##### §43 **5.4.4.5 extruder-state-reasons (1setOf type2 keyword)**

§44 This CONDITIONALLY REQUIRED member attribute provides details concerning the  
§45 extruder sub-unit state. Printers with more than one extruder sub-unit MUST support this  
§46 member attribute. Values include:

§47 'extruder-cooling': The extruder is being cooled.

§48 'extruder-failure': The extruder has failed and requires maintenance or replacement.

§49 'extruder-heating': The extruder is being heated.



§50 'extruder-jam': The extruder is jammed or clogged.

§51 'extruder-temperature-high': The temperature of the extruder is too high.

§52 'extruder-temperature-low': The temperature of the extruder is too low.

#### §53 **5.4.4.6 extruder-temperature (integer(-273:MAX) | no-value)**

§54 This REQUIRED member attribute provides the current extruder head temperature in  
 §55 degrees Celsius. The 'no-value' value is returned when the extruder head is not  
 §56 temperature controlled.

#### §57 **5.4.5 printer-fan (1setOf collection)**

§58 This Printer Status attribute provides current information about the fan sub-units, if any, of  
 §59 the Printer. Each of the member attributes are modeled using the common Printer MIB v2  
 §60 [RFC3805] sub-unit properties.

##### §61 **5.4.5.1 fan-info (text(127))**

§62 This REQUIRED member attribute provides a localized description of the fan sub-unit.

##### §63 **5.4.5.2 fan-info-uri (uri)**

§64 This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page  
 §65 providing additional information about the fan sub-unit.

##### §66 **5.4.5.3 fan-name (name(127))**

§67 This REQUIRED member attribute provides a unique name for the fan sub-unit.

#### §68 **5.4.6 fan-speed (integer(0:100))**

§69 This REQUIRED member attribute provides the current fan speed in percent.

##### §70 **5.4.6.1 fan-state (type1 enum)**

§71 This REQUIRED member attribute provides the overall state of the fan sub-unit. Values  
 §72 are:

§73 '3' ('idle'): The fan sub-unit is available and either idle or in standby mode.

§74 '4' ('processing'): The fan sub-unit is available and either active or busy.

§75 '5' ('stopped'): The fan sub-unit is unavailable.

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§79 **5.4.6.2 fan-state-reasons (1setOf type2 keyword)**

§80 This CONDITIONALLY REQUIRED member attribute provides details concerning the fan  
§81 sub-unit state. Printers with more than one fan sub-unit MUST support this member  
§82 attribute. Values include:

§83 'fan-failure': The fan has failed.

§84 **5.4.7 printer-lamp (1setOf collection)**

§85 This Printer Status attribute provides current information about the lamp sub-units, if any,  
§86 of the Printer. Each of the member attributes are modeled using the common Printer MIB  
§87 v2 [RFC3805] sub-unit properties.

§88 **5.4.7.1 lamp-info (text(127))**

§89 This REQUIRED member attribute provides a localized description of the lamp sub-unit.

§90 **5.4.7.2 lamp-info-uri (uri)**

§91 This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page  
§92 providing additional information about the lamp sub-unit.

§93 **5.4.7.3 lamp-name (name(127))**

§94 This REQUIRED member attribute provides a unique name for the lamp sub-unit.

§95 **5.4.7.4 lamp-state (type1 enum)**

§96 This REQUIRED member attribute provides the overall state of the lamp sub-unit. Values  
§97 are:

§98 '3' ('idle'): The lamp sub-unit is available and either idle or in standby mode.

§99 '4' ('processing'): The lamp sub-unit is available and either active or busy.

§00 '5' ('stopped'): The lamp sub-unit is unavailable.

§01 **5.4.7.5 lamp-state-reasons (1setOf type2 keyword)**

§02 This CONDITIONALLY REQUIRED member attribute provides details concerning the lamp  
§03 sub-unit state. Printers with more than one fan sub-unit MUST support this member  
§04 attribute. Values include:

§05 'lamp-at-eol': The lamp has reached its end-of-life and will need to be replaced  
§06 soon.

§07 'lamp-failure': The lamp has failed.

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

#### 909 **5.4.8 printer-laser (1setOf collection)**

910 This Printer Status attribute provides current information about the laser sub-units, if any,  
911 of the Printer. Each of the member attributes are modeled using the common Printer MIB  
912 v2 [RFC3805] sub-unit properties.

##### 913 **5.4.8.1 laser-info (text(127))**

914 This REQUIRED member attribute provides a localized description of the laser sub-unit.

##### 915 **5.4.8.2 laser-info-uri (uri)**

916 This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page  
917 providing additional information about the laser sub-unit.

##### 918 **5.4.8.3 laser-name (name(127))**

919 This REQUIRED member attribute provides a unique name for the laser sub-unit.

##### 920 **5.4.8.4 laser-state (type1 enum)**

921 This REQUIRED member attribute provides the overall state of the laser sub-unit. Values  
922 are:

923 '3' ('idle'): The laser sub-unit is available and either idle or in standby mode.

924 '4' ('processing'): The laser sub-unit is available and either active or busy.

925 '5' ('stopped'): The laser sub-unit is unavailable.

##### 926 **5.4.8.5 laser-state-reasons (1setOf type2 keyword)**

927 This CONDITIONALLY REQUIRED member attribute provides details concerning the laser  
928 sub-unit state. Printers with more than one fan sub-unit MUST support this member  
929 attribute. Values include:

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

932 'laser-failure': The laser has failed.

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

934 **5.4.9 printer-motor (1setOf collection)**

935 This Printer Status attribute provides current information about the motor sub-units, if any,  
936 of the Printer. Each of the member attributes are modeled using the common Printer MIB  
937 v2 [RFC3805] sub-unit properties.

938 **5.4.9.1 motor-info (text(127))**

939 This REQUIRED member attribute provides a localized description of the motor sub-unit.

940 **5.4.9.2 motor-info-uri (uri)**

941 This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page  
942 providing additional information about the motor sub-unit.

943 **5.4.9.3 motor-name (name(127))**

944 This REQUIRED member attribute provides a unique name for the motor sub-unit.

945 **5.4.9.4 motor-state (type1 enum)**

946 This REQUIRED member attribute provides the overall state of the motor sub-unit. Values  
947 are:

948 '3' ('idle'): The motor sub-unit is available and either idle or in standby mode.

949 '4' ('processing'): The motor sub-unit is available and either active or busy.

950 '5' ('stopped'): The motor sub-unit is unavailable.

951 **5.4.9.5 motor-state-reasons (1setOf type2 keyword)**

952 This CONDITIONALLY REQUIRED member attribute provides details concerning the  
953 motor sub-unit state. Printers with more than one fan sub-unit MUST support this member  
954 attribute. Values include:

955 'motor-failure': The motor has failed.

956 **5.4.10 printer-platform (1setOf collection)**

957 This Printer Status attribute provides current information about the Build Platform sub-  
958 units, if any, of the Printer. Each of the member attributes are modeled using the common  
959 Printer MIB v2 [RFC3805] sub-unit properties.

960 **5.4.10.1 platform-info (text(127))**

961 This REQUIRED member attribute provides a localized description of the Build Platform  
962 sub-unit.

**5.4.10.2 platform-info-uri (uri)**

This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page providing additional information about the Build Platform sub-unit.

**5.4.10.3 platform-name (name(127))**

This REQUIRED member attribute provides a unique name for the Build Platform sub-unit.

**5.4.10.4 platform-state (type1 enum)**

This REQUIRED member attribute provides the overall state of the Build Platform sub-unit. Values are:

'3' ('idle'): The Build Platform sub-unit is available and either idle or in standby mode.

'4' ('processing'): The Build Platform sub-unit is available and either active or busy.

'5' ('stopped'): The Build Platform sub-unit is unavailable.

**5.4.10.5 platform-state-reasons (1setOf type2 keyword)**

This CONDITIONALLY REQUIRED member attribute provides details concerning the Build Platform sub-unit state. Printers with more than one fan sub-unit MUST support this member attribute. Values include:

'platform-failure': The Build Platform has failed.

**5.4.10.6 platform-temperature (integer(-273:MAX) | no-value)**

This REQUIRED member attribute provides the current Build Platform sub-unit temperature in degrees Celsius. If the Build Platform is not temperature controlled, the 'no-value' value is returned.

**5.4.11 printer-reservoir (1setOf collection)**

This Printer Status attribute provides current information about the reservoir sub-units, if any, of the Printer. Each of the member attributes are modeled using the common Printer MIB v2 [RFC3805] sub-unit properties.

**5.4.11.1 reservoir-info (text(127))**

This REQUIRED member attribute provides a localized description of the reservoir sub-unit.

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**5.4.11.2 reservoir-info-uri (uri)**

This RECOMMENDED member attribute provides the 'http' or 'https' URI of a web page providing additional information about the reservoir sub-unit.

**5.4.11.3 reservoir-name (name(127))**

This REQUIRED member attribute provides a unique name for the reservoir sub-unit.

**5.4.11.4 reservoir-state (type1 enum)**

This REQUIRED member attribute provides the overall state of the reservoir sub-unit. Values are:

'3' ('idle'): The fan sub-unit is available and either idle or in standby mode.

'4' ('processing'): The fan sub-unit is available and either active or busy.

'5' ('stopped'): The fan sub-unit is unavailable.

**5.4.11.5 reservoir-state-reasons (1setOf type2 keyword)**

This CONDITIONALLY REQUIRED member attribute provides details concerning the reservoir sub-unit state. Printers with more than one reservoir sub-unit MUST support this member attribute. Values include:

'reservoir-empty': The reservoir is empty.

'reservoir-low': The reservoir is almost empty.

'reservoir-needed': The reservoir is empty but needs to be filled for a processing Job.

1015 **6. New Values for Existing Attributes**

1016 **6.1 ipp-features-supported (1setOf type2 keyword)**

1017 This document registers the new value 'ipp-3d'.

Deleted: suggests (but does not  
Deleted: )

1018 **6.2 printer-state-reasons (1setOf type2 keyword)**

1019 This document registers the following new values:

Deleted: suggests (but does not  
Deleted: )

- 1020 'camera-failure': A camera is no longer working.
- 1021 'chamber-cooling': A chamber is being cooled.
- 1022 'chamber-heating': A chamber is being heated.
- 1023 'chamber-temperature-high': The temperature of a chamber is high.
- 1024 'chamber-temperature-low': The temperature of a chamber is low.
- 1025 'cutter-at-eol': A cutter has reached its end-of-life and will need to be replaced soon.
- 1026 'cutter-failure': A cutter has failed.
- 1027 'cutter-near-eol': A cutter is near its end-of-life and may need to be replaced soon.
- 1028 'extruder-cooling': An extruder is being cooled.
- 1029 'extruder-failure': An extruder has failed and requires maintenance or replacement.
- 1030 'extruder-heating': An extruder is being heated.
- 1031 'extruder-jam': An extruder is jammed or clogged.
- 1032 'extruder-temperature-high': The temperature of an extruder is too high.
- 1033 'extruder-temperature-low': The temperature of an extruder is too low.
- 1034 'fan-failure': A fan has failed.
- 1035 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.
- 1036 'lamp-failure': A lamp has failed.
- 1037 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.
- 1038 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.

- 1043 'laser-failure': A laser has failed.
- 1044 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.
- 1045 'material-empty': One or more build materials have been exhausted.
- 1046 'material-low': One or more build materials may need replenishment soon.
- 1047 'material-needed': One or more build materials need to be loaded for a processing
- 1048 Job.
- 1049 'motor-failure': A motor has failed.
- 1050 'reservoir-empty': One or more reservoirs are empty.
- 1051 'reservoir-low': One or more reservoirs are almost empty.
- 1052 'reservoir-needed': One or more reservoirs are empty but need to be filled for a
- 1053 processing Job.
- 1054 [Editor's Note: Additional keywords may be needed, for discussion]
- 1055



1056

**7. Conformance Requirements**

1057

**7.1 Printer Conformance Requirements**

1058

**7.2 Client Conformance Requirements**

1059

## 1060 8. Internationalization Considerations

1061 For interoperability and basic support for multiple languages, conforming implementations  
1062 MUST support:

- 1063 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)  
1064 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 1065 2. The Unicode Format for Network Interchange [RFC5198] which requires  
1066 transmission of well-formed UTF-8 strings and recommends transmission of  
1067 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1068 Unicode NFC is defined as the result of performing Canonical Decomposition (into base  
1069 characters and combining marks) followed by Canonical Composition (into canonical  
1070 composed characters wherever Unicode has assigned them).

1071 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and  
1072 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in  
1073 IPP Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8  
1074 URIs now 'hidden').

1075 Implementations of this document SHOULD conform to the following standards on  
1076 processing of human-readable Unicode text strings, see:

- 1077 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical
- 1078 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping
- 1079 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]
- 1080 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences
- 1081 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization
- 1082 Unicode Character Encoding Model [UTR17] – multi-layer character model
- 1083 Unicode in XML and other Markup Languages [UTR20] – XML usage
- 1084 Unicode Character Property Model [UTR23] – character properties
- 1085 Unicode Conformance Model [UTR33] – Unicode conformance basis+
- 1086 Unicode Collation Algorithm [UTS10] – sorting
- 1087 Unicode Locale Data Markup Language [UTS35] – locale databases

1088 **9. Security Considerations**

1089 In addition to the security considerations described in the IPP/1.1: Model and Semantics  
1090 [RFC2911], the following sub-sections describe issues that are unique to 3D printing.

1091 Implementations of this specification SHOULD conform to the following standards on  
1092 processing of human-readable Unicode text strings, see:

1093       Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1094       Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

1095 **9.1 Access Control**

1096 Because of the potential for abuse and misuse, Printers SHOULD provide access control  
1097 mechanisms including lists of allowed Clients, authentication, and authorization to site  
1098 defined policies.

1099 **9.2 Physical Safety**

1100 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such  
1101 as protective gates, covers, or interlocks.

1102 **9.3 Material Safety**

1103 Printers MUST restrict usage and combination of materials to those that can be safely  
1104 printed. Access controls (section 9.1) MAY be used to allow authorized users to  
1105 experiment with untested materials or combinations, but only when such materials or  
1106 combinations can reasonably be expected to not pose a safety risk.

1107 **9.4 Temperature Control**

1108 Printers MUST validate temperature and fan speed values provided by Clients and limit  
1109 material, extruder, build platform, and print chamber temperatures within designed limits to  
1110 prevent unsafe operating conditions, damage to the hardware, explosions, and/or fires.  
1111

## 10. IANA and PWG Considerations

### 10.1 Attribute Registrations

The attributes defined in this document will be published by IANA according to the procedures in IPP/1.1 Model and Semantics [RFC2911] section 6.2 in the following file:

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

The registry entries will contain the following information:

Document Description attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Document Status attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Document Template attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Job Description attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Job Status attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Job Template attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Operation attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Printer Description attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Printer Status attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Subscription Description attributes:	Reference
-----	-----
name (type)	[REFERENCE]
Subscription Status attributes:	Reference
-----	-----

name (type)	[REFERENCE]
Subscription Template attributes:	
-----	-----
name (type)	[REFERENCE]

## 10.2 Attribute Value Registrations

The attributes defined in this document will be published by IANA according to the procedures in IPP/1.1 Model and Semantics [RFC2911] section 6.1 in the following file:

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

The registry entries will contain the following information:

Attributes (attribute syntax)		Reference
Keyword	Attribute Value	Reference
-----	-----	-----
name (type2 keyword)		[REFERENCE]
value-1		[REFERENCE]
value-2		[REFERENCE]
name-supported (1setOf type2 keyword)		[REFERENCE]
< all name values >		[REFERENCE]

## 10.3 Type2 enum Registrations

The attributes defined in this document will be published by IANA according to the procedures in IPP Model and Semantics [RFC2911] section 6.1 in the following file:

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

The registry entries will contain the following information:

Attributes (attribute syntax)			Reference
Enum Value	Enum Symbolic Name		Reference
-----	-----		-----
name (type2 enum)			[REFERENCE]
3	value-3		[REFERENCE]
4	value-4		[REFERENCE]
operations-supported (1setOf type2 enum)			[RFC2911]
0xXXXX	Operation-Name		[REFERENCE]

## 10.4 Operation Registrations

The attributes defined in this document will be published by IANA according to the procedures in IPP/1.1 Model and Semantics [RFC2911] section 6.4 in the following file:

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

1197 The registry entries will contain the following information:

Operation Name	Reference
-----	-----
Operation-Name	[REFERENCE]
Exiting-Operation-Name (Extension)	[REFERENCE]

## 1202 10.5 Status Code Registrations

1203 The attributes defined in this document will be published by IANA according to the  
 1204 procedures in IPP/1.1 Model and Semantics [RFC2911] section 6.6 in the following file:

1205 <http://www.iana.org/assignments/ipp-registrations>

1206 The registry entries will contain the following information:

Value	Status Code Name	Reference
-----	-----	-----
0x0400:0x04FF - Client Error:		
0x04XX client-error-name		[REFERENCE]
0x0500:0x05FF - Server Error:		
0x05XX server-error-name		[REFERENCE]

## 1213 10.6 Semantic Model Registrations

1214 The IPP attributes, values, and operations defined in this specification and listed in the  
 1215 preceding sections will be added to the PWG Semantic Model XML schema using the  
 1216 method defined in section 21 of [PWG5108.07].

## 11. References

### 11.1 Normative References

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- 1247 [RFC3806] R. Bergman, H. Lewis, I. McDonald, "Printer Finishing MIB", RFC  
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Field Code Changed

Field Code Changed

Field Code Changed

Field Code Changed

Field Code Changed

1249	[RFC5198]	J. Klensin, M. Padlipsky, "Unicode Format for Network Interchange", RFC 5198, March 2008, <a href="http://tools.ietf.org/html/rfc5198">http://tools.ietf.org/html/rfc5198</a>	Field Code Changed
1250			
1251	[STD63]	F. Yergeau, "UTF-8, a transformation format of ISO 10646", RFC 3629/STD 63, November 2003, <a href="http://tools.ietf.org/html/rfc3629">http://tools.ietf.org/html/rfc3629</a>	Field Code Changed
1252			
1253	[STLFORMAT]	3D Systems, Inc., "SLC File Specification", 1994	
1254	[UAX9]	Unicode Consortium, "Unicode Bidirectional Algorithm", UAX#9, June 2014,	
1255			
1256		<a href="http://www.unicode.org/reports/tr9/tr9-31.html">http://www.unicode.org/reports/tr9/tr9-31.html</a>	Field Code Changed
1257	[UAX14]	Unicode Consortium, "Unicode Line Breaking Algorithm", UAX#14, June 2014,	
1258			
1259		<a href="http://www.unicode.org/reports/tr14/tr14-33.html">http://www.unicode.org/reports/tr14/tr14-33.html</a>	Field Code Changed
1260	[UAX15]	Unicode Consortium, "Normalization Forms", UAX#15, June 2014,	
1261		<a href="http://www.unicode.org/reports/tr15/tr15-41.html">http://www.unicode.org/reports/tr15/tr15-41.html</a>	Field Code Changed
1262	[UAX29]	Unicode Consortium, "Unicode Text Segmentation", UAX#29, June 2014,	
1263			
1264		<a href="http://www.unicode.org/reports/tr29/tr29-25.html">http://www.unicode.org/reports/tr29/tr29-25.html</a>	Field Code Changed
1265	[UAX31]	Unicode Consortium, "Unicode Identifier and Pattern Syntax", UAX#31, June 2014,	
1266			
1267		<a href="http://www.unicode.org/reports/tr31/tr31-21.html">http://www.unicode.org/reports/tr31/tr31-21.html</a>	Field Code Changed
1268	[UNICODE]	Unicode Consortium, "Unicode Standard", Version 7.0.0, June 2014,	
1269		<a href="http://www.unicode.org/versions/Unicode7.0.0/">http://www.unicode.org/versions/Unicode7.0.0/</a>	Field Code Changed
1270	<del>[UTS10]</del>	<del>Unicode Consortium, "Unicode Collation Algorithm", UTS#10, June 2014,</del>	<del>Moved (insertion) [1]</del>
1271		<del><a href="http://www.unicode.org/reports/tr10/tr10-30.html">http://www.unicode.org/reports/tr10/tr10-30.html</a>,</del>	
1272			
1273	<del>[UTS35]</del>	<del>Unicode Consortium, "Unicode Locale Data Markup Language", UTS#35, September 2014,</del>	
1274		<del><a href="http://www.unicode.org/reports/tr35/tr35-37/tr35.html">http://www.unicode.org/reports/tr35/tr35-37/tr35.html</a></del>	
1275			Field Code Changed
1276	<del>[UTS39]</del>	<del>Unicode Consortium, "Unicode Security Mechanisms", UTS#39, September 2014,</del>	
1277		<del><a href="http://www.unicode.org/reports/tr39/tr39-9.html">http://www.unicode.org/reports/tr39/tr39-9.html</a></del>	
1278			Field Code Changed
1279		<b><u>11.2 Informative References</u></b>	
1280	[UNISECFAQ]	Unicode Consortium "Unicode Security FAQ", November 2013,	
1281		<a href="http://www.unicode.org/faq/security.html">http://www.unicode.org/faq/security.html</a>	Field Code Changed



1282 [\[UTR17\]](#) [Unicode Consortium “Unicode Character Encoding Model”, UTR#17,](#)  
1283 [November 2008,](#)  
1284 <http://www.unicode.org/reports/tr17/tr17-7.html>

Field Code Changed

1285 [UTR20] [Unicode Consortium “Unicode in XML and other Markup Languages”,](#)  
1286 [UTR#20, January 2013,](#)  
1287 <http://www.unicode.org/reports/tr20/tr20-9.html>

Field Code Changed

1288 [UTR23] [Unicode Consortium “Unicode Character Property Model”, UTR#23,](#)  
1289 [November 2008,](#)  
1290 <http://www.unicode.org/reports/tr23/tr23-9.html>

Field Code Changed

1291 [UTR33] [Unicode Consortium “Unicode Conformance Model”, UTR#33,](#)  
1292 [November 2008,](#)  
1293 <http://www.unicode.org/reports/tr33/tr33-5.html>

Field Code Changed

1294 **12. Author's Address**

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Moved up [1]: [UTS10] . Unicode Consortium, "Unicode Collation Algorithm", UTS#10, June 2014, . <http://www.unicode.org/reports/tr10/tr10-30.html> ... [5]

Deleted: [UTS10] . Unicode Consortium, "Unicode Collation Algorithm", UTS#10, June 2014, . <http://www.unicode.org/reports/tr10/tr10-30.html> ... [6]

1302 The authors would also like to thank the following individuals for their contributions to this  
1303 standard:

1304 Olliver Schinagl, Ultimaker B.V.  
1305

## 1314 13. Object Definition Languages (ODLs)

1315 This section provides information on several commonly used ODLs with either existing  
1316 (registered) or suggested MIME media types.

### 1317 13.1 3D Manufacturing Format (3MF)

1318 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that  
1319 provides geometry, material, and texture information necessary to support a wide variety of  
1320 3D printers. Materials can be named and composed within the geometry, facilitating  
1321 multiple material support in coordination with a Job Ticket.

1322 The registered MIME media type for the original Microsoft published specification is  
1323 "application/vnd.ms-3mfdocument". The suggested (but not registered) MIME media type  
1324 for the 3MF Consortium's published specification is "model/3mf".

### 1325 13.2 Additive Manufacturing Format (AMF)

1326 AMF [ISO52915] is a relatively new format that was designed as a replacement for the  
1327 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-  
1328 available specification, but has several advantages over STL including:

- 1329 1. Shared vertices which eliminates holes and other breaks in the surface  
1330 geometry of objects,
- 1331 2. Specification of multiple materials in a single file,
- 1332 3. Curved surfaces can be specified, and
- 1333 4. Coordinates use explicit units for proper output dimensions.

1334 The suggested (but not registered) MIME media type is 'model/amf'.

### 1335 13.3 Standard Tessellation Language (STL)

1336 STL [STLFORMAT] is widely supported by existing client software. The registered MIME  
1337 media type is 'application/sla'.  
1338

1339 **14. Design Choices**

1340 This section documents some of the design choices that were made during the  
1341 development of this specification.

1342 **14.1 "material-rate-units" Values**

1343 The list of units for the "material-rate" values was explicitly limited because larger units are  
1344 unnecessary for current printers and technologies, and because additional units may pose  
1345 interoperability issues.

1346 **14.2 Use of Celsius for Temperatures**

1347 The various integer attributes for temperature use degrees Celsius. This was done  
1348 because most existing printers and materials are specified using degrees Celsius. There is  
1349 no advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to  
1350 perform additional unit conversions could cause safety issues.  
1351

## 1352 15. Change History

### 1353 15.1 January 28, 2016

- 1354 1. Updated to working draft template.
- 1355 2. Fixed document URLs.
- 1356 3. Global: "white paper" changed to "specification" as needed.
- 1357 4. Abstract: "this specification", extension to IPP Everywhere as well.
- 1358 5. Section 4: "3D Print Service Model", remove old intro text
- 1359 6. Dropped tables 1-3, instead just say "same as 2D print service" and mention that
- 1360 certain Job Template attributes such as "media" are not applicable to most 3D
- 1361 printers.
- 1362 7. Table 4: Added section references, reordered so that all RFC 3805 subunits are
- 1363 listed first.
- 1364 8. Section 4.x: Reword in places now that this is a specification.
- 1365 9. Section 5: Added subunit collection attributes
- 1366 10. Section 6: Add registration (instead of just suggestion)
- 1367 11. Added Section 14 on design choices

### 1368 15.2 November 16, 2015

- 1369 1. Section 1: Fix typos
- 1370 2. Section 3: Updated rationale to talk about 3MF instead of AMF and STL
- 1371 3. Section 4: Added new subsection on the 3D Print Service and the operations
- 1372 and attributes that are used.
- 1373 4. Section 4.3: Added Chambers to list of subunits since we are providing access
- 1374 to the temperature.
- 1375 5. Section 5.1.1: Added table listing all member attributes.
- 1376 6. Section 5.1.1.x: Added sections on material-amount, material-amount-units,
- 1377 material-diameter, material-rate, material-rate-units
- 1378 7. Section 5.1.1.x: Renamed "material-use" to "material-purpose" to avoid
- 1379 confusion with "material-amount-xxx".
- 1380 8. Section 5.3: Add new materials-col member attribute -supported attributes
- 1381 9. Section 7.1: Note existing MS 3DMF MIME media type
- 1382 10. Global: printer-bed-xxx -> printer-platform-xxx
- 1383 11. Global: Add range for all temperature attributes (-273:MAX)

### 1384 15.3 October 29, 2015

- 1385 1. Greatly expanded the discussion of how current solutions work and the IPP
- 1386 model
- 1387 2. Added discussion points for amount of material used
- 1388 3. Added materials-col-actual Job Description attribute
- 1389 4. Added 3MF description and reference
- 1390 5. Fixed link to IPP Everywhere in references

**1391 15.4 August 12, 2015**

- 1392 1. Dropped “0.1” from the title
- 1393 2. Various typographical changes
- 1394 3. Section 2.2: Added ODL acronym
- 1395 4. Table 1: Added reference column
- 1396 5. Figure 1: Updated figure to show Z increasing downward (direction of build platform movement)
- 1397
- 1398 6. Section 4.x: Added sub-section on output intent.
- 1399 7. Section 5.1: Added table listing Job Template and corresponding -default and -supported attributes.
- 1400
- 1401 8. Section 5.1.1.4: Added more types of filament, solid wax, and clarification on the names used for material type keywords.
- 1402
- 1403 9. Section 5.1.1.5: Made material-use 1setOf, added 'all' value.
- 1404 10. Updated printer-bed-temperature-supported and printer-chamber-temperature-supported to allow 'no-value' values.
- 1405
- 1406 11. Section 9.x: Added subsections on specific 3D printing security considerations.

**1407 15.5 July 29, 2015**

- 1408 1. Dropped all references to X3G and G-code.
- 1409 2. Reworked materials-col to specify materials but not temperatures and other physical properties
- 1410
- 1411 3. Added “material-use” member attribute to assign materials to specific uses.
- 1412 4. Supports and rafts pick materials based on “material-use” values and not indices.
- 1413
- 1414 5. Added reference to IPP INFRA
- 1415 6. Added printer-camera-image-uri Printer Description attribute.

**1416 15.6 April 13, 2015**

- 1417 1. Updated front matter to incorporate new IEEE-ISTO boilerplate for a contributed white paper.
- 1418

**1419 15.7 April 5, 2015**

- 1420 1. Updated front matter to remove IEEE-ISTO boilerplate.
- 1421 2. Fixed various typos
- 1422 3. Clarified that SLC files are commonly known as STL files.
- 1423 4. Clarified that S3G is a binary version of G-code with a standard packet format.
- 1424 5. Added use case for printing with loaded materials
- 1425 6. Added use case for multi-material printing on a single material printer.
- 1426 7. Added use case for monitoring print progress visually with a web cam.
- 1427 8. Added exception for “skipping” (insufficient material flow/feed)
- 1428 9. Added exception for adhesion issues

- 1429 10. Added exception for build plate being full.
- 1430 11. Added exception for head movement issues.
- 1431 12. Added figure showing the typical coordinate system.
- 1432 13. Expanded Job Template and Printer Description details, added comments for
- 1433 discussion.
- 1434 14. Added new Unicode considerations and references.

1435 **15.8 January 23, 2015**

- 1436 Initial revision.

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

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

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

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

## High-Level Model

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**

<b>Code</b>	<b>Operation Name</b>	<b>Reference</b>
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**

<b>Attribute Name</b>	<b>Object</b>	<b>Reference</b>
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

<b>Attribute Name</b>	<b>Object</b>	<b>Reference</b>
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

<b>Attribute Name</b>	<b>Object</b>	<b>Reference</b>
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

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

This Printer Status attribute provides the current extruder head temperatures in degrees Celsius. The 'no-value' value is returned when the extruder head is not temperature controlled.

**printer-**

#### 1.1.1.1

[UTS10] Unicode Consortium, "Unicode Collation Algorithm", UTS#10, June 2014, <http://www.unicode.org/reports/tr10/tr10-30.html>,

[UTS35] Unicode Consortium, “Unicode Locale Data Markup Language”, UTS#35, September 2014,  
<http://www.unicode.org/reports/tr35/tr35-37/tr35.html>

[UTS39] Unicode Consortium, “Unicode Security Mechanisms”, UTS#39, September 2014,  
<http://www.unicode.org/reports/tr39/tr39-9.html>

[UTS10] Unicode Consortium, “Unicode Collation Algorithm”, UTS#10, June 2014,  
<http://www.unicode.org/reports/tr10/tr10-30.html>,

[UTS35] Unicode Consortium, “Unicode Locale Data Markup Language”, UTS#35, September 2014,  
<http://www.unicode.org/reports/tr35/tr35-37/tr35.html>

[UTS39] Unicode Consortium, “Unicode Security Mechanisms”, UTS#39, September 2014,  
<http://www.unicode.org/reports/tr39/tr39-9.html>