



The Printer Working Group

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Working Draft

## IPP 3D Printing Extensions v1.1 (3D)

Status: Initial

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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63 Contact information:

64 The Printer Working Group  
65 c/o The IEEE Industry Standards and Technology Organization  
66 445 Hoes Lane  
67 Piscataway, NJ 08854  
68 USA  
69

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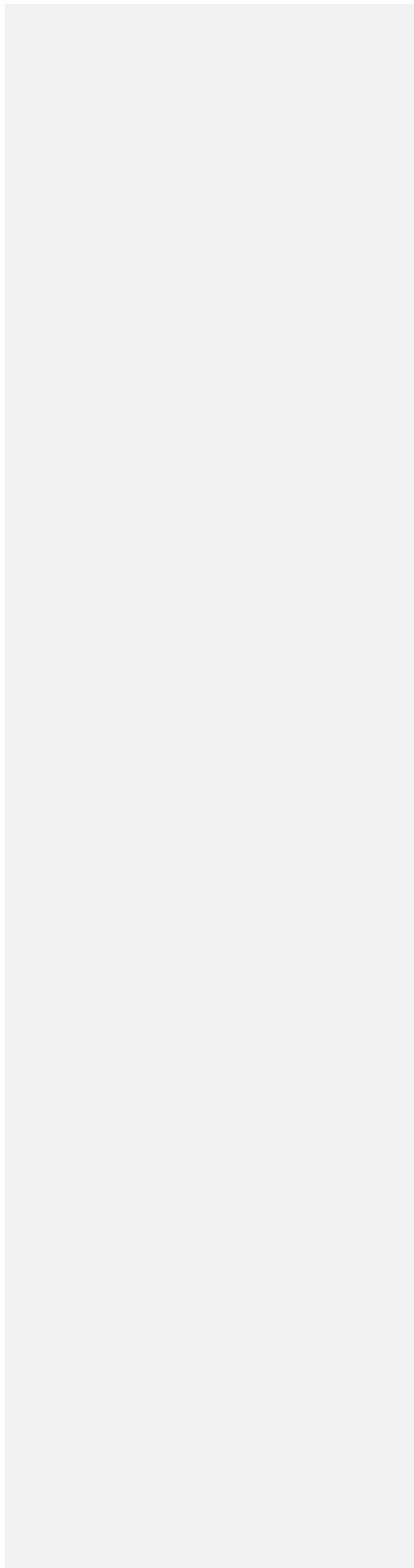
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## 259 **1. Introduction**

260 This specification defines an extension to the Internet Printing Protocol (IPP) that supports  
261 printing of physical objects by Additive Manufacturing devices such as three-dimensional  
262 (3D) printers.

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

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

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

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

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

## 279 **2. Terminology**

### 280 **2.1 Conformance Terminology**

281 Capitalized terms, such as MUST, MUST NOT, RECOMMENDED, REQUIRED, SHOULD,  
282 SHOULD NOT, MAY, and OPTIONAL, have special meaning relating to conformance as  
283 defined in Key words for use in RFCs to Indicate Requirement Levels [BCP14]. The term  
284 CONDITIONALLY REQUIRED is additionally defined for a conformance requirement that  
285 applies when a specified condition is true.

### 286 **2.2 Printing Terminology**

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

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

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

295 *Logical Device*: a print server, software service, or gateway that processes Jobs and either  
296 forwards or stores the processed Job or uses one or more Physical Devices to render output.

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

298 *Physical Device*: a hardware implementation of an endpoint device, e.g., a marking engine, a  
299 fax modem, etc.

### 300 **2.3 Protocol Role Terminology**

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

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

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

### 308 **2.4 3D Printing Terminology**

309 *Additive Manufacturing*: A 3D printing process where material is progressively added to  
310 produce the final output, as opposed to Subtractive Manufacturing and Formative  
311 Manufacturing technologies.

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

314 *Digital Light Processing*: A 3D printing process that uses light with a negative image to  
315 selectively cure layers of a liquid material, sometimes also called vat photopolymerization.

316 Formative Manufacturing: Traditional casting, moulding, or forming processes used for mass  
317 production, for example injection moulding of plastic parts.

318 *Fused Deposition Modeling*: A 3D printing process that extrudes a molten material to draw  
319 layers, sometimes also called material extrusion.

320 *Laser Sintering*: A 3D printing process that uses a laser to melt and fuse layers of powdered  
321 materials, sometimes also called directed energy deposition or powder bed fusion.

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

324 *Selective Deposition Lamination*: A 3D printing process that laminates cut sheets of material,  
325 sometimes also called sheet lamination.

326 *Slicing*: The process of converting three-dimensional geometry into two-dimensional planes  
327 that can be layered to produce an equivalent three-dimensional object.

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

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

## 332 **2.5 Other Terminology**

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

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

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

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

## 340 **2.6 Acronyms and Organizations**

341 *3D PDF Consortium*: <http://www.3dpdfconsortium.org/>

342 *3MF Consortium*: 3D Manufacturing Format Consortium, <http://www.3mf.io/>

343 *CNC*: Computer Numerical Control

344 *DLP*: Digital Light Processing

345 *FDM*: Fused Deposition Modeling

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

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

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

349 *ODL*: Object Definition Language

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

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

352 *SDL*: Selective Deposition Lamination

353 *SL*: Stereo Lithography

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

355

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

357 Existing specifications define the following:

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

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

#### 381 **3.1 Use Cases**

##### 382 **3.1.1 Print a 3D Object**

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

##### 386 **3.1.2 Print a 3D Object Using Loaded Materials**

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

**390 3.1.3 Print a 3D Object with Multiple Materials**

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

**395 3.1.4 Print a Tool**

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

**400 3.1.5 View a 3D Object During Printing**

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

**403 3.2 Exceptions****404 3.2.1 Clogged Extruder**

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

**408 3.2.2 Extruder Temperature Out of Range**

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

**413 3.2.3 Extruder Head Movement Issues**

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

**417 3.2.4 Filament Feed Jam**

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

421 **3.2.5 Filament Feed Skip**

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

425 **3.2.6 Material Empty**

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

429 **3.2.7 Material Adhesion Issues**

430 While printing a 3D object, the printed object releases from the Build Platform or the current  
431 layer is not adhering to the previous one. The printer stops printing and sets the  
432 corresponding state reason to allow Jane's Client device to discover the issue and display  
433 an appropriate alert.

434 **3.2.8 Build Platform Temperature Out of Range**

435 While printing a 3D object, the Build Platform temperature goes out of the requested range.  
436 The printer pauses printing until the temperature stabilizes and sets the corresponding state  
437 reason to allow Jane's Client device to discover the issue and display an appropriate alert.

438 **3.2.9 Build Platform Not Clear**

439 When starting to print a 3D object, the Printer detects that the Build Platform is not  
440 empty/clear. The Printer stops printing and sets the corresponding state reason to allow  
441 Jane's Client device to discover the issue and display an appropriate alert. The Printer starts  
442 printing once the Build Platform is cleared.

443 **3.3 Out of Scope**

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

- 445 1. Definition of new file formats;  
446 2. Support for Subtractive Manufacturing technologies such as CNC milling  
447 machines; and  
448 3. Support for industrial and/or medical printing technologies.

449

450 **3.4 Design Requirements**

451 The design requirements for this document are:

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

467 The design recommendations for this document are:

- 468 1. Support 3D printing technologies other than FDM
- 469



#### 470 **4. 3D Print Service Model**

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

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

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

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

488 The IPP Document object contains the document data or a reference (URI) to the data and  
489 tracks the progress of the Document throughout its life cycle. The Document Ticket  
490 (attribute supplied when creating the Document) and Document Receipt (attributes  
491 describing the final disposition of the Document) are also stored here.

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

496

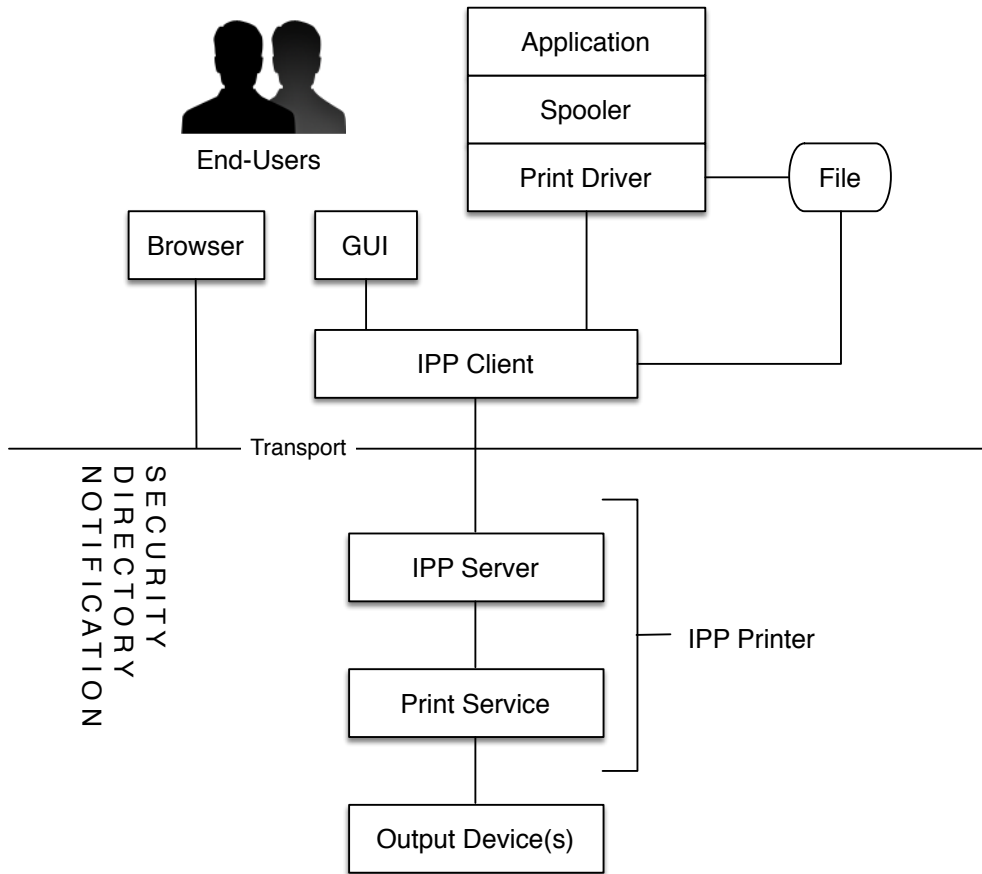


Figure 1 - Generalized IPP Model (RFC 8011)

497  
498  
499

## 500 4.1 3D Print Service

501 3D printing uses a variation of the traditional Print service that maintains state and capability  
 502 information specific to 3D printing. The 3D Print service supports all of the same operations  
 503 of the Print service described in [RFC8011] except for the Print-Job and Print-URI operations  
 504 which are compound requests that are not used in newer IPP services. Similarly, the 3D  
 505 Print service uses a superset of the Print service attributes except where such attributes are  
 506 not applicable, for example the "media" attributes for a 3D printer that does not use media  
 507 sheets. Attributes specific to the 3D Print Service are defined in section 8.

## 508 4.2 3D Printer Subunits

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

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

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

### 512 4.2.1 Finishing Devices

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

### 515 4.2.2 Input Trays/Rolls

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

### 517 4.2.3 Marker Supplies

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

**520 4.2.4 Markers**

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

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

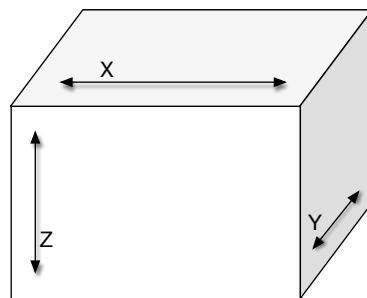
**526 4.2.5 Media Paths**

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

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

**532 4.3 3D Printer Coordinate System**

533 3D printers operate in three dimensions and thus have three axis of movement. For the  
534 purposes of IPP, the build volume is defined as a rectangular prism (Figure 2) with the X  
535 axis representing the width, the Y axis representing the depth, and the Z axis representing  
536 the height. The origin is implementation-specific.



537

538

**Figure 2 - 3D Build Volume**

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

#### 543 **4.4 Output Intent and Job Processing**

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

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

#### 553 **4.5 Job Spooling**

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

#### 557 **4.6 Multiple Document Jobs**

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

562 The "multiple-object-handling" (section 8.1.4) Job Template attribute controls whether the  
563 Printer performs this optimization.

#### 564 **4.7 Cloud-Based Printing**

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

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

572

573 **5. Discovery Protocols**

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

576 **5.1 DNS Service Discovery (DNS-SD)**

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

581 **5.1.1 Service Instance Name**

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

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

585 **5.1.2 Service Type**

586 Printers MUST advertise the "\_ipp3d.\_tcp" (IPPS 3D Print) service over DNS-SD.

587 **5.1.3 TXT Record**

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

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

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

**592 5.2 LDAP Discovery**

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

**596 5.2.1 printerIPPS3D Class**

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

```
599     ( 1.3.18.0.2.24.46.2.1
600       NAME 'printerIPPS3D'
601       DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
602       AUXILIARY
603       SUP top
604       MAY ( printer-ipp-versions-supported $
605            printer-ipp-features-supported $
606            printer-multiple-document-jobs-supported )
607     )
608
```

## 609 **6. Protocol Binding**

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

### 613 **6.1 Transport and Resource Path**

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

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

### 621 **6.2 HTTP Features**

622 In addition to the IPP over HTTP conformance requirements defined in section 7.3 of IPP  
623 2.0, 2.1, and 2.2 [PWG5100.12], Printers MUST support the following additional HTTP  
624 headers and status codes defined in Hypertext Transfer Protocol -- HTTP/1.1 [RFC7230].

#### 625 **6.2.1 Host**

626 Printers MUST validate the Host request header and SHOULD use the Host value in  
627 generated URIs.

#### 628 **6.2.2 If-Modified-Since, Last-Modified, and 304 Not Modified**

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

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

#### 635 **6.2.3 Cache-Control**

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



641 **6.3 IPP Operations**

642 Table 3 lists the REQUIRED operations for a Printer. The Create-Job and Send-Document  
 643 operations are required in order to support reliable Job management (e.g., cancellation)  
 644 during print Job submission, but Printers are not required to support multiple document Jobs.

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

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

646 **6.4 IPP Operation Attributes**

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

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

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

649 **6.5 IPP Printer Description Attributes**

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

651

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

<b>Attribute</b>	<b>Reference</b>
accuracy-units-supported	Section 8.3.1
charset-configured	RFC 8011
charset-supported	RFC 8011
color-supported	RFC 8011
compression-supported	RFC 8011
document-format-default	RFC 8011
document-format-supported	RFC 8011
generated-natural-language-supported	RFC 8011
identify-actions-default	PWG 5100.13
identify-actions-supported	PWG 5100.13
ipp-features-supported	PWG 5100.13
ipp-versions-supported	RFC 8011
job-creation-attributes-supported	PWG 5100.11
job-ids-supported	PWG 5100.11
material-diameter-supported (note 2)	Section 8.3.7
material-purpose-supported	Section 8.3.9
material-rate-supported	Section 8.3.10
material-rate-units-supported	Section 8.3.11
material-shell-thickness-supported	Section 8.3.12
material-temperature-supported (note 3)	Section 8.3.12
material-type-supported	Section 8.3.14
materials-col-default	Section 8.3.16
materials-col-ready	Section 8.3.17
materials-col-supported	Section 8.3.18
max-materials-col-supported	Section 8.3.19
multiple-document-jobs-supported	RFC 8011
multiple-object-handling-default	Section 8.3.20
multiple-object-handling-supported	Section 8.3.21
multiple-operation-timeout	RFC 8011
multiple-operation-timeout-action	PWG 5100.13
natural-language-configured	RFC 8011
operations-supported	RFC 8011
platform-temperature-default (note 4)	Section 8.3.24
platform-temperature-supported (note 4)	Section 8.3.25
print-accuracy-default	Section 8.3.26
print-accuracy-supported	Section 8.3.27
print-base-default	Section 8.3.28
print-base-supported	Section 8.3.29
print-objects-supported	Section 8.3.30
print-quality-default	RFC 8011
print-quality-supported	RFC 8011
print-supports-default	Section 8.3.31
print-supports-supported	Section 8.3.32

---

printer-geo-location	PWG 5100.13
printer-get-attributes-supported	PWG 5100.13
printer-icons (note 1)	PWG 5100.13
printer-info	RFC 8011
printer-location	RFC 8011
printer-make-and-model	RFC 8011
printer-more-info	RFC 8011
printer-name	RFC 8011
printer-organization	PWG 5100.13
printer-organizational-unit	PWG 5100.13
printer-volume-supported	Section 8.3.33
printer-xri-supported (note 1)	RFC 3380
which-jobs-supported	PWG 5100.11

---

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

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

655 Note 3: REQUIRED for Printers that control the material temperature during  
656 printing.

657 Note 4: REQUIRED for Printers that have a temperature-controlled Build Platform.  
658

659 **6.6 IPP Printer Status Attributes**

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

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

<b>Attribute</b>	<b>Reference</b>
printer-camera-image-uri (notes 1, 2)	Section 8.4.1
printer-config-change-date-time	PWG 5100.13
printer-config-change-time	PWG 5100.13
printer-is-accepting-jobs	RFC 8011
printer-state	RFC 8011
printer-state-change-date-time	RFC 3995
printer-state-change-time	RFC 3995
printer-state-message	RFC 8011
printer-state-reasons	RFC 8011
printer-up-time	RFC 8011
printer-uri-supported (note 1)	RFC 8011
printer-uuid	PWG 5100.13
queued-job-count	RFC 8011
uri-authentication-supported	RFC 8011
uri-security-supported	RFC 8011
xri-authentication-supported	RFC 3380
xri-security-supported	RFC 3380
xri-uri-scheme-supported	RFC 3380

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

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

665

## 666 6.7 IPP Job Template Attributes

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

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

Attribute	Reference
materials-col	Section 8.1.1
multiple-document-handling	RFC 8011
multiple-object-handling (note 1)	Section 8.1.4
platform-temperature (note 2)	Section 8.1.5
print-accuracy	Section 8.1.6
print-base	Section 8.1.7
print-objects (note 1)	Section 8.1.8
print-quality	RFC 8011
print-supports	Section 8.1.9

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

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

## 671 6.8 IPP Job Description Attributes

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

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

Attribute	Source
job-name	RFC 8011

## 674 6.9 IPP Job Status Attributes

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

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

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

Attribute	Source
job-state	RFC 8011
job-state-message	RFC 8011
job-state-reasons	RFC 8011
job-uri	RFC 8011
job-uuid	PWG 5100.13
materials-col-actual	Section 8.2.1
multiple-object-handling-actual (note 1)	Section 8.2.2
platform-temperature-actual (note 2)	Section 8.2.4
print-accuracy-actual	Section 8.2.5
print-base-actual	Section 8.2.6
print-objects-actual (note 1)	Section 8.2.7
print-supports-actual	Section 8.2.8
time-at-completed	RFC 8011
time-at-creation	RFC 8011
time-at-processing	RFC 8011

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

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

#### 679 **6.9.1 job-id (integer)**

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

#### 685 **6.9.2 job-uri (uri)**

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

## 692 **7. Document Formats**

693 Printers that support Slicing MUST support Documents conforming to the 3MF [3MF]  
 694 ("model/3mf") format and SHOULD support Documents conforming to the PDF [ISO32000]  
 695 ("application/pdf") format containing U3D [U3D] or PRC [PRC] content. Printers that do not  
 696 support Slicing SHOULD support Documents conforming to a layered format such as PWG  
 697 Safe G-Code [PWGGCODE] and/or the 3MF Slice Extension [3MF-SLICE].

698 **8. New Attributes**

699 **8.1 Job Template Attributes**

700 Table 10 lists the Job Template attributes and their corresponding “–default” and “-  
701 supported” attributes.

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

<b>Job Template</b>	<b>Printer: Default</b>	<b>Printer: Supported</b>
<a href="#">chamber-humidity (integer   no-value)</a>	<a href="#">chamber-humidity-default (integer   no-value)</a>	<a href="#">chamber-humidity-supported (boolean)</a>
<a href="#">chamber-temperature (integer   no-value)</a>	<a href="#">chamber-temperature-default (integer   no-value)</a>	<a href="#">chamber-temperature-supported (1setOf (integer   rangeOfInteger)   no-value)</a>
materials-col (collection)	materials-col-default (1setOf collection)	materials-col-database (1setOf collection) materials-col-ready (1setOf collection) materials-col-supported (1setOf type2 keyword)
multiple-object-handling (type2 keyword)	multiple-object-handling-default (type2 keyword)	multiple-object-handling-supported (1setOf type2 keyword)
platform-temperature (integer   no-value)	platform-temperature-default (integer   no-value)	platform-temperature-supported (1setOf (integer   rangeOfInteger)   no-value)
print-accuracy (collection)	print-accuracy-default (collection)	accuracy-units-supported (1setOf type2 keyword) print-accuracy-supported (collection)
print-base (type2 keyword)	print-base-default (type2 keyword)	print-base-supported (1setOf type2 keyword)
print-objects (1setOf collection)	N/A	print-objects-supported (boolean)
print-supports (type2 keyword)	print-supports-default (type2 keyword)	print-supports-supported (1setOf type2 keyword)

703 **8.1.1 chamber-humidity (integer(0:100) | no-value)**

704 This Job Template attribute specifies the desired relative humidity of the build chamber as a  
705 percentage. Printers that support humidity control **SHOULD** support this attribute.

**Deleted:** printer-volume-temperature (integer | no-value) ... [1]

**Moved (insertion) [1]**

**Deleted:** CONDITIONALLY REQUIRED

**Deleted:** MUST

710 **8.1.2 chamber-temperature (integer(-273:MAX) | no-value)**

Deleted: printer-volume

711 This Job Template attribute specifies the desired temperature of the build chamber in  
 712 degrees Celsius. Printers that support a temperature-controlled build chamber SHOULD  
 713 support this attribute.

Deleted: CONDITIONALLY REQUIRED

Deleted: MUST

714 **8.1.3 materials-col (1setOf collection)**

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

720 The Printer advertises which "materials-col" member attributes are supported in the  
 721 "materials-col-supported" (section 8.3.18) Printer Description attribute. The Printer lists only  
 722 those member attributes that are applicable to the technology being used for printing.

723 The Client typically supplies "materials-col" values matching those returned in the "materials-  
 724 col-database" (section 8.3.1) or "materials-col-ready" (section 8.3.17) Printer Description  
 725 attributes, although specifying the "material-name" or "material-key" member attribute from  
 726 either of these Printer Description attributes is enough to specify the default values for the  
 727 named material. Table 11 lists the member attributes.

728 **Table 11 - "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-diameter-tolerance	N/A
material-fill-density	N/A
material-key	materials-col-database materials-col-ready
material-name	materials-col-database materials-col-ready
material-nozzle-diameter	material-nozzle-diameter-supported
material-purpose	material-purpose-supported
material-rate	material-rate-supported
material-rate-units	material-rate-units-supported
material-retraction	materials-col-supported
material-shell-thickness	material-shell-thickness-supported
material-temperate	material-temperature-supported
material-type	material-type-supported



**732 8.1.3.1 material-amount (integer(0:MAX) | unknown)**

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

**737 8.1.3.2 material-amount-units (type2 keyword)**

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

740 'g': Value is mass in grams.

741 'kg': Value is mass in kilograms.

742 'l': Value is volume in liters.

743 'm': Value is length in meters.

744 'ml': Value is volume in milliliters.

745 'mm': Value is length in millimeters.

**746 8.1.3.3 material-color (type2 keyword)**

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

**749 8.1.3.4 material-diameter (integer(0:MAX))**

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

**753 8.1.3.5 material-diameter-tolerance (integer(0:MAX))**

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

**756 8.1.3.6 material-fill-density (integer(0:100))**

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

759 **8.1.3.7 material-key (keyword)**

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

762 **8.1.3.8 material-name (name(MAX))**

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

764 **8.1.3.9 material-nozzle-diameter (integer(0:MAX))**

765 This member attribute provides the diameter of the extruder nozzle in nanometers, with the  
766 value 0 being used for diameters less than 0.000001mm. Printers that use filament materials  
767 SHOULD support this member attribute.

768 **8.1.3.10 material-purpose (1setOf type2 keyword)**

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

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

772 'base': The material will be used to print a brim, raft, or skirt under/around the  
773 printed object.

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

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

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

777 **8.1.3.11 material-rate (integer(1:MAX))**

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

780 **8.1.3.12 material-rate-units (type2 keyword)**

781 This member attribute provides the units for the "material-rate" member attribute. Values  
782 include:

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

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

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

**786 8.1.3.13 material-retraction (boolean)**

787 This member attribute specifies whether filament retraction is used for this material. Printers  
788 that use filament materials SHOULD support this member attribute.

**789 8.1.3.14 material-shell-thickness (integer(0:MAX))**

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

**792 8.1.3.15 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))**

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

**796 8.1.3.16 material-type (type2 keyword | name(MAX))**

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

Deleted: Values

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

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

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

805 'chocolate': Chocolate.

806 'gold': Gold (metal).

807 'nylon': Nylon.

808 'pet': Polyethylene terephthalate (PET).

809 'photopolymer': Photopolymer (liquid) resin.

810 'pla': Polylactic Acid (PLA).

811 'pla-conductive': Conductive PLA.

812 'pla-dissolvable': Dissolvable PLA.

813 'pla-flexible': Flexible PLA.

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

- 816 'pla-steel': PLA with embedded steel particles.
- 817 'pla-stone': PLA with embedded stone chips.
- 818 'pla-wood': PLA with embedded wood fibers.
- 819 'polycarbonate': Polycarbonate.
- 820 'silver': Silver (metal).
- 821 'titanium': Titanium (metal).
- 822 'wax': Wax.

823 [Keyword values for materials that are defined by other standards organizations use a format](#)  
824 [consisting of the organization abbreviation, the standard number, a hyphen \("-"\), and the](#)  
825 [material identifier. In order to conform to the syntax for keyword values \(section 5.1.4 of](#)  
826 [\[RFC8011\]\), all letters are converted to lowercase \(with any diacritical marks removed\),](#)  
827 [ASCII digits, hyphens \("-"\), underscores \(" "\) and periods \("."\) are preserved, spaces are](#)  
828 [replaced with the hyphen \("-"\), and slashes \("/"\) are replaced with the underscore \(" "\). Any](#)  
829 [other characters are removed. For example, "7050 Aluminum" as defined in ASTM B247M](#)  
830 [would have a keyword value of 'astmb247m-a97050'.](#)

#### 831 8.1.4 multiple-object-handling (type2 keyword)

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

- 836 'auto': Automatically determine the best way to print multiple objects in a Job.
- 837 'best-fit': Fit as many objects as possible within the build volume.
- 838 'best-quality': Optimize the number of objects for print quality.
- 839 'best-speed': Optimize the number of objects for print speed.
- 840 'one-at-a-time': Print one object at a time.

#### 841 8.1.5 platform-temperature (integer(-273:MAX))

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

**Deleted:** Editor's note: Discuss naming convention for materials defined by other standards bodies, e.g. "iso1234\_name" or "asme5678\_other-name".

849 **8.1.6 print-accuracy (collection)**

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

852 When enforcing attribute fidelity ("ipp-attribute-fidelity" with a value of 'true'), Printers only  
853 reject "print-accuracy" values that are smaller than the "print-accuracy-supported" (section  
854 8.3.27) value.

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

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

856 **8.1.6.1 accuracy-units (type2 keyword)**

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

859 'mm': Accuracy numbers are in millimeters.

860 'um': Accuracy numbers are in micrometers.

861 'nm': Accuracy numbers are in nanometers.

862 **8.1.6.2 x-accuracy (integer(0:MAX))**

863 This REQUIRED member attribute specifies the X axis accuracy in the units specified by the  
864 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than  
865 1 unit.

866 **8.1.6.3 y-accuracy (integer(0:MAX))**

867 This REQUIRED member attribute specifies the Y axis accuracy in the units specified by the  
868 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than  
869 1 unit.

870 **8.1.6.4 z-accuracy (integer(0:MAX))**

871 This REQUIRED member attribute specifies the Z axis accuracy in the units specified by the  
872 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than  
873 1 unit.

874 **8.1.7 print-base (type2 keyword)**

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

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

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

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

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

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

883 **8.1.8 print-objects (1setOf collection)**

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

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

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

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

890

891 **8.1.8.1 document-number (integer(1:MAX))**

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

894 **8.1.8.2 object-offset (collection)**

895 This member attribute specifies the offset to apply to the object. The "x-offset  
896 (integer(0:MAX))", "y-offset (integer(0:MAX))", and "z-offset (integer(0:MAX))" member

897 attributes specify the offsets from the left, front, and Build Platform respectively in hundredths  
898 of millimeters (1/2540th of an inch).

#### 899 **8.1.8.3 object-size (collection)**

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

#### 903 **8.1.8.4 object-uuid (uri)**

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

#### 906 **8.1.9 print-supports (type2 keyword)**

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

909 'none': Do not print supports.

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

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

912

**Moved up [1]: <#>printer-volume-humidity (integer(0:100) | no-value)**  
<#>This CONDITIONALLY REQUIRED Job Template attribute specifies the desired relative humidity of the build chamber as a percentage. Printers that support humidity control MUST support this attribute.  
**<#>printer-volume-temperature (integer(-273:MAX) | no-value)**  
<#>This CONDITIONALLY REQUIRED Job Template attribute specifies the desired temperature of the build chamber in degrees Celsius. Printers that support a temperature-controlled build chamber MUST support this attribute.

## 928 8.2 Job Status Attributes

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

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

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

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

933 Note 2: REQUIRED for Printers that provide a temperature-controlled Build  
934 Platform.

### 935 8.2.1 materials-col-actual (1setOf collection)

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

### 938 8.2.2 multiple-object-handling-actual (type2 keyword)

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

### 942 8.2.3 print-accuracy-actual (collection)

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

### 944 8.2.4 platform-temperature-actual (1setOf integer(-273:MAX))

945 This CONDITIONALLY REQUIRED Job Status attribute specifies the Build Platform  
946 temperature(s) that were used during the process of the Job. Printers that provide a  
947 temperature-controlled Build Platform MUST support this attribute.

### 948 8.2.5 print-accuracy-actual (1setOf collection)

949 This REQUIRED Job Status attribute lists the general positioning and feature accuracies  
950 that were used during the processing of the Job.



951 **8.2.6 print-base-actual (1setOf type2 keyword)**

952 This REQUIRED Job Status attribute specifies whether rafts, brims, or skirts were printed  
953 during the processing of the Job.

954 **8.2.7 print-objects-actual (1setOf collection)**

955 This CONDITIONALLY REQUIRED Job Status attribute lists the objects that were  
956 processed. Printers that support the 'application/pdf' document format MUST support this  
957 attribute.

958 **8.2.8 print-supports-actual (1setOf type2 keyword)**

959 This REQUIRED Job Status attribute specifies whether supports were printed during the  
960 processing of the Job.

961 **8.3 Printer Description Attributes**

962 **8.3.1 accuracy-units-supported (1setOf type2 keyword)**

963 This REQUIRED Printer Description attribute specifies the supported "accuracy-units"  
964 member attribute values.

965 **8.3.2 chamber-humidity-default (integer(0:100) | no-value)**

966 This [Printer Description](#) attribute specifies the default relative humidity of the build chamber  
967 as a percentage. Printers that support the "chamber-humidity" Job Template attribute  
968 ([section 8.1.1](#)) MUST support this attribute.

969 **8.3.3 chamber-humidity-supported (boolean)**

970 This [Printer Description](#) attribute specifies whether the "chamber-humidity" Job Template  
971 attribute ([section 8.1.1](#)) is supported. Printers that support the "chamber-humidity" Job  
972 Template attribute MUST support this attribute.

973 **8.3.4 chamber-temperature-default (integer(-273:MAX) | no-value)**

974 This [Printer Description](#) attribute contains the default temperature of the build chamber in  
975 degrees Celsius, if configured. Printers that support the "chamber-temperature" Job  
976 Template attribute ([section 8.1.2](#)) MUST support this attribute.

977 **8.3.5 chamber-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-  
978 273:MAX)))**

979 This [Printer Description](#) attribute lists the supported temperatures (or ranges of  
980 temperatures) of the build chamber in degrees Celsius. Printers that support the "chamber-  
981 temperature" Job Template attribute ([section 8.1.2](#)) MUST support this attribute.

Moved (insertion) [4]

Deleted: printer-volume

Deleted: CONDITIONALLY REQUIRED

Deleted: humidity control

Deleted: printer-volume

Deleted: CONDITIONALLY REQUIRED

Deleted: printer-volume

Deleted:

Deleted: 8.1.8

Deleted: humidity control

Moved (insertion) [3]

Deleted: printer-volume

Deleted: CONDITIONALLY REQUIRED

Deleted: provide a temperature-controlled build chamber

Deleted: printer-volume

Deleted: CONDITIONALLY REQUIRED

Deleted: provide a temperature-controlled build chamber

- 999 **8.3.6 material-amount-units-supported (1setOf type2 keyword)**
- 1000 This Printer Description attribute lists the supported "material-amount-units" values for the  
1001 Printer. This attribute MUST be supported if the "material-amount-units" member attribute  
1002 (Section 8.1.3.2) is supported.
- 1003 **8.3.7 material-diameter-supported (1setOf (integer | rangeOfInteger))**
- 1004 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
1005 "material-diameter" values for the Printer. This attribute MUST be supported if the "material-  
1006 diameter" member attribute (Section 8.1.3.4) is supported.
- 1007 **8.3.8 material-nozzle-diameter-supported (1setOf (integer | rangeOfInteger))**
- 1008 This Printer Description attribute lists the supported "material-nozzle-diameter" values for  
1009 the Printer. This attribute MUST be supported if the "material-nozzle-diameter" member  
1010 attribute (Section 8.1.3.9) is supported.
- 1011 **8.3.9 material-purpose-supported (1setOf type2 keyword)**
- 1012 This REQUIRED Printer Description attribute lists the supported "material-purpose" values  
1013 for the Printer.
- 1014 **8.3.10 material-rate-supported (1setOf (integer | rangeOfInteger))**
- 1015 This Printer Description attribute lists the supported "material-rate" values for the Printer.  
1016 This attribute MUST be supported if the "material-rate" member attribute (Section 8.1.3.11)  
1017 is supported.
- 1018 **8.3.11 material-rate-units-supported (1setOf type2 keyword)**
- 1019 This Printer Description attribute lists the supported "material-rate-units" values for the  
1020 Printer. This attribute MUST be supported if the "material-rate-units" member attribute  
1021 (Section 8.1.3.12) is supported.
- 1022 **8.3.12 material-shell-thickness-supported (1setOf (integer(1:MAX) |  
1023 rangeOfInteger(1:MAX)))**
- 1024 This REQUIRED Printer Description attribute specifies the supported "material-shell-  
1025 thickness" values (or ranges of values) in nanometers.
- 1026 **8.3.13 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-  
1027 273:MAX)))**
- 1028 This CONDITIONALLY REQUIRED Printer Description attribute specifies the supported  
1029 "material-temperature" values (or ranges of values) in degrees Celsius. This attribute MUST  
1030 be supported if the "material-temperature" member attribute (Section 8.1.3.15) is supported.

**1031 8.3.14 material-type-supported (1setOf type2 keyword)**

1032 This REQUIRED Printer Description attribute lists the supported "material-type" values for  
1033 the Printer.

**1034 8.3.15 materials-col-database (1setOf collection)**

1035 This RECOMMENDED Printer Description attribute lists the pre-configured materials for the  
1036 Printer. Each value contains the corresponding "materials-col" member attributes and will  
1037 typically reflect vendor and site ("third party") materials that are supported by the Printer.

1038 In order to optimize the total size of this attribute, Printers MAY omit member attributes that  
1039 allow the full range of supported values in a particular collection. For example, a Printer that  
1040 supports generic PLA filament can report a single collection value:

```
1041     materials-col-database =  
1042     { material-name="Generic PLA Filament" material-key="generic-pla"  
1043     material-diameter=285 material-temperature=215-235 }
```

1044 Such "wildcard" values can be combined with more precise collections that identify a specific  
1045 product, for example:

```
1046     materials-col-database =  
1047     { material-name="Generic PLA Filament" material-key="generic-pla"  
1048     material-diameter=285 material-temperature=215-235 },  
1049     { material-name="Example Corp Flexible Midnight Blue PLA" material-  
1050     key="com.example.flexible-midnight-blue" material-  
1051     color="com.example.midnight-blue_000027" material-diameter=285 material-  
1052     temperature=210-225 }
```

**1053 8.3.16 materials-col-default (1setOf collection)**

1054 This REQUIRED Printer Description attribute lists the default materials that will be used if  
1055 the "materials-col" Job Template attribute (Section 8.1.1) is not specified.

**1056 8.3.17 materials-col-ready (1setOf collection)**

1057 This REQUIRED Printer Description attribute lists the materials that have been loaded into  
1058 the Printer. Each value contains the corresponding "materials-col" member attributes.

**1059 8.3.18 materials-col-supported (1setOf type2 keyword)**

1060 This REQUIRED Printer Description attribute lists the "materials-col" member attributes that  
1061 are supported by the Printer. Printers MUST include the following values: 'material-fill-  
1062 density', 'material-key', 'material-name', 'material-purpose', 'material-shell-thickness', and  
1063 'material-type'.

1064 **8.3.19 max-materials-col-supported (integer(1:MAX))**

1065 This REQUIRED Printer Description attribute specifies the maximum number of values that  
1066 can be provided with the "materials-col" Job Template attribute (section 8.1.1).

1067 **8.3.20 multiple-object-handling-default (type2 keyword)**

1068 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
1069 "multiple-object-handling" value. Printers that support the 'application/pdf' Document format  
1070 MUST support this attribute.

1071 **8.3.21 multiple-object-handling-supported (1setOf type2 keyword)**

1072 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
1073 "multiple-object-handling" values. Printers that support the 'application/pdf' Document format  
1074 MUST support this attribute.

1075 **8.3.22 pdf-features-supported (1setOf type2 keyword)**

1076 This CONDITIONALLY REQUIRED Printer Description attribute lists the PDF features that  
1077 are supported by the Printer. Printers that support the 'application/pdf' Document format  
1078 MUST support this attribute.

1079 Values include:

1080 'prc': The Printer supports 3D objects in the Product Representation Compact  
1081 (PRC) format [ISO14739-1].

1082 'u3d': The Printer supports 3D objects in the Universal 3D (U3D) format [ECMA363].

1083 **8.3.23 platform-shape (type2 keyword)**

1084 This RECOMMENDED Printer Description attribute describes the overall shape of the build  
1085 platform. Values include:

1086 'ellipse': The build platform is elliptical, forming a cylindrical build volume.

1087 'rectangle': The build platform is rectangular, forming a cubic build volume.

1088 **8.3.24 platform-temperature-default (integer(-273:MAX))**

1089 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
1090 "platform-temperature" value. Printers that control the temperature of the Build Platform  
1091 MUST support this attribute.

1092 **8.3.25 platform-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-**  
 1093 **273:MAX)))**

1094 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
 1095 "platform-temperature" values and/or ranges. Printers that control the temperature of the  
 1096 Build Platform MUST support this attribute.

1097 **8.3.26 print-accuracy-default (collection)**

1098 This REQUIRED Printer Description attribute specifies the default "print-accuracy" value.

1099 **8.3.27 print-accuracy-supported (collection)**

1100 This REQUIRED Printer Description attribute specifies the best "print-accuracy" value that  
 1101 is supported by the Printer.

1102 **8.3.28 print-base-default (type2 keyword)**

1103 This REQUIRED Printer Description attribute specifies the default "print-base" value.

1104 **8.3.29 print-base-supported (1setOf type2 keyword)**

1105 This REQUIRED Printer Description attribute lists the supported "print-base" values.

1106 **8.3.30 print-objects-supported (1setOf type2 keyword)**

1107 This CONDITIONALLY REQUIRED Printer Description attribute specifies which "print-  
 1108 objects" member attributes are supported. Printers that support the 'application/pdf'  
 1109 Document format MUST support this attribute.

1110 **8.3.31 print-supports-default (type2 keyword)**

1111 This REQUIRED Printer Description attribute specifies the default "print-supports" value.

1112 **8.3.32 print-supports-supported (1setOf type2 keyword)**

1113 This REQUIRED Printer Description attribute lists the supported "print-supports" values.

1114 **8.3.33 printer-volume-supported (collection)**

1115 This REQUIRED Printer Description attribute specifies the maximum build volume supported  
 1116 by the Printer. Table 15 lists the REQUIRED member attributes.

1117 **Table 15 - REQUIRED "printer-volume-supported" Member Attributes**

**Member Attribute**

x-dimension (integer(1:MAX))

y-dimension (integer(1:MAX))

z-dimension (integer(1:MAX))

**Moved up [4]: <#>printer-volume-humidity-  
 default (integer(0:100) | no-value)¶**  
 <#>This CONDITIONALLY REQUIRED attribute  
 specifies the default relative humidity of the  
 build chamber as a percentage. Printers that  
 support humidity control MUST support this  
 attribute.¶  
**<#>printer-volume-humidity-supported  
 (boolean)¶**  
 <#>This CONDITIONALLY REQUIRED attribute  
 specifies whether the "printer-volume-humidity"  
 Job Template attribute (section 8.1.8) is  
 supported. Printers that support humidity control  
 MUST support this attribute.¶

1132 **8.3.33.1 x-dimension (integer(1:MAX))**

1133 This member attributes specifies the width of the build volume in hundredths of millimeters  
1134 (1/2540th of an inch).

1135 **8.3.33.2 y-dimension (integer(1:MAX))**

1136 This member attributes specifies the depth of the build volume in hundredths of millimeters  
1137 (1/2540th of an inch).

1138 **8.3.33.3 z-dimension (integer(1:MAX))**

1139 This member attributes specifies the height of the build volume in hundredths of millimeters  
1140 (1/2540th of an inch).

1141 **8.4 Printer Status Attributes**

1142 **8.4.1 chamber-humidity-current (integer(0:100) | unknown)**

1143 This Printer Status attribute reports the current relative humidity of the build chamber as a  
1144 percentage. Printers that support the "chamber-humidity" Job Template attribute (section  
1145 8.1.1) MUST support this attribute.

1146 **8.4.2 chamber-temperature-current (integer(-273:MAX) | unknown)**

1147 This Printer Status attribute reports the current temperature of the build chamber in degrees  
1148 Celsius, if known. Printers that support the "chamber-temperature" Job Template attribute  
1149 (section 8.1.2) MUST support this attribute.

1150 **8.4.3 printer-camera-image-uri (1setOf uri)**

1151 This Printer Status attribute lists the URIs for one or more resident camera snapshots. Each  
1152 URI corresponds to a separate resident camera. The images referenced by each URI can  
1153 change at any time so it is up to the Client to periodically poll for changes and for the Printer  
1154 to atomically update the images so that Clients can safely do so. The referenced images  
1155 MUST be PNG [RFC2083] or JPEG [JFIF] format.

1156 **9. New Values for Existing Attributes**

1157 **9.1 ipp-features-supported (1setOf type2 keyword)**

1158 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-  
1159 supported" Printer Description attribute.

Moved up [3]: <#>printer-volume-temperature-default (integer(-273:MAX) | no-value)¶

<#>This CONDITIONALLY REQUIRED attribute contains the default temperature of the build chamber in degrees Celsius, if configured. Printers that provide a temperature-controlled build chamber MUST support this attribute.¶ <#>printer-volume-temperature-supported (1setOf (integer(-273:MAX) | rangeOfinteger(-273:MAX)))¶

<#>This CONDITIONALLY REQUIRED attribute lists the supported temperatures (or ranges of temperatures) of the build chamber in degrees Celsius. Printers that provide a temperature-controlled build chamber MUST support this attribute.¶

Moved (insertion) [2]

Deleted: printer-volume

Deleted: CONDITIONALLY REQUIRED

Deleted: humidity control

Deleted: printer-volume

Deleted: CONDITIONALLY REQUIRED

Deleted: provide a temperature-controlled build chamber

Moved up [2]: <#>printer-volume-humidity-current (integer(0:100) | unknown)¶

<#>This CONDITIONALLY REQUIRED attribute reports the current relative humidity of the build chamber as a percentage. Printers that support humidity control MUST support this attribute.¶ <#>printer-volume-temperature-current (integer(-273:MAX) | unknown)¶

<#>This CONDITIONALLY REQUIRED attribute reports the current temperature of the build chamber in degrees Celsius, if known. Printers that provide a temperature-controlled build chamber MUST support this attribute.¶

**1197 9.2 printer-state-reasons (1setOf type2 keyword)**

1198 This specification registers the following new values for the "printer-state-reasons" Printer  
1199 Status attribute:

- 1200 'camera-failure': A camera is no longer working.
- 1201 'chamber-cooling': A chamber is being cooled.
- 1202 'chamber-failure': A chamber has failed and requires maintenance or replacement.
- 1203 'chamber-heating': A chamber is being heated.
- 1204 'chamber-temperature-high': The temperature of a chamber is high.
- 1205 'chamber-temperature-low': The temperature of a chamber is low.
- 1206 'extruder-cooling': An extruder is being cooled.
- 1207 'extruder-failure': An extruder has failed and requires maintenance or replacement.
- 1208 'extruder-heating': An extruder is being heated.
- 1209 'extruder-jam': An extruder is jammed or clogged.
- 1210 'extruder-temperature-high': The temperature of an extruder is too high.
- 1211 'extruder-temperature-low': The temperature of an extruder is too low.
- 1212 'fan-failure': A fan has failed.
- 1213 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.
- 1214 'lamp-failure': A lamp has failed.
- 1215 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.
- 1216 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.
- 1217 'laser-failure': A laser has failed.
- 1218 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.
- 1219 'material-empty': One or more build materials have been exhausted.
- 1220 'material-low': One or more build materials may need replenishment soon.
- 1221 'material-needed': One or more build materials need to be loaded for a processing  
1222 Job.

- 1223 'motor-failure': A motor has failed.
- 1224 'platform-cooling': A Build Platform is being cooled.
- 1225 'platform-failure': A Build Platform has failed and requires maintenance or  
1226 replacement.
- 1227 'platform-heating': A Build Platform is being heated.
- 1228 'platform-temperature-high': The temperature of a Build Platform is too high.
- 1229 'platform-temperature-low': The temperature of a Build Platform is too low.  
1230



1231 **10. Conformance Requirements**

1232 **10.1 Printer Conformance Requirements**

1233 In order for a Printer to claim conformance to this specification, a Printer MUST support:

- 1234 1. The required discovery protocols in section 5;
- 1235 2. The required transports and resource paths in section 6.1;
- 1236 3. The required HTTP features in section 6.2;
- 1237 4. The required IPP operations in section 6.3;
- 1238 5. The required IPP attributes in sections 6.4 through 6.9;
- 1239 6. The required document formats in section 7;
- 1240 7. The additional values defined in section 9;
- 1241 8. The internationalization considerations in section 11; and
- 1242 9. The security considerations in section 12.

1243 **10.2 Client Conformance Requirements**

1244 In order for a Client to claim conformance to this specification, a Client MUST support:

- 1245 1. The required discovery protocols in section 5;
- 1246 2. The required transports and resource paths in section 6.1;
- 1247 3. The required HTTP features in section 6.2;
- 1248 4. The required IPP operations in section 6.3;
- 1249 5. The required IPP attributes in sections 6.4 through 6.9;
- 1250 6. The required document formats in section 7;
- 1251 7. The additional values defined in section 9;
- 1252 8. The internationalization considerations in section 11; and
- 1253 9. The security considerations in section 12.

1254

## 1255 **11. Internationalization Considerations**

1256 For interoperability and basic support for multiple languages, conforming implementations  
1257 MUST support:

- 1258 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)  
1259 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 1260 2. The Unicode Format for Network Interchange [RFC5198] which requires  
1261 transmission of well-formed UTF-8 strings and recommends transmission of  
1262 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1263 Unicode NFC is defined as the result of performing Canonical Decomposition (into base  
1264 characters and combining marks) followed by Canonical Composition (into canonical  
1265 composed characters wherever Unicode has assigned them).

1266 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and  
1267 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in IPP  
1268 Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8 URIs  
1269 now 'hidden').

1270 Implementations of this specification SHOULD conform to the following standards on  
1271 processing of human-readable Unicode text strings, see:

1272 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical

1273 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping

1274 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]

1275 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences

1276 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization

1277 Unicode Character Encoding Model [UTR17] – multi-layer character model

1278 Unicode in XML and other Markup Languages [UTR20] – XML usage

1279 Unicode Character Property Model [UTR23] – character properties

1280 Unicode Conformance Model [UTR33] – Unicode conformance basis+

1281 Unicode Collation Algorithm [UTS10] – sorting

1282 Unicode Locale Data Markup Language [UTS35] – locale databases

1283 **12. Security Considerations**

1284 In addition to the security considerations described in the IPP/1.1: Model and Semantics  
1285 [RFC8011], the following sub-sections describe issues that are unique to 3D printing.

1286 Implementations of this specification SHOULD conform to the following standards on  
1287 processing of human-readable Unicode text strings, see:

1288       Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1289       Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

1290 **12.1 Confidentiality**

1291 Clients and Printers MUST provide confidentiality of data in transit using either an interface  
1292 providing physical security such as USB or using TLS encryption [RFC5246] over  
1293 unsecured/network connections,

1294 **12.2 Access Control**

1295 Because of the potential for abuse and misuse, Printers SHOULD provide access control  
1296 mechanisms including lists of allowed Clients, authentication, and authorization to site  
1297 defined policies.

1298 **12.3 Physical Safety**

1299 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such  
1300 as protective gates, covers, or interlocks.

1301 **12.4 Material Safety**

1302 Printers MUST restrict usage and combination of materials to those that can be safely  
1303 printed. Access controls (section 12.2) MAY be used to allow authorized End Users to  
1304 experiment with untested materials or combinations, but only when such materials or  
1305 combinations can reasonably be expected to not pose a safety risk.

1306 **12.5 Temperature Control**

1307 Printers MUST validate values provided by Clients and limit material, extruder, Build  
1308 Platform, and print chamber temperatures within designed limits to prevent unsafe operating  
1309 conditions, damage to the hardware, hazardous emissions, explosions, and/or fires.

1310

1311 **13. IANA and PWG Considerations**1312 **13.1 Attribute Registrations**

1313 The attributes defined in this specification will be published by IANA according to the  
 1314 procedures in IPP/1.1 Model and Semantics [RFC8011] section 7.2 in the following file:

1315 <http://www.iana.org/assignments/ipp-registrations>

1316 The registry entries will contain the following information:

1317	Document Status attributes:	Reference
1318	-----	-----
1319	materials-col-actual (1setOf collection)	[PWG5100.21]
1320	< member attributes are the same as materials-col >	[PWG5100.21]
1321	multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1322	platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1323	print-accuracy-actual (collection)	[PWG5100.21]
1324	< member attributes are the same as print-accuracy >	[PWG5100.21]
1325	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1326	print-objects-actual (1setOf collection)	[PWG5100.21]
1327	< member attributes are the same as print-objects >	[PWG5100.21]
1328	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1329		
1330	Document Template attributes:	Reference
1331	-----	-----
1332	materials-col (1setOf collection)	[PWG5100.21]
1333	material-amount (integer(0:MAX))	[PWG5100.21]
1334	material-amount-units (type2 keyword)	[PWG5100.21]
1335	material-color (type2 keyword)	[PWG5100.21]
1336	material-diameter (integer(0:MAX))	[PWG5100.21]
1337	material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1338	material-fill-density (integer(0:100))	[PWG5100.21]
1339	material-key (keyword)	[PWG5100.21]
1340	material-name (name(MAX))	[PWG5100.21]
1341	material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
1342	material-purpose (1setOf type2 keyword)	[PWG5100.21]
1343	material-rate (integer(1:MAX))	[PWG5100.21]
1344	material-rate-units (type2 keyword)	[PWG5100.21]
1345	material-retraction (boolean)	[PWG5100.21]
1346	material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1347	material-temperature (integer(-273:MAX)   rangeOfInteger(-273:MAX))	[PWG5100.21]
1348		
1349	material-type (type2 keyword   name(MAX))	[PWG5100.21]
1350	multiple-object-handling (type2 keyword)	[PWG5100.21]
1351	platform-temperature (integer(-273:MAX))	[PWG5100.21]
1352	print-accuracy (collection)	[PWG5100.21]
1353	accuracy-units (type2 keyword)	[PWG5100.21]
1354	x-accuracy (integer(0:MAX))	[PWG5100.21]
1355	y-accuracy (integer(0:MAX))	[PWG5100.21]
1356	z-accuracy (integer(0:MAX))	[PWG5100.21]
1357	print-base (type2 keyword)	[PWG5100.21]
1358	print-objects (1setOf collection)	[PWG5100.21]

1359	document-number (integer(1:MAX))	[PWG5100.21]
1360	object-offset (collection)	[PWG5100.21]
1361	x-offset (integer(0:MAX))	[PWG5100.21]
1362	y-offset (integer(0:MAX))	[PWG5100.21]
1363	z-offset (integer(0:MAX))	[PWG5100.21]
1364	object-size (collection)	[PWG5100.21]
1365	x-dimension (integer(1:MAX))	[PWG5100.21]
1366	y-dimension (integer(1:MAX))	[PWG5100.21]
1367	z-dimension (integer(1:MAX))	[PWG5100.21]
1368	object-uuid (uri)	[PWG5100.21]
1369	print-supports (type2 keyword)	[PWG5100.21]
1370	printer-volume-humidity (integer(0:100)   no-value)	[PWG5100.21]
1371	printer-volume-temperature (integer(-273:MAX)   no-value)	[PWG5100.21]
1372		[PWG5100.21]
1373		
1374	Job Status attributes:	Reference
1375	-----	-----
1376	materials-col-actual (1setOf collection)	[PWG5100.21]
1377	< member attributes are the same as materials-col >	[PWG5100.21]
1378	multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1379	platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1380	print-accuracy-actual (collection)	[PWG5100.21]
1381	< member attributes are the same as print-accuracy >	[PWG5100.21]
1382	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1383	print-objects-actual (1setOf collection)	[PWG5100.21]
1384	< member attributes are the same as print-objects >	[PWG5100.21]
1385	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1386		
1387	Job Template attributes:	Reference
1388	-----	-----
1389	materials-col (1setOf collection)	[PWG5100.21]
1390	material-amount (integer(0:MAX))	[PWG5100.21]
1391	material-amount-units (type2 keyword)	[PWG5100.21]
1392	material-color (type2 keyword)	[PWG5100.21]
1393	material-diameter (integer(0:MAX))	[PWG5100.21]
1394	material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1395	material-fill-density (integer(0:100))	[PWG5100.21]
1396	material-key (keyword)	[PWG5100.21]
1397	material-name (name(MAX))	[PWG5100.21]
1398	material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
1399	material-purpose (1setOf type2 keyword)	[PWG5100.21]
1400	material-rate (integer(1:MAX))	[PWG5100.21]
1401	material-rate-units (type2 keyword)	[PWG5100.21]
1402	material-retraction (boolean)	[PWG5100.21]
1403	material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1404	material-temperature (integer(-273:MAX)   rangeOfInteger(-273:MAX))	[PWG5100.21]
1405		[PWG5100.21]
1406	material-type (type2 keyword   name(MAX))	[PWG5100.21]
1407	multiple-object-handling (type2 keyword)	[PWG5100.21]
1408	platform-temperature (integer(-273:MAX))	[PWG5100.21]
1409	print-accuracy (collection)	[PWG5100.21]
1410	accuracy-units (type2 keyword)	[PWG5100.21]
1411	x-accuracy (integer(0:MAX))	[PWG5100.21]
1412	y-accuracy (integer(0:MAX))	[PWG5100.21]
1413	z-accuracy (integer(0:MAX))	[PWG5100.21]
1414	print-base (type2 keyword)	[PWG5100.21]

1415	print-objects (1setOf collection)	[PWG5100.21]
1416	document-number (integer(1:MAX))	[PWG5100.21]
1417	object-offset (collection)	[PWG5100.21]
1418	x-offset (integer(0:MAX))	[PWG5100.21]
1419	y-offset (integer(0:MAX))	[PWG5100.21]
1420	z-offset (integer(0:MAX))	[PWG5100.21]
1421	object-size (collection)	[PWG5100.21]
1422	x-dimension (integer(1:MAX))	[PWG5100.21]
1423	y-dimension (integer(1:MAX))	[PWG5100.21]
1424	z-dimension (integer(1:MAX))	[PWG5100.21]
1425	object-uuid (uri)	[PWG5100.21]
1426	print-supports (type2 keyword)	[PWG5100.21]
1427	printer-volume-humidity (integer(0:100)   no-value)	[PWG5100.21]
1428	printer-volume-temperature (integer(-273:MAX)   no-value)	
1429		[PWG5100.21]
1430		
1431	Printer Description attributes:	Reference
1432	-----	-----
1433	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.21]
1434	material-amount-units-supported (1setOf type2 keyword)	[PWG5100.21]
1435	material-diameter-supported (1setOf (integer(0:MAX)	
1436	rangeOfInteger(0:MAX)))	[PWG5100.21]
1437	material-nozzle-diameter-supported (1setOf (integer(0:MAX)	
1438	rangeOfInteger(0:MAX)))	[PWG5100.21]
1439	material-purpose-supported (1setOf type2 keyword)	[PWG5100.21]
1440	material-rate-supported (1setOf (integer(1:MAX)   rangeOfInteger(1:MAX)))	
1441		[PWG5100.21]
1442	material-rate-units-supported (1setOf type2 keyword)	[PWG5100.21]
1443	material-shell-thickness-supported (1setOf (integer(0:MAX)	
1444	rangeOfInteger(0:MAX)))	[PWG5100.21]
1445	material-temperature-supported (1setOf (integer(-273:MAX)	
1446	rangeOfInteger(-273:MAX)))	[PWG5100.21]
1447	material-type-supported (1setOf type2 keyword)	[PWG5100.21]
1448	materials-col-database (1setOf collection)	[PWG5100.21]
1449	< member attributes are the same as materials-col >	[PWG5100.21]
1450	materials-col-default (1setOf collection)	[PWG5100.21]
1451	< member attributes are the same as materials-col >	[PWG5100.21]
1452	materials-col-ready (1setOf collection)	[PWG5100.21]
1453	< member attributes are the same as materials-col >	[PWG5100.21]
1454	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1455	max-materials-col-supported (integer(1:MAX))	[PWG5100.21]
1456	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1457	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1458	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1459	platform-shape (type2 keyword)	[PWG5100.21]
1460	platform-temperature-default (integer(-273:MAX))	[PWG5100.21]
1461	platform-temperature-supported (1setOf (integer(-273:MAX)	
1462	rangeOfInteger(-273:MAX)))	[PWG5100.21]
1463	print-accuracy-supported (collection)	[PWG5100.21]
1464	< member attributes are the same as print-accuracy >	[PWG5100.21]
1465	print-base-default (type2 keyword)	[PWG5100.21]
1466	print-base-supported (1setOf type2 keyword)	[PWG5100.21]
1467	print-objects-supported (1setOf type2 keyword)	[PWG5100.21]
1468	print-supports-default (type2 keyword)	[PWG5100.21]
1469	print-supports-supported (1setOf type2 keyword)	[PWG5100.21]

```

1470 printer-volume-humidity-default (integer(0:100) | no-value)
1471                                     [PWG5100.21]
1472 printer-volume-humidity-supported (boolean) [PWG5100.21]
1473 printer-volume-supported (collection) [PWG5100.21]
1474     x-dimension (integer(1:MAX)) [PWG5100.21]
1475     y-dimension (integer(1:MAX)) [PWG5100.21]
1476     z-dimension (integer(1:MAX)) [PWG5100.21]
1477 printer-volume-temperature-default (integer(-273:MAX) | no-value)
1478                                     [PWG5100.21]
1479 printer-volume-temperature-supported (1setOf (integer(-273:MAX) |
1480 rangeOfInteger(-273:MAX)) [PWG5100.21]
1481
1482 Printer Status attributes: Reference
1483 -----
1484 printer-camera-image-uri (1setOf uri) [PWG5100.21]
1485 printer-volume-humidity-current (integer(0:100) | unknown)
1486                                     [PWG5100.21]
1487 printer-volume-temperature-current (integer(-273:MAX) | unknown)
1488                                     [PWG5100.21]

```

## 1489 13.2 Attribute Value Registrations

1490 The attributes defined in this specification will be published by IANA according to the  
 1491 procedures in IPP/1.1 Model and Semantics [RFC8011] section 7.1 in the following file:

1492 <http://www.iana.org/assignments/ipp-registrations>

1493 The registry entries will contain the following information:

```

1494 Attributes (attribute syntax)
1495 Keyword Attribute Value Reference
1496 -----
1497 accuracy-units (type2 keyword) [PWG5100.21]
1498     mm [PWG5100.21]
1499     nm [PWG5100.21]
1500     um [PWG5100.21]
1501 accuracy-units-supported (1setOf type2 keyword) [PWG5100.21]
1502     < any accuracy-units values > [PWG5100.21]
1503 ipp-features-supported (1setOf type2 keyword) [PWG5100.13]
1504     ipp-3d [PWG5100.21]
1505 material-amount-units (type2 keyword) [PWG5100.21]
1506     g [PWG5100.21]
1507     kg [PWG5100.21]
1508     l [PWG5100.21]
1509     m [PWG5100.21]
1510     ml [PWG5100.21]
1511     mm [PWG5100.21]
1512 material-color (type2 keyword) [PWG5100.21]
1513     < any "media" color name > [PWG5100.21]
1514 material-purpose (1setOf type2 keyword) [PWG5100.21]
1515     all [PWG5100.21]
1516     base [PWG5100.21]
1517     in-fill [PWG5100.21]
1518     shell [PWG5100.21]

```

1519	support	[PWG5100.21]
1520	material-rate-units (type2 keyword)	[PWG5100.21]
1521	mg_second	[PWG5100.21]
1522	ml_second	[PWG5100.21]
1523	mm_second	[PWG5100.21]
1524	material-type (type2 keyword)	[PWG5100.21]
1525	abs	[PWG5100.21]
1526	abs-carbon-fiber	[PWG5100.21]
1527	abs-carbon-nanotube	[PWG5100.21]
1528	chocolate	[PWG5100.21]
1529	gold	[PWG5100.21]
1530	nylon	[PWG5100.21]
1531	pet	[PWG5100.21]
1532	photopolymer	[PWG5100.21]
1533	pla	[PWG5100.21]
1534	pla-conductive	[PWG5100.21]
1535	pla-dissolvable	[PWG5100.21]
1536	pla-flexible	[PWG5100.21]
1537	pla-magnetic	[PWG5100.21]
1538	pla-steel	[PWG5100.21]
1539	pla-stone	[PWG5100.21]
1540	pla-wood	[PWG5100.21]
1541	polycarbonate	[PWG5100.21]
1542	silver	[PWG5100.21]
1543	titanium	[PWG5100.21]
1544	wax	[PWG5100.21]
1545	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1546	< any materials-col member attribute name >	[PWG5100.21]
1547	multiple-object-handling (type2 keyword)	[PWG5100.21]
1548	auto	[PWG5100.21]
1549	best-fit	[PWG5100.21]
1550	best-quality	[PWG5100.21]
1551	best-speed	[PWG5100.21]
1552	one-at-a-time	[PWG5100.21]
1553	multiple-object-handling-actual (1setOf type2 keyword)	[PWG5100.21]
1554	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1555		[PWG5100.21]
1556	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1557	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1558		[PWG5100.21]
1559	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1560	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1561		[PWG5100.21]
1562	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1563	prc	[PWG5100.21]
1564	u3d	[PWG5100.21]
1565	platform-shape (type2 keyword)	[PWG5100.21]
1566	ellipse	[PWG5100.21]
1567	rectangle	[PWG5100.21]
1568	print-base (type2 keyword)	[PWG5100.21]
1569	brim	[PWG5100.21]
1570	none	[PWG5100.21]
1571	raft	[PWG5100.21]
1572	skirt	[PWG5100.21]
1573	standard	[PWG5100.21]
1574	print-base-actual (1setOf type2 keyword)	[PWG5100.21]



```

1575     < any print-base Job Template attribute value > [PWG5100.21]
1576 print-base-default (type2 keyword) [PWG5100.21]
1577     < any print-base Job Template attribute value > [PWG5100.21]
1578 print-base-supported (1setOf type2 keyword) [PWG5100.21]
1579     < any print-base Job Template attribute value > [PWG5100.21]
1580 print-objects-supported (1setOf type2 keyword) [PWG5100.21]
1581     < any print-objects member attribute name > [PWG5100.21]
1582 print-supports (type2 keyword) [PWG5100.21]
1583     material [PWG5100.21]
1584     none [PWG5100.21]
1585     standard [PWG5100.21]
1586 print-supports-actual (1setOf type2 keyword) [PWG5100.21]
1587     < any print-supports Job Template attribute value > [PWG5100.21]
1588 print-supports-default (type2 keyword) [PWG5100.21]
1589     < any print-supports Job Template attribute value > [PWG5100.21]
1590 print-supports-supported (1setOf type2 keyword) [PWG5100.21]
1591     < any print-supports Job Template attribute value > [PWG5100.21]
1592 printer-state-reasons (1setOf type2 keyword) [RFC8011]
1593     camera-failure [PWG5100.21]
1594     chamber-cooling [PWG5100.21]
1595     chamber-failure [PWG5100.21]
1596     chamber-heating [PWG5100.21]
1597     chamber-temperature-high [PWG5100.21]
1598     chamber-temperature-low [PWG5100.21]
1599     extruder-cooling [PWG5100.21]
1600     extruder-failure [PWG5100.21]
1601     extruder-heating [PWG5100.21]
1602     extruder-jam [PWG5100.21]
1603     extruder-temperature-high [PWG5100.21]
1604     extruder-temperature-low [PWG5100.21]
1605     fan-failure [PWG5100.21]
1606     lamp-at-eol [PWG5100.21]
1607     lamp-failure [PWG5100.21]
1608     lamp-near-eol [PWG5100.21]
1609     laser-at-eol [PWG5100.21]
1610     laser-failure [PWG5100.21]
1611     laser-near-eol [PWG5100.21]
1612     material-empty [PWG5100.21]
1613     material-low [PWG5100.21]
1614     material-needed [PWG5100.21]
1615     motor-failure [PWG5100.21]
1616     platform-cooling [PWG5100.21]
1617     platform-failure [PWG5100.21]
1618     platform-heating [PWG5100.21]
1619     platform-temperature-high [PWG5100.21]
1620     platform-temperature-low [PWG5100.21]

```

### 1621 13.3 Service Type Registration

1622 The DNS-SD service type defined in this specification will be published by IANA according  
 1623 to the procedures in Internet Assigned Numbers Authority (IANA) Procedures for the  
 1624 Management of the Service Name and Transport Protocol Port Number Registry [BCP165].

1625 The registration template is as follows:

1626 Service Name: ipp3d  
1627  
1628 Transport Protocol(s): tcp  
1629  
1630 Assignee/Contact: Michael Sweet, msweet@apple.com  
1631  
1632 Description: 3D Print services (3D printers) using the Internet Printing  
1633 Protocol over HTTPS.  
1634  
1635 Reference: <http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf>  
1636  
1637  
1638 Port Number:  
1639  
1640 Service Code:  
1641  
1642 Known Unauthorized Uses:  
1643  
1644 Assignment Notes: Change controller is The Printer Working Group, c/o The  
1645 IEEE Industry Standards and Technology Organization, 445 Hoes Lane,  
1646 Piscataway, NJ 08854, USA

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Field Code Changed

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**1803 15. Author's Address**

1804 Primary author:

1805 Michael Sweet

1806 Apple Inc.  
1807 One Apple Park Way  
1808 MS 111-HOMC  
1809 Cupertino, CA 95014  
1810 msweet@apple.com

1811 The authors would also like to thank the following individuals for their contributions to this  
1812 standard:

1813 Olliver Schinagl, Ultimaker B.V.  
1814 Michael Scrutton, Adobe Systems  
1815 Emmet Lalish, Microsoft Corporation  
1816

## 1817 **16. Object Definition Languages (ODLs)**

1818 This section provides information on several commonly used ODLs with either existing  
1819 (registered) or suggested MIME media types.

### 1820 **16.1 3D Manufacturing Format (3MF)**

1821 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that  
1822 provides geometry, material, and texture information necessary to support a wide variety of  
1823 3D printers. Materials can be named and composed within the geometry, facilitating multiple  
1824 material support in coordination with a Job Ticket.

1825 The registered MIME media type for the original Microsoft published specification is  
1826 "application/vnd.ms-3mfdocument". The MIME media type for the 3MF Consortium's  
1827 published specification is "model/3mf".

### 1828 **16.2 Additive Manufacturing Format (AMF)**

1829 AMF [ISO52915] is a relatively new format that was designed as a replacement for the  
1830 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-  
1831 available specification, but has several advantages over STL including:

- 1832 1. Shared vertices which eliminates holes and other breaks in the surface  
1833 geometry of objects,
- 1834 2. Specification of multiple materials in a single file,
- 1835 3. Curved surfaces can be specified, and
- 1836 4. Coordinates use explicit units for proper output dimensions.

1837 The suggested (but not registered) MIME media type is 'model/amf'.

### 1838 **16.3 Portable Document Format (PDF)**

1839 PDF [ISO32000] is widely supported for 2D printing and has two 3D formats that are used  
1840 to embed 3D objects - PRC [ISO14739-1] and U3D [ECMA363]. The registered MIME media  
1841 type for PDF is "application/pdf".

1842 [For discussion: define a "model/pdf" MIME media type for PDFs containing 3D content?]

### 1843 **16.4 Standard Tessellation Language (STL)**

1844 STL [STLFORMAT] is widely supported by existing client software. The registered MIME  
1845 media type is 'application/sla'.

1846



## 1847 **17. Design Choices**

1848 This section documents some of the design choices that were made during the development  
1849 of this specification.

### 1850 **17.1 Units for Length Values**

1851 The default unit for most length values is hundredths of millimeters (1/2540th of an inch),  
1852 matching the units for 2D printing and providing a range of 0.01mm to 21.47km. This was  
1853 determined to be sufficient for the class of printers this specification targets.

### 1854 **17.2 Units for Thickness Values**

1855 The default unit for most thickness values is nanometers, which provides a range of  
1856 0.000001mm to 2.147m. This was determined to be sufficient for the class of printers this  
1857 specification targets.

### 1858 **17.3 Use of Celsius for Temperatures**

1859 The various integer attributes for temperature use degrees Celsius. This was done because  
1860 most existing printers and materials are specified using degrees Celsius. There is no  
1861 advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to perform  
1862 additional unit conversions could cause safety issues. All temperature attributes use a range  
1863 of -273 (absolute zero) to MAX (2147483647 - significantly hotter than our sun) to allow  
1864 flexibility.

### 1865 **17.4 Explicit Units for Other Values**

1866 Some attributes have a companion "xxx-units" attribute that specifies an explicit unit for the  
1867 given measurement(s). The initial list of unit values for each attribute has been limited to  
1868 those necessary for current printers and technologies at the time of writing of this  
1869 specification in order to minimize interoperability issues.

### 1870 **17.5 Intent vs. Process**

1871 The IPP Model [RFC8011], and more generally the PWG Semantic Model [PWG5108.1],  
1872 have long focused on Job Tickets specifying "what" is wanted for the printed output vs. "how"  
1873 that output is produced. This focus has served IPP well and allowed it to be used with wildly  
1874 different printing technologies.

1875 During the development of this specification, attributes that define a specific process or  
1876 technological parameter have been introduced and later replaced by intent-based  
1877 alternatives that allow an implementation to select suitable process-based parameters at

1878 print time, preserving the intrinsic value of such parameters without burdening the Client or  
1879 End User with such things.

1880 At the same time, some process parameters are needed for things like material specification.  
1881 For example, a particular brand of PLA may require a higher melting temperature - this  
1882 information might only be known to the End User, so the "materials-col" collection contains  
1883 an member attribute to convey this process-specific parameter. The Printer advertises  
1884 whether temperature is a valid material property in the "materials-col-supported" Printer  
1885 Description attribute.

1886 Finally, IPP does not prohibit the definition or use of process-based Job Template attributes  
1887 for specific implementations. Such extension attributes can be listed in the "job-creation-  
1888 attributes-supported" Printer Description attribute to notify Clients of their existence.

## 1889 **17.6 Choosing a Required Document Format**

1890 One of the design consideration of this specification is to choose an open, freely available  
1891 file format for use as required document format. Having a required document format makes  
1892 interoperability significantly easier, and using an open and freely available format allows  
1893 developers of "consumer" printers to support IPP 3D. Several formats were considered,  
1894 including STL, AMF, PDF, and 3MF.

1895 While STL is a widely-implemented, open, and freely available file format, it lacks support  
1896 for multiple materials and colors/textures, and has technical issues that cause "holes" in  
1897 generated models.

1898 While AMF supports multiple materials and does not have the "holes" issue, it is not freely  
1899 available nor widely-implemented.

1900 PDF is the most capable 3D format but is not freely available and has the interoperability  
1901 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-  
1902 features-supported" Printer Description attribute (section 8.3.22) allows Clients to determine  
1903 whether a 3D PDF file can be printed by the Printer.

1904 3MF is open and freely available, supports multiple materials and color/textures, does not  
1905 have the "holes" issue of STL, and has a freely available open source implementation that  
1906 supports both creation and consumption of 3MF files.  
1907

1908 **18. Overview of Changes**

1909 **18.1 IPP 3D Printing Extensions v1.1**

1910 The following changes were made since v1.0 of this document:

- 1911 5. Made 3MF CONDITIONALLY REQUIRED for Printers that do Slicing,  
1912 RECOMMEND support for a standard layered format otherwise.
- 1913 6. Added the CONDITIONALLY REQUIRED "material-nozzle-diameter" and  
1914 "material-retraction" member attributes for the "materials-col" Job Template  
1915 attribute.
- 1916 7. Added the RECOMMENDED "platform-shape" Printer Description attribute
- 1917 8. Added the ~~RECOMMENDED~~ "chamber-humidity" and "chamber-temperature"  
1918 Job Template attributes.
- 1919 9. Defined a naming convention for standard "material-type" values.
- 1920

**Deleted:** CONDITIONALLY REQUIRED

**Deleted:** printer-volume

**Deleted:** printer-volume

1924 **19. Change History**

1925 **19.1 June 5, 2018**

- 1926
  - [Renamed "printer-volume-xxx" to "chamber-xxx".](#)
- 1927
  - [Added "chamber-humidity" to Table 10.](#)
- 1928
  - [All new attributes that were CONDITIONALLY REQUIRED are now](#)
- 1929
  - [RECOMMENDED.](#)
- 1930
  - [Added definition of material-type keyword format for standard materials.](#)
- 1931
  - [Update Unicode reference now that v11 has been published.](#)

1932 **19.2 April 26, 2018**

1933 Initial revision.

**printer-volume-  
temperature (integer | no-  
value)**

**printer-volume-  
temperature-default  
(integer | no-value)**

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

---

**printer-volume**

**1.1.1**