



The Printer Working Group

January 23, 2015  
White Paper

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

Status: Initial

**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-20150123.docx>  
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48 systems providers, network connectivity vendors, and print management application  
49 developers. The group is chartered to make printers and the applications and operating  
50 systems supporting them work together better. All references to the PWG in this  
51 document implicitly mean “The Printer Working Group, a Program of the IEEE ISTO.” In  
52 order to meet this objective, the PWG will document the results of their work as open  
53 standards that define print related protocols, interfaces, procedures and conventions.  
54 Printer manufacturers and vendors of printer related software will benefit from the  
55 interoperability provided by voluntary conformance to these standards.

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

59 For additional information regarding the Printer Working Group visit:

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67

68 **About the Internet Printing Protocol Workgroup**

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

74 For additional information regarding IPP visit:

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

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

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## 187 **1. Introduction**

188 This white paper defines an extension to the Internet Printing Protocol (IPP) that supports  
189 printing of physical objects by Additive Manufacturing devices such as three-dimensional  
190 (3D) printers. The attributes and values defined in this document have been prototyped  
191 using the CUPS software [CUPS].

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

197 This document also does not address the larger issue of choosing a common Object  
198 Definition Language (ODL) for interoperability, however there are suggested MIME media  
199 type names listed in section 0 for several formats in common use.

## 200 **2. Terminology**

### 201 **2.1 Terms Used in This Document**

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

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

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

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

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

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

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

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

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

## 220 **2.2 Acronyms and Organizations**

221 *CNC*: Computer Numerical Control

222 *DLP*: Digital Light Processing

223 *FDM*: Fused Deposition Modeling

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

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

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

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

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

229 *SDL*: Selective Deposition Lamination

230 *SL*: Stereo Lithography

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

232

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

234 Existing specifications define the following:

- 235 1. IPP/2.0 Second Edition [PWG5100.12] defines version 2.0, 2.1, and 2.2 of the  
236 Internet Printing Protocol which defines a standard operating and data model,  
237 interface protocol, and extension mechanism to support traditional Printers;
- 238 2. IPP Everywhere [PWG5100.14] defines a profile of existing IPP specifications,  
239 standard Job Template attributes, and standard document formats;
- 240 3. The Standard Specification for Additive Manufacturing File Format (AMF)  
241 Version 1.1 [ISO52915] defines an XML schema and file format for describing  
242 3D objects with one or more materials;
- 243 4. The SLC File Specification [STLFORMAT] defines a file format for describing 3D  
244 object with a single material;
- 245 5. The Interchangeable Variable Block Data Format for Positioning, Contouring,  
246 and Contouring/Positioning Numerically Controlled Machines [RS274D] defines  
247 the "G-code" format that is commonly used by 3D printers; and
- 248 6. The S3G protocol [S3G] defines a simple network protocol and file format for  
249 controlling 3D printers.

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

### 253 **3.1 Use Cases**

#### 254 **3.1.1 Print a 3D Object**

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

### 258 **3.2 Exceptions**

#### 259 **3.2.1 Clogged Extruder**

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

#### 263 **3.2.2 Extruder Temperature Out of Range**

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

### 268 **3.2.3 Filament Feed Jam**

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

### 272 **3.2.4 Material Empty**

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

### 276 **3.2.5 Print Bed Temperature Out of Range**

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

## 280 **3.3 Out of Scope**

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

- 282 1. Definition of new file formats; and
- 283 2. Support for Subtractive Manufacturing technologies such as CNC milling
- 284 machines.

## 285 **3.4 Design Requirements**

286 The design requirements for this document are:

- 287 1. Define attributes and values to describe supported and loaded (ready) materials
- 288 used for FDM; and
- 289 2. Define attributes and values to describe FDM printer capabilities and state

290 The design recommendations for this document are:

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

292

## 293 4. Technical Solutions/Approaches

294 Current 3D printers offer limited connectivity and status monitoring capabilities. Many  
295 printers simply print G-code files from SD memory cards, with all interaction and status  
296 monitoring happening at the printer's console.

297 Makerbot Industries uses a proprietary protocol [S3G] and file format that generalizes  
298 some aspects of the interface between a host device and 3D printer, and this interface  
299 does offer an improved printing experience from the host device. However, this solution is  
300 highly specific to FDM printing and does not offer any spooling or security functionality.

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

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

### 310 4.1 High-Level Model

311 IPP [RFC2911] and the IETF Printer MIB [RFC3805] already define a comprehensive  
312 model for the operation and data elements of a typical 2D printer. The IPP Job processing  
313 model matches how 3D printers process Jobs and Documents. However, more types of  
314 subunits are used in a 3D printer, requiring additions to the model and state values. Table  
315 1 lists the subunits of 3D printers for different technologies.

316 **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

### 317 **4.1.1 Build Platforms**

318 Build Platforms hold the printed object. The platform moves up or down during printing as  
319 layers are applied.

### 320 **4.1.2 Cameras**

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

### 323 **4.1.3 Cutters**

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

### 326 **4.1.4 Fans**

327 Fans are used to cool printed material and maintain proper extruder temperature.

### 328 **4.1.5 Lamps**

329 Lamps are used by DLP printers to provide an ultraviolet light source for curing the liquid  
330 material while printing a layer.

### 331 **4.1.6 Lasers**

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

### 334 **4.1.7 Markers (or Extruders)**

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

### 338 **4.1.8 Motors**

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

### 340 **4.1.9 Reservoirs**

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

## 342 **4.2 Coordinate System**

343 3D printers operate in three dimensions and thus have three axis of movement. The X axis  
344 represents the width of the object, the Y axis represents the depth of the object, and the Z  
345 axis represents the height of the object. [Editor's note: probably want a figure for this]

## 346 **5. New Attributes**

### 347 **5.1 Job Template Attributes**

#### 348 **5.1.1 materials-col (1setOf collection)**

349 This Job Template attribute defines the materials to be used for the Job.

##### 350 **5.1.1.1 material-color (type2 keyword)**

351 This member attribute provides a PWG media color value representing the color of the  
352 material.

##### 353 **5.1.1.2 material-diameter (integer)**

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

##### 356 **5.1.1.3 material-feed-rate (integer)**

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

##### 359 **5.1.1.4 material-key (keyword)**

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

##### 362 **5.1.1.5 material-name (name(MAX))**

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

##### 364 **5.1.1.6 material-type (type2 keyword)**

365 This member attribute specifies the type of material. Values include:

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

367 'chocolate\_powder': Chocolate powder.

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

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

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

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

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

373 **5.1.1.7 filament-retraction-distance (integer(0:MAX))**

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

376 **5.1.1.8 filament-retraction-speed (integer(0:MAX))**

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

379 **5.1.1.9 extruder-temperature (integer | rangeOfInteger)**

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

383 **5.1.1.10 print-speed (integer(1:MAX))**

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

385 **5.1.2 print-fill-density (integer(0:100))**

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

387 **5.1.3 print-fill-thickness (integer(0:MAX))**

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

390 **5.1.4 print-layer-thickness (integer(0:MAX))**

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

393 **5.1.5 print-rafts (type2 keyword)**

394 This Job Template attribute specifies whether to print rafts under the object. Values  
395 include:

396 'none': Do not print rafts.

397 'standard': Print rafts using implementation-defined default parameters.

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

**400 5.1.6 print-shell-thickness (integer(0:MAX))**

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

**403 5.1.7 print-supports (type2 keyword)**

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

406 'none': Do not print supports.

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

408 'material-N': Print supports using the Nth material, where N is an integer from 1 to  
409 the number of materials for the Job.

**410 5.1.8 printer-bed-temperature (integer | no-value)**

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

**413 5.1.9 printer-fan-speed (integer(0:100))**

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

**416 5.2 Printer Description Attributes****417 5.2.1 materials-col-database (1setOf collection)**

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

**421 5.2.2 materials-col-default (1setOf collection)**

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

**424 5.2.3 materials-col-ready (1setOf collection)**

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

**427 5.2.4 materials-col-supported (1setOf type2 keyword)**

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

**430 5.2.5 material-diameter-supported (1setOf (integer | rangeOfInteger))**

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

**433 5.2.6 material-feed-rate-supported (1setOf (integer | rangeOfInteger))**

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

**436 5.2.7 material-type-supported (1setOf type2 keyword)**

437 This Printer Description attribute lists the supported material types for the Printer.

**438 5.2.8 print-fill-density-default (integer(0:100))**

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

**440 5.2.9 print-fill-thickness-default (integer(0:MAX))**

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

**443 5.2.10 print-fill-thickness-supported (1setOf (integer(0:MAX) |  
444 rangeOfInteger(0:MAX)))**

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

**447 5.2.11 print-layer-order (type1 keyword)**

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

**450 5.2.12 print-layer-thickness-default (integer(0:MAX))**

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

453 **5.2.13 print-layer-thickness-supported (1setOf (integer(0:MAX) |**  
454 **rangeOfInteger(0:MAX)))**

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

457 **5.2.14 print-rafts-default (type2 keyword)**

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

459 **5.2.15 print-rafts-supported (1setOf type2 keyword)**

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

461 **5.2.16 print-shell-thickness-default (integer(0:MAX))**

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

464 **5.2.17 print-shell-thickness-supported (1setOf (integer(0:MAX) |**  
465 **rangeOfInteger(0:MAX)))**

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

468 **5.2.18 print-supports-default (type2 keyword)**

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

470 **5.2.19 print-supports-supported (1setOf type2 keyword)**

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

472 **5.2.20 printer-bed-temperature-default (integer | no-value)**

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

475 **5.2.21 printer-bed-temperature-supported (1setOf (integer | rangeOfInteger))**

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

478 **5.2.22 printer-fan-speed-default (integer(0:MAX))**

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

**480 5.2.23 printer-fan-speed-supported (boolean)**

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

**483 5.2.24 printer-head-temperature-supported (1setOf integer | rangeOfInteger)**

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

**486 5.2.25 filament-retraction-distance-supported (1setOf (integer(0:MAX) |  
487 rangeOfInteger(0:MAX)))**

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

**490 5.2.26 filament-speed-supported (1setof (integer(0:MAX) | rangeOfInteger(0:MAX)))**

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

**493 5.2.27 print-speed-supported (1setOf integer(1:MAX) | rangeOfInteger(1:MAX))**

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

**496 5.2.28 printer-accuracy-supported (collection)**

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

**500 5.2.29 printer-volume-supported (collection)**

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

**505 5.3 Printer Status Attributes****506 5.3.1 printer-bed-temperature-current (integer | no-value)**

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

**509 5.3.2 printer-fan-speed-current (integer(0:100))**

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

**511 5.3.3 printer-head-temperature-current (1setOf (integer | no-value))**

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

**515 5.4 Other Potential Attributes**

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

- 518 1. Initial layer thickness in nanometers
- 519 2. Initial layer line width in percent
- 520 3. Dual extrusion overlap in nanometers
- 521 4. Travel speed in nanometers per second
- 522 5. Bottom layer speed in nanometers per second
- 523 6. Infill speed in nanometers per second
- 524 7. Outer shell speed in nanometers per second
- 525 8. Inner shell speed in nanometers per second
- 526 9. Minimum layer time in seconds or milliseconds
- 527

## 528 **6. New Values for Existing Attributes**

### 529 **6.1 ipp-features-supported (1setOf type2 keyword)**

530 This document defines the new value 'ipp-3d'. [Editor's note: do we want to include a  
531 version number here, e.g., 'ipp-3d-0.1?']

### 532 **6.2 printer-state-reasons (1setOf type2 keyword)**

533 This document defines the following new values:

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

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

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

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

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

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

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

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

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

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

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

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

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

547 'material-empty': One or more build materials have been exhausted.

548 'material-low': One or more build materials may need replenishment soon.

549 'material-needed': One or more build materials need to be loaded for a processing  
550 Job.

551 'motor-failure': A motor has failed.

552 'reservoir-empty': One or more reservoirs are empty.

- 553 'reservoir-low': One or more reservoirs are almost empty.
- 554 'reservoir-needed': One or more reservoirs are empty but need to be filled for a
- 555 processing Job.
- 556

## 557 **7. Object Definition Languages (ODLs)**

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

### 560 **7.1 Additive Manufacturing Format (AMF)**

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

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

569 The suggested (but not registered) MIME media type is 'application/amf'.

### 570 **7.2 Standard Tessellation Language (STL)**

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

### 573 **7.3 G-Code**

574 The G-code [RS274] format has long been a common low-level format used by 3D  
575 printers, with higher level formats being processed on the Client to produce G-code. The  
576 suggested (but not registered) MIME media type is 'application/g-code'.

### 577 **7.4 S3G Protocol and X3G File Format**

578 The S3G protocol [S3G] defines a simple network protocol for communicating with a 3D  
579 printer as well as a low-level file format, typically using a "x3g" extension, that provides a  
580 serialization of extrusion commands similar to G-code. The suggested (but not registered)  
581 MIME media type is 'application/vnd.makerbot-x3g'.

582

## 583 **8. Internationalization Considerations**

584 For interoperability and basic support for multiple languages, conforming implementations  
585 MUST support:

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

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

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

## 598 **9. Security Considerations**

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

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

603

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648 **12. Change History**

649 **12.1 January 23, 2015**

650 Initial revision.