



The Printer Working Group

February 1, 2019  
Working Draft

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

Status: Stable

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

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56 manufacturers and vendors of printer related software benefit from the interoperability  
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59 technically competent, has multiple, independent and interoperable implementations with  
60 substantial operational experience, and enjoys significant public support.

61 For additional information regarding the Printer Working Group visit:

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## 264 **1. Introduction**

265 This specification defines an extension to the Internet Printing Protocol (IPP) that supports  
266 printing of physical objects by Additive Manufacturing devices such as three-dimensional  
267 (3D) printers.

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

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

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

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

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

## 284 **2. Terminology**

### 285 **2.1 Conformance Terminology**

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

### 291 **2.2 Printing Terminology**

292 Normative definitions and semantics of printing terms are imported from IETF Printer MIB  
293 v2 [RFC3805], IETF Finisher MIB [RFC3806], and IETF Internet Printing Protocol/1.1: Model  
294 and Semantics [STD92].

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

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

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

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

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

### 305 **2.3 Protocol Role Terminology**

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

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

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

### 313 **2.4 3D Printing Terminology**

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

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

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

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

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

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

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

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

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

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

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

## 337 **2.5 Other Terminology**

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

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

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

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

## 345 **2.6 Acronyms and Organizations**

346 *3D PDF Consortium*: <http://www.3dpdfconsortium.org/>

347 *3MF Consortium*: 3D Manufacturing Format Consortium, <http://www.3mf.io/>

348 *CNC*: Computer Numerical Control

349 *DLP*: Digital Light Processing

350 *FDM*: Fused Deposition Modeling

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

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

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

354 *ODL*: Object Definition Language

- 355 *PWG*: Printer Working Group, <http://www.pwg.org/>
- 356 *SD*: SD Card Association, <http://www.sdcard.org/>
- 357 *SDL*: Selective Deposition Lamination
- 358 *SL*: Stereo Lithography
- 359 *USB*: Universal Serial Bus, <http://www.usb.org/>
- 360

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

362 Existing specifications define the following:

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

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

#### 384 **3.1 Use Cases**

##### 385 **3.1.1 Print a 3D Object**

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

##### 389 **3.1.2 Print a 3D Object Using Loaded Materials**

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

##### 393 **3.1.3 Print a 3D Object with Multiple Materials**

394 Jane wants to print a multi-material object on a single-material Printer. Jane uses software  
395 on her Client device to create Document data that instructs the Printer to pause printing and

396 provide status information at specific layers so that she can change materials at the Printer  
397 and resume printing with the new material.

#### 398 **3.1.4 Print a Tool**

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

#### 403 **3.1.5 View a 3D Object During Printing**

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

### 406 **3.2 Exceptions**

#### 407 **3.2.1 Clogged Extruder**

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

#### 411 **3.2.2 Extruder Temperature Out of Range**

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

#### 416 **3.2.3 Extruder Head Movement Issues**

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

#### 420 **3.2.4 Filament Feed Jam**

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

#### 424 **3.2.5 Filament Feed Skip**

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

**428 3.2.6 Material Empty**

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

**432 3.2.7 Material Adhesion Issues**

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

**437 3.2.8 Build Platform Temperature Out of Range**

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

**441 3.2.9 Build Platform Not Clear**

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

**446 3.3 Out of Scope**

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

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

452

### 453 **3.4 Design Requirements**

454 The design requirements for this document are:

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

470 The design recommendations for this document are:

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

472



## 473 **4. 3D Print Service Model**

474 The IPP/1.1 Model and Semantics [STD92], the IETF Printer MIB [RFC3805], and the IETF  
475 Finisher MIB [RFC3806] already define a comprehensive model for the operation and data  
476 elements of a typical 2D printer. Figure 1 shows the generalized IPP model. The IPP Server  
477 provides the external network interface for IPP Clients, while the Print Service manages and  
478 processes Jobs and communicates with the Output Device(s) and their sub-units.

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

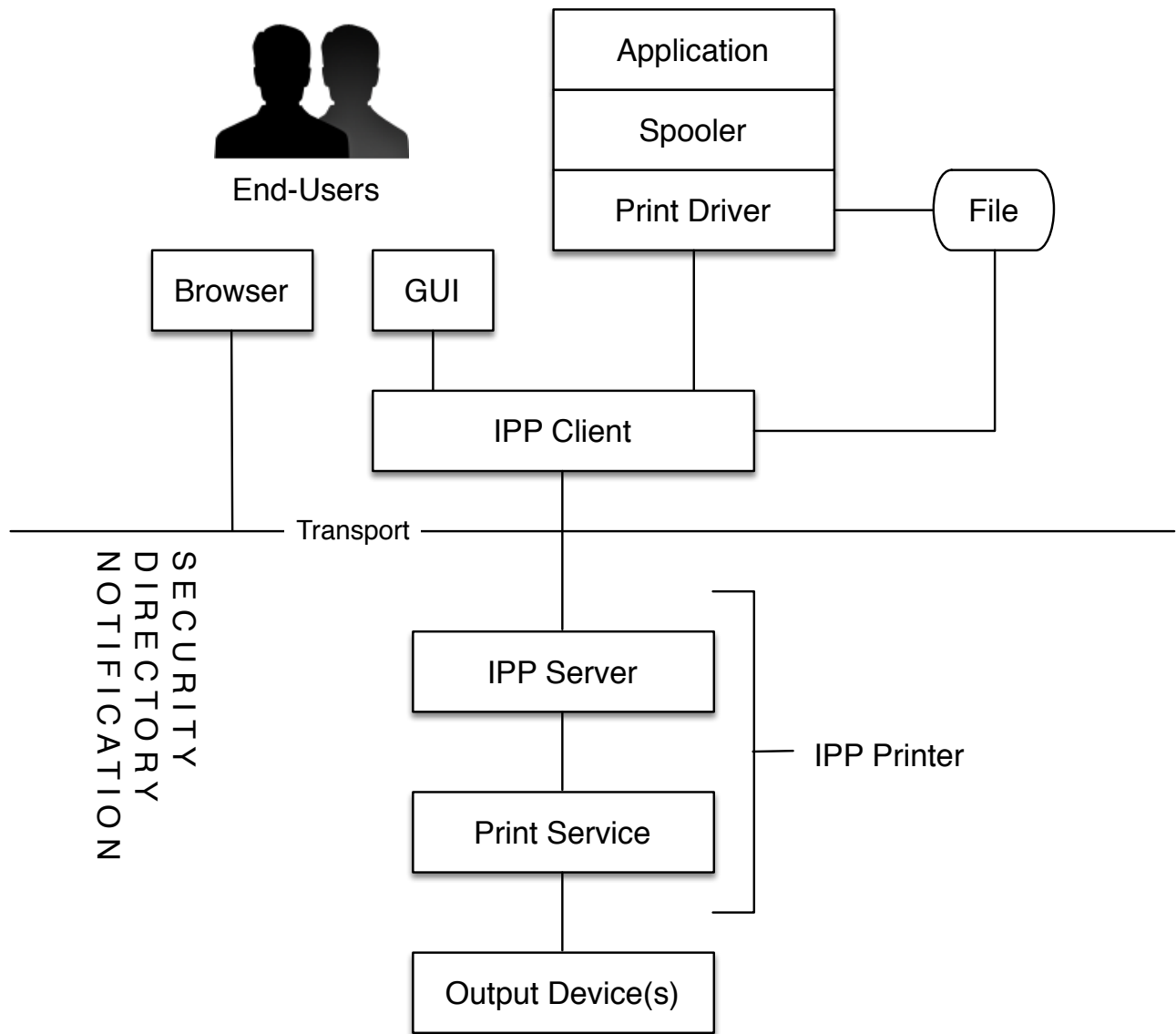
484 The IPP Printer object contains zero or more Job objects and is responsible for managing,  
485 scheduling, and processing Jobs. It also provides the current state of the Output Device(s)  
486 and communicates with them as needed.

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

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

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

498



499

500

501

**Figure 1 - Generalized IPP Model (RFC 8011)**

## 502 **4.1 3D Print Service**

503 3D printing uses a variation of the traditional Print service that maintains state and capability  
 504 information specific to 3D printing. The 3D Print service supports all of the same operations  
 505 of the Print service described in [STD92] except for the Print-Job and Print-URI operations  
 506 which are compound requests that are not used in newer IPP services. Similarly, the 3D  
 507 Print service uses a superset of the Print service attributes except where such attributes are  
 508 not applicable, for example the "media" attributes for a 3D printer that does not use media  
 509 sheets. Attributes specific to the 3D Print Service are defined in section 8.

## 510 **4.2 3D Printer Subunits**

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

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

<b>2D Subunit</b>	<b>3D Subunit(s)</b>	<b>Technology</b>	<b>Reference</b>
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

### 514 **4.2.1 Finishing Devices**

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

### 517 **4.2.2 Input Trays/Rolls**

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

### 519 **4.2.3 Marker Supplies**

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

#### 522 4.2.4 Markers

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

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

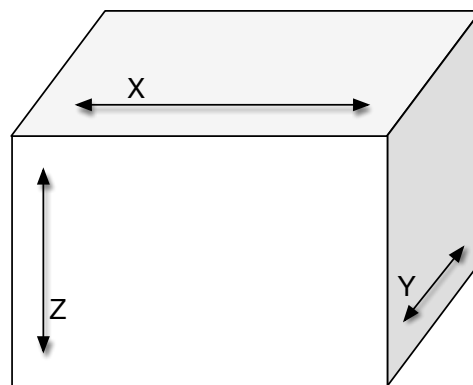
#### 528 4.2.5 Media Paths

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

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

### 534 4.3 3D Printer Coordinate System

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



539

540

**Figure 2 - 3D Build Volume**

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

#### 545 **4.4 Output Intent and Job Processing**

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

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

#### 555 **4.5 Job Spooling**

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

#### 559 **4.6 Multiple Document Jobs**

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

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

#### 566 **4.7 Cloud-Based Printing**

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

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

574

## 575 **5. Discovery Protocols**

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

### 578 **5.1 DNS Service Discovery (DNS-SD)**

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

#### 583 **5.1.1 Service Instance Name**

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

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

#### 587 **5.1.2 Service Type**

588 Printers MUST advertise the "\_ippes-3d.\_tcp" (IPPS 3D Print) service over DNS-SD.

#### 589 **5.1.3 TXT Record**

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

593 **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

## 594 **5.2 LDAP Discovery**

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

### 598 **5.2.1 printerIPPS3D Class**

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

```
601         ( 1.3.18.0.2.24.46.2.1
602           NAME 'printerIPPS3D'
603           DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
604           AUXILIARY
605           SUP top
606           MAY ( printer-ipp-versions-supported $
607                printer-ipp-features-supported $
608                printer-multiple-document-jobs-supported )
609         )
610
```

## 611 **6. Protocol Binding**

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

### 615 **6.1 Transport and Resource Path**

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

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

### 623 **6.2 HTTP Features**

624 In addition to the IPP over HTTP conformance requirements defined in section 7.3 of IPP  
625 2.0, 2.1, and 2.2 [PWG5100.12], Printers MUST support the following additional HTTP  
626 headers and status codes defined in Hypertext Transfer Protocol -- HTTP/1.1 [RFC7230].

#### 627 **6.2.1 Host**

628 Printers MUST validate the Host request header and SHOULD use the Host value in  
629 generated URIs.

#### 630 **6.2.2 If-Modified-Since, Last-Modified, and 304 Not Modified**

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

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

#### 637 **6.2.3 Cache-Control**

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



### 643 **6.3 IPP Operations**

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

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

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

### 648 **6.4 IPP Operation Attributes**

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

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

<b>Attribute</b>	<b>Reference</b>
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

### 651 **6.5 IPP Printer Description Attributes**

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

653

**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

---

- 654 Note 1: URIs SHOULD use Host value from HTTP header (section 6.2.1) and MUST NOT  
655 use link-local addresses (section 8.4 of [PWG5100.14]).
- 656 Note 2: REQUIRED for Printers that use filament-based materials.
- 657 Note 3: REQUIRED for Printers that control the material temperature during printing.
- 658 Note 4: REQUIRED for Printers that have a temperature-controlled Build Platform.  
659

660 **6.6 IPP Printer Status Attributes**

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

662 **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

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

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

666

## 667 **6.7 IPP Job Template Attributes**

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

669 **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

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

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

## 672 **6.8 IPP Job Description Attributes**

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

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

Attribute	Source
job-name	RFC 8011

## 675 **6.9 IPP Job Status Attributes**

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

677 **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 8.2.3
multiple-object-handling-actual (note 1)	Section 8.2.4
platform-temperature-actual (note 2)	Section 8.2.6
print-accuracy-actual	Section 8.2.7
print-base-actual	Section 8.2.8
print-objects-actual (note 1)	Section 8.2.9
print-supports-actual	Section 8.2.10
time-at-completed	RFC 8011
time-at-creation	RFC 8011
time-at-processing	RFC 8011

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

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

### 680 **6.9.1 job-id (integer)**

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

### 686 **6.9.2 job-uri (uri)**

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

## 693 **7. Document Formats**

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

699 **8. New Attributes**700 **8.1 Job Template Attributes**

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

703 **Table 10 - IPP 3D Job Template Attributes**

<b>Job Template</b>	<b>Printer: Default</b>	<b>Printer: Supported</b>
chamber-humidity (integer   no-value)	chamber-humidity-default (integer   no-value)	chamber-humidity-supported (boolean)
chamber-temperature (integer   no-value)	chamber-temperature-default (integer   no-value)	chamber-temperature-supported (1setOf (integer   rangeOfInteger)   no-value)
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)

704 **8.1.1 chamber-humidity (integer(0:100) | no-value)**

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

707 **8.1.2 chamber-temperature (integer(-273:MAX) | no-value)**

708 This Job Template attribute specifies the desired temperature of the build chamber in  
709 degrees Celsius. Printers that support a temperature-controlled build chamber SHOULD  
710 support this attribute.

711 **8.1.3 materials-col (1setOf collection)**

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

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

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

725 **Table 11 - "materials-col" Member Attributes**

<b>Member Attribute</b>	<b>Printer: Supported Values</b>
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



**726 8.1.3.1 material-amount (integer(0:MAX) | unknown)**

727 This RECOMMENDED member attribute provides the estimated amount of material that is  
728 available ("materials-col-database" and "materials-col-ready" values), the estimated amount  
729 of material that is required ("materials-col" values), or the actual amount of material that has  
730 been used ("materials-col-actual" values).

**731 8.1.3.2 material-amount-units (type2 keyword)**

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

734 'g': Value is mass in grams.

735 'kg': Value is mass in kilograms.

736 'l': Value is volume in liters.

737 'm': Value is length in meters.

738 'ml': Value is volume in milliliters.

739 'mm': Value is length in millimeters.

**740 8.1.3.3 material-color (type2 keyword)**

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

**743 8.1.3.4 material-diameter (integer(0:MAX))**

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

**747 8.1.3.5 material-diameter-tolerance (integer(0:MAX))**

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

**750 8.1.3.6 material-fill-density (integer(0:100))**

751 This REQUIRED member attribute specifies the desired density of filled interior regions in  
752 percent.

**753 8.1.3.7 material-key (keyword)**

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

**756 8.1.3.8 material-name (name(MAX))**

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

**758 8.1.3.9 material-nozzle-diameter (integer(0:MAX))**

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

**762 8.1.3.10 material-purpose (1setOf type2 keyword)**

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

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

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

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

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

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

**771 8.1.3.11 material-rate (integer(1:MAX))**

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

**774 8.1.3.12 material-rate-units (type2 keyword)**

775 This member attribute provides the units for the "material-rate" member attribute. Values  
776 include:

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

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

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

**780 8.1.3.13 material-retraction (boolean)**

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

**783 8.1.3.14 material-shell-thickness (integer(0:MAX))**

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

**786 8.1.3.15 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))**

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

**790 8.1.3.16 material-type (type2 keyword | name(MAX))**

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

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

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

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

799 'chocolate': Chocolate.

800 'gold': Gold (metal).

801 'nylon': Nylon.

802 'pet': Polyethylene terephthalate (PET).

803 'photopolymer': Photopolymer (liquid) resin.

804 'pla': Polylactic Acid (PLA).

805 'pla-conductive': Conductive PLA.

806 'pla-dissolvable': Dissolvable PLA.

807 'pla-flexible': Flexible PLA.

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

809 'pla-steel': PLA with embedded steel particles.

810 'pla-stone': PLA with embedded stone chips.

811 'pla-wood': PLA with embedded wood fibers.

812 'polycarbonate': Polycarbonate.

813 'silver': Silver (metal).

814 'titanium': Titanium (metal).

815 'wax': Wax.

816 Keyword values for materials that are defined by other standards organizations use a format  
817 consisting of the organization abbreviation, the standard number, a hyphen ("-"), and the  
818 material identifier. In order to conform to the syntax for keyword values (section 5.1.4 of  
819 [STD92]), all letters are converted to lowercase (with any diacritical marks removed), ASCII  
820 digits, hyphens ("-"), underscores ("\_") and periods (".") are preserved, spaces are replaced  
821 with the hyphen ("-"), and slashes ("/") are replaced with the underscore ("\_"). Any other  
822 characters are removed. For example, "7050 Aluminum" as defined in ASTM B247M would  
823 have a keyword value of 'astmb247m-a97050'.

#### 824 **8.1.4 multiple-object-handling (type2 keyword)**

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

829 'auto': Automatically determine the best way to print multiple objects in a Job.

830 'best-fit': Fit as many objects as possible within the build volume.

831 'best-quality': Optimize the number of objects for print quality.

832 'best-speed': Optimize the number of objects for print speed.

833 'one-at-a-time': Print one object at a time.

#### 834 **8.1.5 platform-temperature (integer(-273:MAX))**

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

**838 8.1.6 print-accuracy (collection)**

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

841 When enforcing attribute fidelity ("ipp-attribute-fidelity" with a value of 'true'), Printers only  
842 reject "print-accuracy" values that are smaller than the "print-accuracy-supported" (section  
843 8.3.27) value.

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

<b>Member Attribute</b>	<b>Printer: Supported Values</b>
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

**845 8.1.6.1 accuracy-units (type2 keyword)**

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

848 'mm': Accuracy numbers are in millimeters.

849 'um': Accuracy numbers are in micrometers.

850 'nm': Accuracy numbers are in nanometers.

**851 8.1.6.2 x-accuracy (integer(0:MAX))**

852 This REQUIRED member attribute specifies the X axis accuracy in the units specified by the  
853 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than  
854 1 unit.

**855 8.1.6.3 y-accuracy (integer(0:MAX))**

856 This REQUIRED member attribute specifies the Y axis accuracy in the units specified by the  
857 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than  
858 1 unit.

**859 8.1.6.4 z-accuracy (integer(0:MAX))**

860 This REQUIRED member attribute specifies the Z axis accuracy in the units specified by the  
861 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than  
862 1 unit.

863 **8.1.7 print-base (type2 keyword)**

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

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

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

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

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

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

872 **8.1.8 print-objects (1setOf collection)**

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

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

878 **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

879

880 **8.1.8.1 document-number (integer(1:MAX))**

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

883 **8.1.8.2 object-offset (collection)**

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

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

### 888 **8.1.8.3 object-size (collection)**

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

### 892 **8.1.8.4 object-uuid (uri)**

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

### 895 **8.1.9 print-supports (type2 keyword)**

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

898       'none': Do not print supports.

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

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

901

## 902 8.2 Job Status Attributes

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

905 **Table 14 - IPP 3D "-actual" Job Status Attributes**

<b>Job Status Attribute</b>	<b>Conformance</b>
chamber-humidity-actual (1setOf integer(0:100))	RECOMMENDED
chamber-temperature-actual (1setOf integer(-273:MAX))	RECOMMENDED
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

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

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

### 908 8.2.1 chamber-humidity-actual (1setOf integer(0:100))

909 This Job Status attribute contains the chamber relative humidity value(s) that were used  
910 throughout the processing of the Job. Printers that support humidity control SHOULD  
911 support this attribute.

### 912 8.2.2 chamber-temperature-actual (1setOf integer(-273:MAX))

913 This Job Status attribute contains the chamber temperature(s) in degrees Celsius that were  
914 used throughout the processing of the Job. Printers that support a temperature-controlled  
915 build chamber SHOULD support this attribute.

### 916 8.2.3 materials-col-actual (1setOf collection)

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

### 919 8.2.4 multiple-object-handling-actual (type2 keyword)

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



923 **8.2.5 print-accuracy-actual (collection)**

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

925 **8.2.6 platform-temperature-actual (1setOf integer(-273:MAX))**

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

929 **8.2.7 print-accuracy-actual (1setOf collection)**

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

932 **8.2.8 print-base-actual (1setOf type2 keyword)**

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

935 **8.2.9 print-objects-actual (1setOf collection)**

936 This CONDITIONALLY REQUIRED Job Status attribute lists the objects that were  
937 processed. Printers that support the 'application/pdf' document format MUST support this  
938 attribute.

939 **8.2.10 print-supports-actual (1setOf type2 keyword)**

940 This REQUIRED Job Status attribute specifies whether supports were printed during the  
941 processing of the Job.

942 **8.3 Printer Description Attributes**

943 **8.3.1 accuracy-units-supported (1setOf type2 keyword)**

944 This REQUIRED Printer Description attribute specifies the supported "accuracy-units"  
945 member attribute values.

946 **8.3.2 chamber-humidity-default (integer(0:100) | no-value)**

947 This Printer Description attribute specifies the default relative humidity of the build chamber  
948 as a percentage. Printers that support the "chamber-humidity" Job Template attribute  
949 (section 8.1.1) MUST support this attribute.

**950 8.3.3 chamber-humidity-supported (boolean)**

951 This Printer Description attribute specifies whether the "chamber-humidity" Job Template  
952 attribute (section 8.1.1) is supported. Printers that support the "chamber-humidity" Job  
953 Template attribute MUST support this attribute.

**954 8.3.4 chamber-temperature-default (integer(-273:MAX) | no-value)**

955 This Printer Description attribute contains the default temperature of the build chamber in  
956 degrees Celsius, if configured. Printers that support the "chamber-temperature" Job  
957 Template attribute (section 8.1.2) MUST support this attribute.

**958 8.3.5 chamber-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-  
959 273:MAX)))**

960 This Printer Description attribute lists the supported temperatures (or ranges of  
961 temperatures) of the build chamber in degrees Celsius. Printers that support the "chamber-  
962 temperature" Job Template attribute (section 8.1.2) MUST support this attribute.

**963 8.3.6 material-amount-units-supported (1setOf type2 keyword)**

964 This Printer Description attribute lists the supported "material-amount-units" values for the  
965 Printer. This attribute MUST be supported if the "material-amount-units" member attribute  
966 (Section 8.1.3.2) is supported.

**967 8.3.7 material-diameter-supported (1setOf (integer | rangeOfInteger))**

968 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
969 "material-diameter" values for the Printer. This attribute MUST be supported if the "material-  
970 diameter" member attribute (Section 8.1.3.4) is supported.

**971 8.3.8 material-nozzle-diameter-supported (1setOf (integer | rangeOfInteger))**

972 This Printer Description attribute lists the supported "material-nozzle-diameter" values for  
973 the Printer. This attribute MUST be supported if the "material-nozzle-diameter" member  
974 attribute (Section 8.1.3.9) is supported.

**975 8.3.9 material-purpose-supported (1setOf type2 keyword)**

976 This REQUIRED Printer Description attribute lists the supported "material-purpose" values  
977 for the Printer.

**978 8.3.10 material-rate-supported (1setOf (integer | rangeOfInteger))**

979 This Printer Description attribute lists the supported "material-rate" values for the Printer.  
980 This attribute MUST be supported if the "material-rate" member attribute (Section 8.1.3.11)  
981 is supported.

**982 8.3.11 material-rate-units-supported (1setOf type2 keyword)**

983 This Printer Description attribute lists the supported "material-rate-units" values for the  
984 Printer. This attribute MUST be supported if the "material-rate-units" member attribute  
985 (Section 8.1.3.12) is supported.

**986 8.3.12 material-shell-thickness-supported (1setOf (integer(1:MAX) |  
987 rangeOfInteger(1:MAX)))**

988 This REQUIRED Printer Description attribute specifies the supported "material-shell-  
989 thickness" values (or ranges of values) in nanometers.

**990 8.3.13 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-  
991 273:MAX)))**

992 This CONDITIONALLY REQUIRED Printer Description attribute specifies the supported  
993 "material-temperature" values (or ranges of values) in degrees Celsius. This attribute MUST  
994 be supported if the "material-temperature" member attribute (Section 8.1.3.15) is supported.

**995 8.3.14 material-type-supported (1setOf type2 keyword)**

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

**998 8.3.15 materials-col-database (1setOf collection)**

999 This RECOMMENDED Printer Description attribute lists the pre-configured materials for the  
1000 Printer. Each value contains the corresponding "materials-col" member attributes and will  
1001 typically reflect vendor and site ("third party") materials that are supported by the Printer.

1002 In order to optimize the total size of this attribute, Printers MAY omit member attributes that  
1003 allow the full range of supported values in a particular collection. For example, a Printer that  
1004 supports generic PLA filament can report a single collection value:

```
1005     materials-col-database =  
1006     { material-name="Generic PLA Filament" material-key="generic-pla"  
1007     material-diameter=285 material-temperature=215-235 }
```

1008 Such "wildcard" values can be combined with more precise collections that identify a specific  
1009 product, for example:

```
1010     materials-col-database =  
1011     { material-name="Generic PLA Filament" material-key="generic-pla"  
1012     material-diameter=285 material-temperature=215-235 },  
1013     { material-name="Example Corp Flexible Midnight Blue PLA" material-  
1014     key="com.example.flexible-midnight-blue" material-  
1015     color="com.example.midnight-blue_000027" material-diameter=285 material-  
1016     temperature=210-225 }
```

**1017 8.3.16 materials-col-default (1setOf collection)**

1018 This REQUIRED Printer Description attribute lists the default materials that will be used if  
1019 the "materials-col" Job Template attribute (Section 8.1.1) is not specified.

**1020 8.3.17 materials-col-ready (1setOf collection)**

1021 This REQUIRED Printer Description attribute lists the materials that have been loaded into  
1022 the Printer. Each value contains the corresponding "materials-col" member attributes.

**1023 8.3.18 materials-col-supported (1setOf type2 keyword)**

1024 This REQUIRED Printer Description attribute lists the "materials-col" member attributes that  
1025 are supported by the Printer. Printers MUST include the following values: 'material-fill-  
1026 density', 'material-key', 'material-name', 'material-purpose', 'material-shell-thickness', and  
1027 'material-type'.

**1028 8.3.19 max-materials-col-supported (integer(1:MAX))**

1029 This REQUIRED Printer Description attribute specifies the maximum number of values that  
1030 can be provided with the "materials-col" Job Template attribute (section 8.1.1).

**1031 8.3.20 multiple-object-handling-default (type2 keyword)**

1032 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
1033 "multiple-object-handling" value. Printers that support the 'application/pdf' Document format  
1034 MUST support this attribute.

**1035 8.3.21 multiple-object-handling-supported (1setOf type2 keyword)**

1036 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
1037 "multiple-object-handling" values. Printers that support the 'application/pdf' Document format  
1038 MUST support this attribute.

**1039 8.3.22 pdf-features-supported (1setOf type2 keyword)**

1040 This CONDITIONALLY REQUIRED Printer Description attribute lists the PDF features that  
1041 are supported by the Printer. Printers that support the 'application/pdf' Document format  
1042 MUST support this attribute.

1043 Values include:

1044 'prc': The Printer supports 3D objects in the Product Representation Compact (PRC)  
1045 format [ISO14739-1].

1046 'u3d': The Printer supports 3D objects in the Universal 3D (U3D) format [ECMA363].

1047 **8.3.23 platform-shape (type2 keyword)**

1048 This RECOMMENDED Printer Description attribute describes the overall shape of the build  
1049 platform. Values include:

1050 'ellipse': The build platform is elliptical, forming a cylindrical build volume.

1051 'rectangle': The build platform is rectangular, forming a cubic build volume.

1052 **8.3.24 platform-temperature-default (integer(-273:MAX))**

1053 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
1054 "platform-temperature" value. Printers that control the temperature of the Build Platform  
1055 MUST support this attribute.

1056 **8.3.25 platform-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-  
1057 273:MAX)))**

1058 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
1059 "platform-temperature" values and/or ranges. Printers that control the temperature of the  
1060 Build Platform MUST support this attribute.

1061 **8.3.26 print-accuracy-default (collection)**

1062 This REQUIRED Printer Description attribute specifies the default "print-accuracy" value.

1063 **8.3.27 print-accuracy-supported (collection)**

1064 This REQUIRED Printer Description attribute specifies the best "print-accuracy" value that  
1065 is supported by the Printer.

1066 **8.3.28 print-base-default (type2 keyword)**

1067 This REQUIRED Printer Description attribute specifies the default "print-base" value.

1068 **8.3.29 print-base-supported (1setOf type2 keyword)**

1069 This REQUIRED Printer Description attribute lists the supported "print-base" values.

1070 **8.3.30 print-objects-supported (1setOf type2 keyword)**

1071 This CONDITIONALLY REQUIRED Printer Description attribute specifies which "print-  
1072 objects" member attributes are supported. Printers that support the 'application/pdf'  
1073 Document format MUST support this attribute.

1074 **8.3.31 print-supports-default (type2 keyword)**

1075 This REQUIRED Printer Description attribute specifies the default "print-supports" value.

1076 **8.3.32 print-supports-supported (1setOf type2 keyword)**

1077 This REQUIRED Printer Description attribute lists the supported "print-supports" values.

1078 **8.3.33 printer-volume-supported (collection)**

1079 This REQUIRED Printer Description attribute specifies the maximum build volume supported  
1080 by the Printer. Table 15 lists the REQUIRED member attributes.

1081 **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))

1082 **8.3.33.1 x-dimension (integer(1:MAX))**

1083 This member attributes specifies the width of the build volume in hundredths of millimeters  
1084 (1/2540th of an inch).

1085 **8.3.33.2 y-dimension (integer(1:MAX))**

1086 This member attributes specifies the depth of the build volume in hundredths of millimeters  
1087 (1/2540th of an inch).

1088 **8.3.33.3 z-dimension (integer(1:MAX))**

1089 This member attributes specifies the height of the build volume in hundredths of millimeters  
1090 (1/2540th of an inch).

1091 **8.4 Printer Status Attributes**

1092 **8.4.1 chamber-humidity-current (integer(0:100) | unknown)**

1093 This Printer Status attribute reports the current relative humidity of the build chamber as a  
1094 percentage. Printers that support the "chamber-humidity" Job Template attribute (section  
1095 8.1.1) MUST support this attribute.

1096 **8.4.2 chamber-temperature-current (integer(-273:MAX) | unknown)**

1097 This Printer Status attribute reports the current temperature of the build chamber in degrees  
1098 Celsius, if known. Printers that support the "chamber-temperature" Job Template attribute  
1099 (section 8.1.2) MUST support this attribute.

### 1100 **8.4.3 printer-camera-image-uri (1setOf uri)**

1101 This Printer Status attribute lists the URIs for one or more resident camera snapshots. Each  
1102 URI corresponds to a separate resident camera. The images referenced by each URI can  
1103 change at any time so it is up to the Client to periodically poll for changes and for the Printer  
1104 to atomically update the images so that Clients can safely do so. The referenced images  
1105 MUST be PNG [RFC2083] or JPEG [JFIF] format.

## 1106 **9. New Values for Existing Attributes**

### 1107 **9.1 ipp-features-supported (1setOf type2 keyword)**

1108 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-  
1109 supported" Printer Description attribute.

### 1110 **9.2 printer-state-reasons (1setOf type2 keyword)**

1111 This specification registers the following new values for the "printer-state-reasons" Printer  
1112 Status attribute:

1113 'camera-failure': A camera is no longer working.

1114 'chamber-cooling': A chamber is being cooled.

1115 'chamber-failure': A chamber has failed and requires maintenance or replacement.

1116 'chamber-heating': A chamber is being heated.

1117 'chamber-temperature-high': The temperature of a chamber is high.

1118 'chamber-temperature-low': The temperature of a chamber is low.

1119 'extruder-cooling': An extruder is being cooled.

1120 'extruder-failure': An extruder has failed and requires maintenance or replacement.

1121 'extruder-heating': An extruder is being heated.

1122 'extruder-jam': An extruder is jammed or clogged.

1123 'extruder-temperature-high': The temperature of an extruder is too high.

1124 'extruder-temperature-low': The temperature of an extruder is too low.

1125 'fan-failure': A fan has failed.

- 1126 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.
- 1127 'lamp-failure': A lamp has failed.
- 1128 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.
- 1129 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.
- 1130 'laser-failure': A laser has failed.
- 1131 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.
- 1132 'material-empty': One or more build materials have been exhausted.
- 1133 'material-low': One or more build materials may need replenishment soon.
- 1134 'material-needed': One or more build materials need to be loaded for a processing Job.
- 1135 'motor-failure': A motor has failed.
- 1136 'platform-cooling': A Build Platform is being cooled.
- 1137 'platform-failure': A Build Platform has failed and requires maintenance or  
1138 replacement.
- 1139 'platform-heating': A Build Platform is being heated.
- 1140 'platform-temperature-high': The temperature of a Build Platform is too high.
- 1141 'platform-temperature-low': The temperature of a Build Platform is too low.
- 1142



## 1143 **10. Conformance Requirements**

### 1144 **10.1 Printer Conformance Requirements**

1145 In order for a Printer to claim conformance to this specification, a Printer MUST support:

- 1146 1. The required discovery protocols in section 5;
- 1147 2. The required transports and resource paths in section 6.1;
- 1148 3. The required HTTP features in section 6.2;
- 1149 4. The required IPP operations in section 6.3;
- 1150 5. The required IPP attributes in sections 6.4 through 6.9;
- 1151 6. The required document formats in section 7;
- 1152 7. The additional values defined in section 9;
- 1153 8. The internationalization considerations in section 11; and
- 1154 9. The security considerations in section 12.

### 1155 **10.2 Client Conformance Requirements**

1156 In order for a Client to claim conformance to this specification, a Client MUST support:

- 1157 1. The required discovery protocols in section 5;
- 1158 2. The required transports and resource paths in section 6.1;
- 1159 3. The required HTTP features in section 6.2;
- 1160 4. The required IPP operations in section 6.3;
- 1161 5. The required IPP attributes in sections 6.4 through 6.9;
- 1162 6. The required document formats in section 7;
- 1163 7. The additional values defined in section 9;
- 1164 8. The internationalization considerations in section 11; and
- 1165 9. The security considerations in section 12.

1166

## 1167 **11. Internationalization Considerations**

1168 For interoperability and basic support for multiple languages, conforming implementations  
1169 MUST support:

- 1170 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8) [STD63]  
1171 encoding of Unicode [UNICODE] [ISO10646]; and
- 1172 2. The Unicode Format for Network Interchange [RFC5198] which requires  
1173 transmission of well-formed UTF-8 strings and recommends transmission of  
1174 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1175 Unicode NFC is defined as the result of performing Canonical Decomposition (into base  
1176 characters and combining marks) followed by Canonical Composition (into canonical  
1177 composed characters wherever Unicode has assigned them).

1178 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and  
1179 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in IPP  
1180 Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8 URIs  
1181 now 'hidden').

1182 Implementations of this specification SHOULD conform to the following standards on  
1183 processing of human-readable Unicode text strings, see:

1184 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical

1185 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping

1186 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]

1187 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences

1188 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization

1189 Unicode Character Encoding Model [UTR17] – multi-layer character model

1190 Unicode Character Property Model [UTR23] – character properties

1191 Unicode Conformance Model [UTR33] – Unicode conformance basis+

1192 Unicode Collation Algorithm [UTS10] – sorting

1193 Unicode Locale Data Markup Language [UTS35] – locale databases

## 1194 **12. Security Considerations**

1195 In addition to the security considerations described in the IPP/1.1: Model and Semantics  
1196 [STD92], the following sub-sections describe issues that are unique to 3D printing.

1197 Implementations of this specification SHOULD conform to the following standards on  
1198 processing of human-readable Unicode text strings, see:

1199           Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1200           Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

## 1201 **12.1 Confidentiality**

1202 Clients and Printers MUST provide confidentiality of data in transit using either an interface  
1203 providing physical security such as USB or using TLS encryption [RFC5246] over  
1204 unsecured/network connections,

## 1205 **12.2 Access Control**

1206 Because of the potential for abuse and misuse, Printers SHOULD provide access control  
1207 mechanisms including lists of allowed Clients, authentication, and authorization to site  
1208 defined policies.

## 1209 **12.3 Physical Safety**

1210 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such  
1211 as protective gates, covers, or interlocks.

## 1212 **12.4 Material Safety**

1213 Printers MUST restrict usage and combination of materials to those that can be safely  
1214 printed. Access controls (section 12.2) MAY be used to allow authorized End Users to  
1215 experiment with untested materials or combinations, but only when such materials or  
1216 combinations can reasonably be expected to not pose a safety risk.

## 1217 **12.5 Temperature Control**

1218 Printers MUST validate values provided by Clients and limit material, extruder, Build  
1219 Platform, and print chamber temperatures within designed limits to prevent unsafe operating  
1220 conditions, damage to the hardware, hazardous emissions, explosions, and/or fires.

1221

## 1222 13. IANA and PWG Considerations

### 1223 13.1 Attribute Registrations

1224 The attributes defined in this specification will be published by IANA according to the  
1225 procedures in IPP/1.1 Model and Semantics [STD92] section 7.2 in the following file:

1226 <http://www.iana.org/assignments/ipp-registrations>

1227 The registry entries will contain the following information:

1228 Document Status attributes:	Reference
-----	-----
1230 chamber-humidity-actual (1setOf integer(0:100))	[PWG5100.21]
1231 chamber-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1232 materials-col-actual (1setOf collection)	[PWG5100.21]
1233 < member attributes are the same as materials-col >	[PWG5100.21]
1234 multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1235 platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1236 print-accuracy-actual (collection)	[PWG5100.21]
1237 < member attributes are the same as print-accuracy >	[PWG5100.21]
1238 print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1239 print-objects-actual (1setOf collection)	[PWG5100.21]
1240 < member attributes are the same as print-objects >	[PWG5100.21]
1241 print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1242	
1243 Document Template attributes:	Reference
-----	-----
1245 chamber-humidity (integer(0:100))	[PWG5100.21]
1246 chamber-temperature (integer(-273:MAX))	[PWG5100.21]
1247 materials-col (1setOf collection)	[PWG5100.21]
1248 material-amount (integer(0:MAX))	[PWG5100.21]
1249 material-amount-units (type2 keyword)	[PWG5100.21]
1250 material-color (type2 keyword)	[PWG5100.21]
1251 material-diameter (integer(0:MAX))	[PWG5100.21]
1252 material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1253 material-fill-density (integer(0:100))	[PWG5100.21]
1254 material-key (keyword)	[PWG5100.21]
1255 material-name (name(MAX))	[PWG5100.21]
1256 material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
1257 material-purpose (1setOf type2 keyword)	[PWG5100.21]
1258 material-rate (integer(1:MAX))	[PWG5100.21]
1259 material-rate-units (type2 keyword)	[PWG5100.21]
1260 material-retraction (boolean)	[PWG5100.21]
1261 material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1262 material-temperature (integer(-273:MAX)   rangeOfInteger(-273:MAX))	[PWG5100.21]
1263	
1264 material-type (type2 keyword   name(MAX))	[PWG5100.21]
1265 multiple-object-handling (type2 keyword)	[PWG5100.21]
1266 platform-temperature (integer(-273:MAX))	[PWG5100.21]
1267 print-accuracy (collection)	[PWG5100.21]
1268 accuracy-units (type2 keyword)	[PWG5100.21]
1269 x-accuracy (integer(0:MAX))	[PWG5100.21]

1270	y-accuracy (integer(0:MAX))	[PWG5100.21]
1271	z-accuracy (integer(0:MAX))	[PWG5100.21]
1272	print-base (type2 keyword)	[PWG5100.21]
1273	print-objects (1setOf collection)	[PWG5100.21]
1274	document-number (integer(1:MAX))	[PWG5100.21]
1275	object-offset (collection)	[PWG5100.21]
1276	x-offset (integer(0:MAX))	[PWG5100.21]
1277	y-offset (integer(0:MAX))	[PWG5100.21]
1278	z-offset (integer(0:MAX))	[PWG5100.21]
1279	object-size (collection)	[PWG5100.21]
1280	x-dimension (integer(1:MAX))	[PWG5100.21]
1281	y-dimension (integer(1:MAX))	[PWG5100.21]
1282	z-dimension (integer(1:MAX))	[PWG5100.21]
1283	object-uuid (uri)	[PWG5100.21]
1284	print-supports (type2 keyword)	[PWG5100.21]
1285		
1286	Job Status attributes:	Reference
1287	-----	-----
1288	chamber-humidity-actual (1setOf integer(0:100))	[PWG5100.21]
1289	chamber-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1290	materials-col-actual (1setOf collection)	[PWG5100.21]
1291	< member attributes are the same as materials-col >	[PWG5100.21]
1292	multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1293	platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1294	print-accuracy-actual (collection)	[PWG5100.21]
1295	< member attributes are the same as print-accuracy >	[PWG5100.21]
1296	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1297	print-objects-actual (1setOf collection)	[PWG5100.21]
1298	< member attributes are the same as print-objects >	[PWG5100.21]
1299	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1300		
1301	Job Template attributes:	Reference
1302	-----	-----
1303	chamber-humidity (integer(0:100))	[PWG5100.21]
1304	chamber-temperature (integer(-273:MAX))	[PWG5100.21]
1305	materials-col (1setOf collection)	[PWG5100.21]
1306	material-amount (integer(0:MAX))	[PWG5100.21]
1307	material-amount-units (type2 keyword)	[PWG5100.21]
1308	material-color (type2 keyword)	[PWG5100.21]
1309	material-diameter (integer(0:MAX))	[PWG5100.21]
1310	material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1311	material-fill-density (integer(0:100))	[PWG5100.21]
1312	material-key (keyword)	[PWG5100.21]
1313	material-name (name(MAX))	[PWG5100.21]
1314	material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
1315	material-purpose (1setOf type2 keyword)	[PWG5100.21]
1316	material-rate (integer(1:MAX))	[PWG5100.21]
1317	material-rate-units (type2 keyword)	[PWG5100.21]
1318	material-retraction (boolean)	[PWG5100.21]
1319	material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1320	material-temperature (integer(-273:MAX)   rangeOfInteger(-273:MAX))	[PWG5100.21]
1321		
1322	material-type (type2 keyword   name(MAX))	[PWG5100.21]
1323	multiple-object-handling (type2 keyword)	[PWG5100.21]
1324	platform-temperature (integer(-273:MAX))	[PWG5100.21]
1325	print-accuracy (collection)	[PWG5100.21]

1326	accuracy-units (type2 keyword)	[PWG5100.21]
1327	x-accuracy (integer(0:MAX))	[PWG5100.21]
1328	y-accuracy (integer(0:MAX))	[PWG5100.21]
1329	z-accuracy (integer(0:MAX))	[PWG5100.21]
1330	print-base (type2 keyword)	[PWG5100.21]
1331	print-objects (1setOf collection)	[PWG5100.21]
1332	document-number (integer(1:MAX))	[PWG5100.21]
1333	object-offset (collection)	[PWG5100.21]
1334	x-offset (integer(0:MAX))	[PWG5100.21]
1335	y-offset (integer(0:MAX))	[PWG5100.21]
1336	z-offset (integer(0:MAX))	[PWG5100.21]
1337	object-size (collection)	[PWG5100.21]
1338	x-dimension (integer(1:MAX))	[PWG5100.21]
1339	y-dimension (integer(1:MAX))	[PWG5100.21]
1340	z-dimension (integer(1:MAX))	[PWG5100.21]
1341	object-uuid (uri)	[PWG5100.21]
1342	print-supports (type2 keyword)	[PWG5100.21]
1343		
1344	Printer Description attributes:	Reference
1345	-----	-----
1346	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.21]
1347	chamber-humidity-default (integer(0:100)   no-value)	[PWG5100.21]
1348	chamber-humidity-supported (boolean)	[PWG5100.21]
1349	chamber-temperature-default (integer(-273:MAX)   no-value)	[PWG5100.21]
1350		
1351	chamber-temperature-supported (1setOf (integer(-273:MAX)	
1352	rangeOfInteger(-273:MAX))	[PWG5100.21]
1353	material-amount-units-supported (1setOf type2 keyword)	[PWG5100.21]
1354	material-diameter-supported (1setOf (integer(0:MAX)	
1355	rangeOfInteger(0:MAX)))	[PWG5100.21]
1356	material-nozzle-diameter-supported (1setOf (integer(0:MAX)	
1357	rangeOfInteger(0:MAX)))	[PWG5100.21]
1358	material-purpose-supported (1setOf type2 keyword)	[PWG5100.21]
1359	material-rate-supported (1setOf (integer(1:MAX)   rangeOfInteger(1:MAX)))	[PWG5100.21]
1360		
1361	material-rate-units-supported (1setOf type2 keyword)	[PWG5100.21]
1362	material-shell-thickness-supported (1setOf (integer(0:MAX)	
1363	rangeOfInteger(0:MAX)))	[PWG5100.21]
1364	material-temperature-supported (1setOf (integer(-273:MAX)	
1365	rangeOfInteger(-273:MAX)))	[PWG5100.21]
1366	material-type-supported (1setOf type2 keyword)	[PWG5100.21]
1367	materials-col-database (1setOf collection)	[PWG5100.21]
1368	< member attributes are the same as materials-col >	[PWG5100.21]
1369	materials-col-default (1setOf collection)	[PWG5100.21]
1370	< member attributes are the same as materials-col >	[PWG5100.21]
1371	materials-col-ready (1setOf collection)	[PWG5100.21]
1372	< member attributes are the same as materials-col >	[PWG5100.21]
1373	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1374	max-materials-col-supported (integer(1:MAX))	[PWG5100.21]
1375	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1376	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1377	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1378	platform-shape (type2 keyword)	[PWG5100.21]
1379	platform-temperature-default (integer(-273:MAX))	[PWG5100.21]
1380	platform-temperature-supported (1setOf (integer(-273:MAX)	
1381	rangeOfInteger(-273:MAX)))	[PWG5100.21]

1382	print-accuracy-supported (collection)	[PWG5100.21]
1383	< member attributes are the same as print-accuracy >	[PWG5100.21]
1384	print-base-default (type2 keyword)	[PWG5100.21]
1385	print-base-supported (1setOf type2 keyword)	[PWG5100.21]
1386	print-objects-supported (1setOf type2 keyword)	[PWG5100.21]
1387	print-supports-default (type2 keyword)	[PWG5100.21]
1388	print-supports-supported (1setOf type2 keyword)	[PWG5100.21]
1389	printer-volume-supported (collection)	[PWG5100.21]
1390	x-dimension (integer(1:MAX))	[PWG5100.21]
1391	y-dimension (integer(1:MAX))	[PWG5100.21]
1392	z-dimension (integer(1:MAX))	[PWG5100.21]
1393		
1394	Printer Status attributes:	Reference
1395	-----	-----
1396	chamber-humidity-current (integer(0:100)   unknown)	[PWG5100.21]
1397	chamber-temperature-current (integer(-273:MAX)   unknown)	[PWG5100.21]
1398	printer-camera-image-uri (1setOf uri)	[PWG5100.21]

## 1399 13.2 Attribute Value Registrations

1400 The attributes defined in this specification will be published by IANA according to the  
1401 procedures in IPP/1.1 Model and Semantics [STD92] section 7.1 in the following file:

1402 <http://www.iana.org/assignments/ipp-registrations>

1403 The registry entries will contain the following information:

1404	Attributes (attribute syntax)	
1405	Keyword Attribute Value	Reference
1406	-----	-----
1407	accuracy-units (type2 keyword)	[PWG5100.21]
1408	mm	[PWG5100.21]
1409	nm	[PWG5100.21]
1410	um	[PWG5100.21]
1411	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.21]
1412	< any accuracy-units values >	[PWG5100.21]
1413	ipp-features-supported (1setOf type2 keyword)	[PWG5100.13]
1414	ipp-3d	[PWG5100.21]
1415	material-amount-units (type2 keyword)	[PWG5100.21]
1416	g	[PWG5100.21]
1417	kg	[PWG5100.21]
1418	l	[PWG5100.21]
1419	m	[PWG5100.21]
1420	ml	[PWG5100.21]
1421	mm	[PWG5100.21]
1422	material-color (type2 keyword)	[PWG5100.21]
1423	< any "media" color name >	[PWG5100.21]
1424	material-purpose (1setOf type2 keyword)	[PWG5100.21]
1425	all	[PWG5100.21]
1426	base	[PWG5100.21]
1427	in-fill	[PWG5100.21]
1428	shell	[PWG5100.21]
1429	support	[PWG5100.21]
1430	material-rate-units (type2 keyword)	[PWG5100.21]

1431	mg_second	[PWG5100.21]
1432	ml_second	[PWG5100.21]
1433	mm_second	[PWG5100.21]
1434	material-type (type2 keyword)	[PWG5100.21]
1435	abs	[PWG5100.21]
1436	abs-carbon-fiber	[PWG5100.21]
1437	abs-carbon-nanotube	[PWG5100.21]
1438	chocolate	[PWG5100.21]
1439	gold	[PWG5100.21]
1440	nylon	[PWG5100.21]
1441	pet	[PWG5100.21]
1442	photopolymer	[PWG5100.21]
1443	pla	[PWG5100.21]
1444	pla-conductive	[PWG5100.21]
1445	pla-dissolvable	[PWG5100.21]
1446	pla-flexible	[PWG5100.21]
1447	pla-magnetic	[PWG5100.21]
1448	pla-steel	[PWG5100.21]
1449	pla-stone	[PWG5100.21]
1450	pla-wood	[PWG5100.21]
1451	polycarbonate	[PWG5100.21]
1452	silver	[PWG5100.21]
1453	titanium	[PWG5100.21]
1454	wax	[PWG5100.21]
1455	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1456	< any materials-col member attribute name >	[PWG5100.21]
1457	multiple-object-handling (type2 keyword)	[PWG5100.21]
1458	auto	[PWG5100.21]
1459	best-fit	[PWG5100.21]
1460	best-quality	[PWG5100.21]
1461	best-speed	[PWG5100.21]
1462	one-at-a-time	[PWG5100.21]
1463	multiple-object-handling-actual (1setOf type2 keyword)	[PWG5100.21]
1464	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1465		[PWG5100.21]
1466	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1467	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1468		[PWG5100.21]
1469	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1470	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1471		[PWG5100.21]
1472	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1473	prc	[PWG5100.21]
1474	u3d	[PWG5100.21]
1475	platform-shape (type2 keyword)	[PWG5100.21]
1476	ellipse	[PWG5100.21]
1477	rectangle	[PWG5100.21]
1478	print-base (type2 keyword)	[PWG5100.21]
1479	brim	[PWG5100.21]
1480	none	[PWG5100.21]
1481	raft	[PWG5100.21]
1482	skirt	[PWG5100.21]
1483	standard	[PWG5100.21]
1484	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1485	< any print-base Job Template attribute value >	[PWG5100.21]
1486	print-base-default (type2 keyword)	[PWG5100.21]



1487	< any print-base Job Template attribute value >	[PWG5100.21]
1488	print-base-supported (1setOf type2 keyword)	[PWG5100.21]
1489	< any print-base Job Template attribute value >	[PWG5100.21]
1490	print-objects-supported (1setOf type2 keyword)	[PWG5100.21]
1491	< any print-objects member attribute name >	[PWG5100.21]
1492	print-supports (type2 keyword)	[PWG5100.21]
1493	material	[PWG5100.21]
1494	none	[PWG5100.21]
1495	standard	[PWG5100.21]
1496	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1497	< any print-supports Job Template attribute value >	[PWG5100.21]
1498	print-supports-default (type2 keyword)	[PWG5100.21]
1499	< any print-supports Job Template attribute value >	[PWG5100.21]
1500	print-supports-supported (1setOf type2 keyword)	[PWG5100.21]
1501	< any print-supports Job Template attribute value >	[PWG5100.21]
1502	printer-state-reasons (1setOf type2 keyword)	[RFC8011]
1503	camera-failure	[PWG5100.21]
1504	chamber-cooling	[PWG5100.21]
1505	chamber-failure	[PWG5100.21]
1506	chamber-heating	[PWG5100.21]
1507	chamber-temperature-high	[PWG5100.21]
1508	chamber-temperature-low	[PWG5100.21]
1509	extruder-cooling	[PWG5100.21]
1510	extruder-failure	[PWG5100.21]
1511	extruder-heating	[PWG5100.21]
1512	extruder-jam	[PWG5100.21]
1513	extruder-temperature-high	[PWG5100.21]
1514	extruder-temperature-low	[PWG5100.21]
1515	fan-failure	[PWG5100.21]
1516	lamp-at-eol	[PWG5100.21]
1517	lamp-failure	[PWG5100.21]
1518	lamp-near-eol	[PWG5100.21]
1519	laser-at-eol	[PWG5100.21]
1520	laser-failure	[PWG5100.21]
1521	laser-near-eol	[PWG5100.21]
1522	material-empty	[PWG5100.21]
1523	material-low	[PWG5100.21]
1524	material-needed	[PWG5100.21]
1525	motor-failure	[PWG5100.21]
1526	platform-cooling	[PWG5100.21]
1527	platform-failure	[PWG5100.21]
1528	platform-heating	[PWG5100.21]
1529	platform-temperature-high	[PWG5100.21]
1530	platform-temperature-low	[PWG5100.21]

### 1531 13.3 Service Type Registration

1532 The DNS-SD service type defined in this specification will be published by IANA according  
 1533 to the procedures in Internet Assigned Numbers Authority (IANA) Procedures for the  
 1534 Management of the Service Name and Transport Protocol Port Number Registry [BCP165].

1535 The registration template is as follows:

1536       Service Name: ipps-3d

1537  
1538 Transport Protocol(s): tcp  
1539  
1540 Assignee/Contact: Michael Sweet, msweet@apple.com  
1541  
1542 Description: 3D Print services (3D printers) using the Internet Printing  
1543 Protocol over HTTPS.  
1544  
1545 Reference: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf)  
1546 [5100.21.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf)  
1547  
1548 Port Number:  
1549  
1550 Service Code:  
1551  
1552 Known Unauthorized Uses:  
1553  
1554 Assignment Notes: Change controller is The Printer Working Group, c/o The  
1555 IEEE Industry Standards and Technology Organization, 445 Hoes Lane,  
1556 Piscataway, NJ 08854, USA

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1702 Michael Scrutton, Adobe Systems  
1703 Emmet Lalish, Microsoft Corporation  
1704

## 1705 **16. Object Definition Languages (ODLs)**

1706 This section provides information on several commonly used ODLs with either existing  
1707 (registered) or suggested MIME media types.

### 1708 **16.1 3D Manufacturing Format (3MF)**

1709 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that  
1710 provides geometry, material, and texture information necessary to support a wide variety of  
1711 3D printers. Materials can be named and composed within the geometry, facilitating multiple  
1712 material support in coordination with a Job Ticket.

1713 The registered MIME media type for the original Microsoft published specification is  
1714 "application/vnd.ms-3mfdocument". The MIME media type for the 3MF Consortium's  
1715 published specification is "model/3mf".

### 1716 **16.2 Additive Manufacturing Format (AMF)**

1717 AMF [ISO52915] is a relatively new format that was designed as a replacement for the  
1718 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-  
1719 available specification, but has several advantages over STL including:

- 1720 1. Shared vertices which eliminates holes and other breaks in the surface geometry of  
1721 objects,
- 1722 2. Specification of multiple materials in a single file,
- 1723 3. Curved surfaces can be specified, and
- 1724 4. Coordinates use explicit units for proper output dimensions.

1725 The suggested (but not registered) MIME media type is 'model/amf'.

### 1726 **16.3 Portable Document Format (PDF)**

1727 PDF [ISO32000] is widely supported for 2D printing and has two 3D formats that are used  
1728 to embed 3D objects - PRC [ISO14739-1] and U3D [ECMA363]. The registered MIME media  
1729 type for PDF is "application/pdf".

1730 [For discussion: define a "model/pdf" MIME media type for PDFs containing 3D content?]

### 1731 **16.4 Standard Tessellation Language (STL)**

1732 STL [STLFORMAT] is widely supported by existing client software. The registered MIME  
1733 media type is 'application/sla'.  
1734

## 1735 **17. Design Choices**

1736 This section documents some of the design choices that were made during the development  
1737 of this specification.

### 1738 **17.1 Units for Length Values**

1739 The default unit for most length values is hundredths of millimeters (1/2540th of an inch),  
1740 matching the units for 2D printing and providing a range of 0.01mm to 21.47km. This was  
1741 determined to be sufficient for the class of printers this specification targets.

### 1742 **17.2 Units for Thickness Values**

1743 The default unit for most thickness values is nanometers, which provides a range of  
1744 0.000001mm to 2.147m. This was determined to be sufficient for the class of printers this  
1745 specification targets.

### 1746 **17.3 Use of Celsius for Temperatures**

1747 The various integer attributes for temperature use degrees Celsius. This was done because  
1748 most existing printers and materials are specified using degrees Celsius. There is no  
1749 advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to perform  
1750 additional unit conversions could cause safety issues. All temperature attributes use a range  
1751 of -273 (absolute zero) to MAX (2147483647 - significantly hotter than our sun) to allow  
1752 flexibility.

### 1753 **17.4 Explicit Units for Other Values**

1754 Some attributes have a companion "xxx-units" attribute that specifies an explicit unit for the  
1755 given measurement(s). The initial list of unit values for each attribute has been limited to  
1756 those necessary for current printers and technologies at the time of writing of this  
1757 specification in order to minimize interoperability issues.

### 1758 **17.5 Intent vs. Process**

1759 The IPP Model [RFC8011], and more generally the PWG Semantic Model [PWG5108.1],  
1760 have long focused on Job Tickets specifying "what" is wanted for the printed output vs. "how"  
1761 that output is produced. This focus has served IPP well and allowed it to be used with wildly  
1762 different printing technologies.

1763 During the development of this specification, attributes that define a specific process or  
1764 technological parameter have been introduced and later replaced by intent-based  
1765 alternatives that allow an implementation to select suitable process-based parameters at



1766 print time, preserving the intrinsic value of such parameters without burdening the Client or  
1767 End User with such things.

1768 At the same time, some process parameters are needed for things like material specification.  
1769 For example, a particular brand of PLA may require a higher melting temperature - this  
1770 information might only be known to the End User, so the "materials-col" collection contains  
1771 an member attribute to convey this process-specific parameter. The Printer advertises  
1772 whether temperature is a valid material property in the "materials-col-supported" Printer  
1773 Description attribute.

1774 Finally, IPP does not prohibit the definition or use of process-based Job Template attributes  
1775 for specific implementations. Such extension attributes can be listed in the "job-creation-  
1776 attributes-supported" Printer Description attribute to notify Clients of their existence.

## 1777 **17.6 Choosing a Required Document Format**

1778 One of the design consideration of this specification is to choose an open, freely available  
1779 file format for use as required document format. Having a required document format makes  
1780 interoperability significantly easier, and using an open and freely available format allows  
1781 developers of "consumer" printers to support IPP 3D. Several formats were considered,  
1782 including STL, AMF, PDF, and 3MF.

1783 While STL is a widely-implemented, open, and freely available file format, it lacks support  
1784 for multiple materials and colors/textures, and has technical issues that cause "holes" in  
1785 generated models.

1786 While AMF supports multiple materials and does not have the "holes" issue, it is not freely  
1787 available nor widely-implemented.

1788 PDF is the most capable 3D format but is not freely available and has the interoperability  
1789 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-  
1790 features-supported" Printer Description attribute (section 8.3.22) allows Clients to determine  
1791 whether a 3D PDF file can be printed by the Printer.

1792 3MF is open and freely available, supports multiple materials and color/textures, does not  
1793 have the "holes" issue of STL, and has a freely available open source implementation that  
1794 supports both creation and consumption of 3MF files.  
1795

## 1796 **18. Overview of Changes**

### 1797 **18.1 IPP 3D Printing Extensions v1.1**

1798 The following changes were made since v1.0 of this document:

- 1799 1. Made 3MF CONDITIONALLY REQUIRED for Printers that do Slicing, RECOMMEND  
1800 support for a standard layered format otherwise.
- 1801 2. Added the CONDITIONALLY REQUIRED "material-nozzle-diameter" and "material-  
1802 retraction" member attributes for the "materials-col" Job Template attribute.
- 1803 3. Added the RECOMMENDED "platform-shape" Printer Description attribute
- 1804 4. Added the CONDITIONALLY REQUIRED "chamber-humidity" and "chamber-  
1805 temperature" Job Template attributes.
- 1806 5. Defined a naming convention for standard "material-type" values.  
1807

## 1808 **19. Change History**

### 1809 **19.1 February 1, 2019**

- 1810 • Really change status to stable.
- 1811 • Removed dates from UTR references since we are not referring to an explicit version
- 1812 of those recommendations.

### 1813 **19.2 January 14, 2019**

- 1814 • Status: Stable
- 1815 • Section 14.1: Updated link for STD92, updated all Unicode links, use HTTPS
- 1816 whenever possible, dropped PWG Semantic Model links since we don't deal with that
- 1817 here.
- 1818 • Section 14.2: Updated all Unicode links, use HTTPS whenever possible, dropped
- 1819 UTR20 (XML).

### 1820 **19.3 July 4, 2018**

- 1821 • Status: Prototype
- 1822 • RFC 8011 is now STD 92.
- 1823 • Added missing chamber-humidity-actual and chamber-temperature-actual attributes.
- 1824 • Updated IANA registrations.

### 1825 **19.4 June 5, 2018**

- 1826 • Renamed "printer-volume-xxx" to "chamber-xxx".
- 1827 • Added "chamber-humidity" to Table 10.
- 1828 • All new attributes that were CONDITIONALLY REQUIRED are now RECOMMENDED.
- 1829 • Added definition of material-type keyword format for standard materials.
- 1830 • Update Unicode reference now that v11 has been published.

1831 **19.5 April 26, 2018**

1832 Initial revision.