



The Printer Working Group

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

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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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**¶**  
**About the Internet Printing Protocol Workgroup**  
The Internet Printing Protocol (IPP) workgroup has developed a modern, full-featured network printing protocol, which is now the industry standard. IPP allows a print client to query a printer for its supported capabilities, features, and parameters to allow the selection of an appropriate printer for each print job. IPP also provides job information prior to, during, and at the end of job processing.  
For additional information regarding IPP visit: <http://www.pwg.org/ipp/>  
Implementers of this specification are encouraged to join the IPP mailing list in order to participate in any discussions of the specification. Suggested additions, changes, or clarification to this specification, should be sent to the IPP mailing list for consideration.

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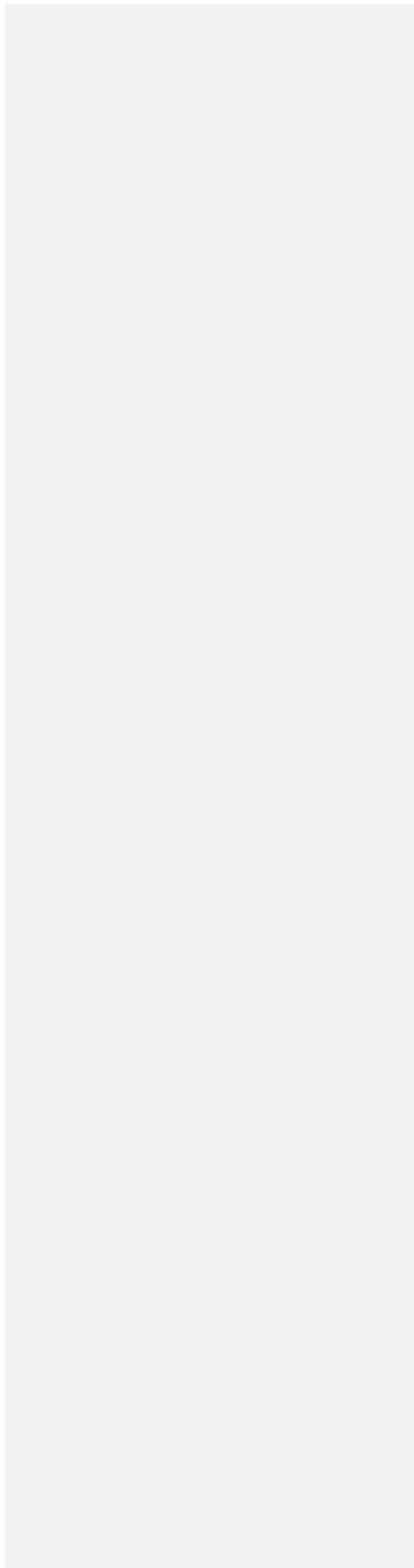
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## 302 1. Introduction

303 This specification defines an extension to the Internet Printing Protocol (IPP) that supports  
304 printing of physical objects by Additive Manufacturing devices such as three-dimensional  
305 (3D) printers.

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

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

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

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

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

## 322 2. Terminology

### 323 2.1 Conformance Terminology

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

### 329 2.2 Printing Terminology

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

Deleted: RFC2119

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

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

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

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

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

## 344 **2.3 Protocol Role Terminology**

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

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

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

## 352 **2.4 3D Printing Terminology**

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

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

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

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

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

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

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

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

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

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

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

## 376 **2.5 Other Terminology**

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

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

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

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

## 384 **2.6 Acronyms and Organizations**

385 *3D PDF Consortium*: <http://www.3dpdfconsortium.org/>

386 *3MF Consortium*: 3D Manufacturing Format Consortium, <http://www.3mf.io/>

387 *CNC*: Computer Numerical Control

388 *DLP*: Digital Light Processing

389 *FDM*: Fused Deposition Modeling

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

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

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

393 *ODL*: Object Definition Language

- 394 *PWG*: Printer Working Group, <http://www.pwg.org/>
- 395 *SD*: SD Card Association, <http://www.sdcard.org/>
- 396 *SDL*: Selective Deposition Lamination
- 397 *SL*: Stereo Lithography
- 398 *USB*: Universal Serial Bus, <http://www.usb.org/>
- 399

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

401 Existing specifications define the following:

- 402 1. IPP Version 2.0, 2.1, and 2.2 [PWG5100.12] defines version 2.0, 2.1, and 2.2 of  
403 the Internet Printing Protocol which defines a standard operating and data  
404 model, interface protocol, and extension mechanism to support traditional  
405 Printers;
- 406 2. IPP Everywhere [PWG5100.14] defines a profile of existing IPP specifications,  
407 standard Job Template attributes, and standard document formats;
- 408 3. IPP Shared Infrastructure Extensions (INFRA) [PWG5100.18] defines an  
409 interface for printing through shared services based in infrastructure such as  
410 Cloud servers;
- 411 4. The 3D Manufacturing Format Core Specification & Reference Guide v1.0 [3MF]  
412 defines an XML schema and file format for describing 3D objects with one or  
413 more materials;
- 414 5. The Universal 3D File Format [ECMA363] defines a binary format for 3D objects  
415 embedded in PDF files;
- 416 6. Document management -- 3D use of Product Representation Compact (PRC)  
417 format -- Part 1: PRC 10001 [ISO14739] defines a binary format for 3D objects  
418 embedded in PDF files; and
- 419 7. Document management — Portable document format — Part 1: PDF 1.7  
420 [ISO32000] defines a binary file format that supports embedded 3D objects with  
421 one or more materials.

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

### 425 **3.1 Use Cases**

#### 426 **3.1.1 Print a 3D Object**

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

#### 430 **3.1.2 Print a 3D Object Using Loaded Materials**

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

434 **3.1.3 Print a 3D Object with Multiple Materials**

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

439 **3.1.4 Print a Tool**

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

444 **3.1.5 View a 3D Object During Printing**

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

447 **3.2 Exceptions**

448 **3.2.1 Clogged Extruder**

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

452 **3.2.2 Extruder Temperature Out of Range**

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

457 **3.2.3 Extruder Head Movement Issues**

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

461 **3.2.4 Filament Feed Jam**

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

465 **3.2.5 Filament Feed Skip**

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

469 **3.2.6 Material Empty**

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

473 **3.2.7 Material Adhesion Issues**

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

478 **3.2.8 Build Platform Temperature Out of Range**

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

482 **3.2.9 Build Platform Not Clear**

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

487 **3.3 Out of Scope**

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

- 489 1. Definition of new file formats;  
490 2. Support for Subtractive Manufacturing technologies such as CNC milling  
491 machines; and  
492 3. Support for industrial and/or medical printing technologies.  
493

494 **3.4 Design Requirements**

495 The design requirements for this document are:

- 496 1. Define attributes and values to describe supported and loaded (ready) materials  
497 used for consumer desktop 3D Printers and print services, including color, fill,  
498 purpose, thickness, and type;
- 499 2. Define attributes and values to describe consumer desktop 3D Printer and print  
500 service capabilities and state;
- 501 3. Define attributes and values to describe printing features and/or constraints  
502 including dimensional accuracy and generation of rafts and supports;
- 503 4. Define attributes and values to describe the objects being printed, including  
504 UUID, bounding box, and offsets;
- 505 5. Define attributes to provide a receipt of the printed Job;
- 506 6. Define discovery mechanisms for 3D Printers;
- 507 7. Define security requirements necessary to support privacy and device safety;
- 508 8. Identify secure transport mechanisms for 3D Printers; and
- 509 9. Define sections to register all attributes, values, operations, and service types  
510 with IANA.

511 The design recommendations for this document are:

- 512 1. Support 3D printing technologies other than FDM  
513



514 **4. 3D Print Service Model**

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

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

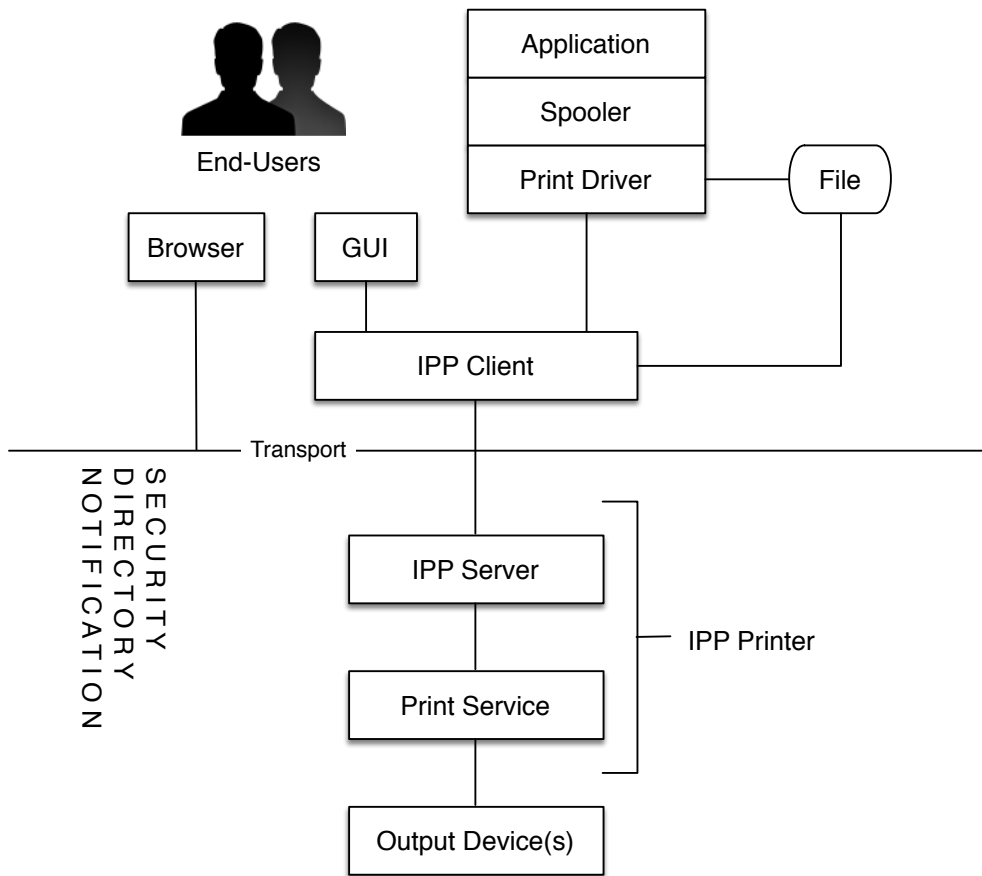
526 The IPP Printer object contains zero or more Job objects and is responsible for managing,  
527 scheduling, and processing Jobs. It also provides the current state of the Output Device(s)  
528 and communicates with them as needed.

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

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

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

540



541  
542  
543

Figure 1 - Generalized IPP Model (RFC 8011)

## 544 4.1 3D Print Service

545 3D printing uses a variation of the traditional Print service that maintains state and capability  
 546 information specific to 3D printing. The 3D Print service supports all of the same operations  
 547 of the Print service described in [RFC8011] except for the Print-Job and Print-URI operations  
 548 which are compound requests that are not used in newer IPP services. Similarly, the 3D  
 549 Print service uses a superset of the Print service attributes except where such attributes are  
 550 not applicable, for example the "media" attributes for a 3D printer that does not use media  
 551 sheets. Attributes specific to the 3D Print Service are defined in section 8.

## 552 4.2 3D Printer Subunits

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

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

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

### 556 4.2.1 Finishing Devices

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

### 559 4.2.2 Input Trays/Rolls

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

### 561 4.2.3 Marker Supplies

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

564 **4.2.4 Markers**

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

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

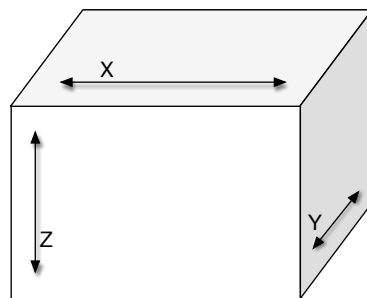
570 **4.2.5 Media Paths**

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

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

576 **4.3 3D Printer Coordinate System**

577 3D printers operate in three dimensions and thus have three axis of movement. For the  
578 purposes of IPP, the build volume is defined as a rectangular prism (Figure 2) with the X  
579 axis representing the width, the Y axis representing the depth, and the Z axis representing  
580 the height. The origin is implementation-specific.



581

582

**Figure 2 - 3D Build Volume**

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

587 **4.4 Output Intent and Job Processing**

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

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

597 **4.5 Job Spooling**

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

601 **4.6 Multiple Document Jobs**

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

606 The "multiple-object-handling" (section 8.1.2) Job Template attribute controls whether the  
607 Printer performs this optimization.

608 **4.7 Cloud-Based Printing**

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

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

616

## 617 5. Discovery Protocols

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

### 620 5.1 DNS Service Discovery (DNS-SD)

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

#### 625 5.1.1 Service Instance Name

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

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

#### 629 5.1.2 Service Type

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

#### 631 5.1.3 TXT Record

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

635 **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

636 **5.2 LDAP Discovery**

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

640 **5.2.1 printerIPPS3D Class**

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

```
643 ( 1.3.18.0.2.24.46.2.1
644   NAME 'printerIPPS3D'
645   DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
646   AUXILIARY
647   SUP top
648   MAY ( printer-ipp-versions-supported $
649         printer-ipp-features-supported $
650         printer-multiple-document-jobs-supported )
651 )
```

652

## 653 **6. Protocol Binding**

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

### 657 **6.1 Transport and Resource Path**

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

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

### 665 **6.2 HTTP Features**

666 In addition to the IPP over HTTP conformance requirements defined in section 7.3 of IPP  
667 2.0, 2.1, and 2.2 [PWG5100.12], Printers MUST support the following additional HTTP  
668 headers and status codes defined in Hypertext Transfer Protocol -- HTTP/1.1 [RFC7230].

#### 669 **6.2.1 Host**

670 Printers MUST validate the Host request header and SHOULD use the Host value in  
671 generated URIs.

#### 672 **6.2.2 If-Modified-Since, Last-Modified, and 304 Not Modified**

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

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

#### 679 **6.2.3 Cache-Control**

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



685 **6.3 IPP Operations**

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

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

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

690 **6.4 IPP Operation Attributes**

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

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

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

693 **6.5 IPP Printer Description Attributes**

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

**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 8.3.3
material-purpose-supported	Section 8.3.5
material-rate-supported	Section 8.3.6
material-rate-units-supported	Section 8.3.7
material-shell-thickness-supported	Section 8.3.8
material-temperature-supported (note 3)	Section 8.3.8
material-type-supported	Section 8.3.10
materials-col-default	Section 8.3.12
materials-col-ready	Section 8.3.13
materials-col-supported	Section 8.3.14
max-materials-col-supported	Section 8.3.15
multiple-document-jobs-supported	RFC 8011
multiple-object-handling-default	Section 8.3.16
multiple-object-handling-supported	Section 8.3.17
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 8.3.20
platform-temperature-supported (note 4)	Section 8.3.21
print-accuracy-default	Section 8.3.22
print-accuracy-supported	Section 8.3.23
print-base-default	Section 8.3.24
print-base-supported	Section 8.3.25
print-objects-supported	Section 8.3.26
print-quality-default	RFC 8011
print-quality-supported	RFC 8011
print-supports-default	Section 8.3.27
print-supports-supported	Section 8.3.28

---

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 8.3.31
printer-xri-supported (note 1)	RFC 3380
which-jobs-supported	PWG 5100.11

---

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

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

699 Note 3: REQUIRED for Printers that control the material temperature during  
700 printing.

701 Note 4: REQUIRED for Printers that have a temperature-controlled Build Platform.  
702

703 **6.6 IPP Printer Status Attributes**

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

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

Attribute	Reference
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

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

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

709

## 710 6.7 IPP Job Template Attributes

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

712 **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 8.1.2
platform-temperature (note 2)	Section 8.1.3
print-accuracy	Section 8.1.4
print-base	Section 8.1.5
print-objects (note 1)	Section 8.1.6
print-quality	RFC 8011
print-supports	Section 8.1.7

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

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

## 715 6.8 IPP Job Description Attributes

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

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

Attribute	Source
job-name	RFC 8011

## 718 6.9 IPP Job Status Attributes

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

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

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

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

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

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

### 723 6.9.1 job-id (integer)

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

### 729 6.9.2 job-uri (uri)

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

## 736 7. Document Formats

737 Printers [that support Slicing](#) MUST support Documents conforming to the 3MF [3MF]  
 738 ("model/3mf") format and SHOULD support Documents conforming to the PDF [ISO32000]  
 739 ("application/pdf") format containing U3D [U3D] or PRC [PRC] content. [Printers that do not](#)  
 740 [support Slicing SHOULD support Documents conforming to a layered format such as PWG](#)  
 741 [Safe G-Code \[PWGGCODE\] and/or the 3MF Slice Extension \[3MF-SLICE\].](#)

742 **8. New Attributes**743 **8.1 Job Template Attributes**

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

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

<b>Job Template</b>	<b>Printer: Default</b>	<b>Printer: Supported</b>
materials-col (collection)	materials-col-default (1setOf collection)	materials-col-database (1setOf collection) materials-col-ready (1setOf collection) materials-col-supported (1setOf type2 keyword)
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)
<a href="#">printer-volume-temperature (integer   no-value)</a>	<a href="#">printer-volume-temperature-default (integer   no-value)</a>	<a href="#">printer-volume-temperature-supported (1setOf (integer   rangeOfInteger)   no-value)</a>

747 **8.1.1 materials-col (1setOf collection)**

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

753 The Printer advertises which "materials-col" member attributes are supported in the  
 754 "materials-col-supported" (section 8.3.14) Printer Description attribute. The Printer lists only  
 755 those member attributes that are applicable to the technology being used for printing.

756 The Client typically supplies "materials-col" values matching those returned in the "materials-  
 757 col-database" (section 8.3.1) or "materials-col-ready" (section 8.3.13) Printer Description  
 758 attributes, although specifying the "material-name" or "material-key" member attribute from  
 759 either of these Printer Description attributes is enough to specify the default values for the  
 760 named material. Table 11 lists the member attributes.

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

Member Attribute	Printer: Supported Values
material-amount	N/A
material-amount-units	material-amount-units-supported
material-color	N/A
material-diameter	material-diameter-supported
material-diameter-tolerance	N/A
material-fill-density	N/A
material-key	materials-col-database materials-col-ready
material-name	materials-col-database materials-col-ready
<a href="#">material-nozzle-diameter</a>	<a href="#">material-nozzle-diameter-supported</a>
material-purpose	material-purpose-supported
material-rate	material-rate-supported
material-rate-units	material-rate-units-supported
<a href="#">material-retraction</a>	<a href="#">materials-col-supported</a>
material-shell-thickness	material-shell-thickness-supported
material-temperate	material-temperature-supported
material-type	material-type-supported

762 **8.1.1.1 material-amount (integer(0:MAX) | unknown)**

763 This RECOMMENDED member attribute provides the estimated amount of material that is  
 764 available ("materials-col-database" and "materials-col-ready" values), the estimated amount  
 765 of material that is required ("materials-col" values), or the actual amount of material that has  
 766 been used ("materials-col-actual" values).

767 **8.1.1.2 material-amount-units (type2 keyword)**

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

770 'g': Value is mass in grams.

771 'kg': Value is mass in kilograms.



772 'l': Value is volume in liters.

773 'm': Value is length in meters.

774 'ml': Value is volume in milliliters.

775 'mm': Value is length in millimeters.

776 **8.1.1.3 material-color (type2 keyword)**

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

779 **8.1.1.4 material-diameter (integer(0:MAX))**

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

783 **8.1.1.5 material-diameter-tolerance (integer(0:MAX))**

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

786 **8.1.1.6 material-fill-density (integer(0:100))**

787 This REQUIRED member attribute specifies the desired density of filled interior regions in  
788 percent.

789 **8.1.1.7 material-key (keyword)**

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

792 **8.1.1.8 material-name (name(MAX))**

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

794 **8.1.1.9 material-nozzle-diameter (integer(0:MAX))**

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

798 **8.1.1.10 material-purpose (1setOf type2 keyword)**

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

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

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

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

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

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

807 **8.1.1.11 material-rate (integer(1:MAX))**

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

810 **8.1.1.12 material-rate-units (type2 keyword)**

811 This member attribute provides the units for the "material-rate" member attribute. Values  
812 include:

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

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

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

816 **8.1.1.13 material-retraction (boolean)**

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

819 **8.1.1.14 material-shell-thickness (integer(0:MAX))**

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

822 **8.1.1.15 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))**

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

826 **8.1.1.16 material-type (type2 keyword | name(MAX))**

827 This REQUIRED member attribute specifies the type of material. Keyword values are  
828 general names for materials (sometimes qualified) and are localized using the message  
829 catalog specified by the "printer-strings-uri" Printer Description attribute [PWG5100.13].

830 Name values are vendor or site specific human readable (already localized) strings. Values  
831 include:

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

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

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

835 'chocolate': Chocolate.

836 'gold': Gold (metal).

837 'nylon': Nylon.

838 'pet': Polyethylene terephthalate (PET).

839 'photopolymer': Photopolymer (liquid) resin.

840 'pla': Polylactic Acid (PLA).

841 'pla-conductive': Conductive PLA.

842 'pla-dissolvable': Dissolvable PLA.

843 'pla-flexible': Flexible PLA.

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

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

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

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

848 'polycarbonate': Polycarbonate.

849 'silver': Silver (metal).

850 'titanium': Titanium (metal).

851 'wax': Wax.

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

854 **8.1.2 multiple-object-handling (type2 keyword)**

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

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

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

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

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

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

864 **8.1.3 platform-temperature (integer(-273:MAX))**

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

868 **8.1.4 print-accuracy (collection)**

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

871 When enforcing attribute fidelity ("ipp-attribute-fidelity" with a value of 'true'), Printers only  
 872 reject "print-accuracy" values that are smaller than the "print-accuracy-supported" (section  
 873 8.3.23) value.

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

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

875 **8.1.4.1 accuracy-units (type2 keyword)**

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

878 'mm': Accuracy numbers are in millimeters.

879 'um': Accuracy numbers are in micrometers.

880 'nm': Accuracy numbers are in nanometers.

881 **8.1.4.2 x-accuracy (integer(0:MAX))**

882 This REQUIRED member attribute specifies the X axis accuracy in the units specified by the  
883 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than  
884 1 unit.

885 **8.1.4.3 y-accuracy (integer(0:MAX))**

886 This REQUIRED member attribute specifies the Y axis accuracy in the units specified by the  
887 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than  
888 1 unit.

889 **8.1.4.4 z-accuracy (integer(0:MAX))**

890 This REQUIRED member attribute specifies the Z axis accuracy in the units specified by the  
891 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than  
892 1 unit.

893 **8.1.5 print-base (type2 keyword)**

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

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

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

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

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

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

902 **8.1.6 print-objects (1setOf collection)**

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

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

908 **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

909

910 **8.1.6.1 document-number (integer(1:MAX))**

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

913 **8.1.6.2 object-offset (collection)**

914 This member attribute specifies the offset to apply to the object. The "x-offset  
915 (integer(0:MAX))", "y-offset (integer(0:MAX))", and "z-offset (integer(0:MAX))" member  
916 attributes specify the offsets from the left, front, and Build Platform respectively in hundredths  
917 of millimeters (1/2540th of an inch).

918 **8.1.6.3 object-size (collection)**

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

922 **8.1.6.4 object-uuid (uri)**

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

925 **8.1.7 print-supports (type2 keyword)**

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

928 'none': Do not print supports.

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

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

931 **8.1.8 printer-volume-humidity (integer(0:100) | no-value)**

932 This CONDITIONALLY REQUIRED Job Template attribute specifies the desired relative  
933 humidity of the build chamber as a percentage. Printers that support humidity control MUST  
934 support this attribute.

935 **8.1.9 printer-volume-temperature (integer(-273:MAX) | no-value)**

936 This CONDITIONALLY REQUIRED Job Template attribute specifies the desired  
937 temperature of the build chamber in degrees Celsius. Printers that support a temperature-  
938 controlled build chamber MUST support this attribute.

939

Commented [MS1]: DISCUSS: Should these be "chamber-xxx" instead?

940 **8.2 Job Status Attributes**

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

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

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

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

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

947 **8.2.1 materials-col-actual (1setOf collection)**

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

950 **8.2.2 multiple-object-handling-actual (type2 keyword)**

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

954 **8.2.3 print-accuracy-actual (collection)**

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

956 **8.2.4 platform-temperature-actual (1setOf integer(-273:MAX))**

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

960 **8.2.5 print-accuracy-actual (1setOf collection)**

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



963 **8.2.6 print-base-actual (1setOf type2 keyword)**

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

966 **8.2.7 print-objects-actual (1setOf collection)**

967 This CONDITIONALLY REQUIRED Job Status attribute lists the objects that were  
968 processed. Printers that support the 'application/pdf' document format MUST support this  
969 attribute.

970 **8.2.8 print-supports-actual (1setOf type2 keyword)**

971 This REQUIRED Job Status attribute specifies whether supports were printed during the  
972 processing of the Job.

973 **8.3 Printer Description Attributes**

974 **8.3.1 accuracy-units-supported (1setOf type2 keyword)**

975 This REQUIRED Printer Description attribute specifies the supported "accuracy-units"  
976 member attribute values.

977 **8.3.2 material-amount-units-supported (1setOf type2 keyword)**

978 This Printer Description attribute lists the supported "material-amount-units" values for the  
979 Printer. This attribute MUST be supported if the "material-amount-units" member attribute  
980 (Section 8.1.1.2) is supported.

981 **8.3.3 material-diameter-supported (1setOf (integer | rangeOfInteger))**

982 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
983 "material-diameter" values for the Printer. This attribute MUST be supported if the "material-  
984 diameter" member attribute (Section 8.1.1.4) is supported.

985 **8.3.4 material-nozzle-diameter-supported (1setOf (integer | rangeOfInteger))**

986 This Printer Description attribute lists the supported "material-nozzle-diameter" values for  
987 the Printer. This attribute MUST be supported if the "material-nozzle-diameter" member  
988 attribute (Section 8.1.1.9) is supported.

989 **8.3.5 material-purpose-supported (1setOf type2 keyword)**

990 This REQUIRED Printer Description attribute lists the supported "material-purpose" values  
991 for the Printer.

**992 8.3.6 material-rate-supported (1setOf (integer | rangeOfInteger)**

993 This Printer Description attribute lists the supported "material-rate" values for the Printer.  
994 This attribute MUST be supported if the "material-rate" member attribute (Section 8.1.1.11)  
995 is supported.

**996 8.3.7 material-rate-units-supported (1setOf type2 keyword)**

997 This Printer Description attribute lists the supported "material-rate-units" values for the  
998 Printer. This attribute MUST be supported if the "material-rate-units" member attribute  
999 (Section 8.1.1.12) is supported.

**1000 8.3.8 material-shell-thickness-supported (1setOf (integer(1:MAX) |  
1001 rangeOfInteger(1:MAX)))**

1002 This REQUIRED Printer Description attribute specifies the supported "material-shell-  
1003 thickness" values (or ranges of values) in nanometers.

**1004 8.3.9 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-  
1005 273:MAX)))**

1006 This CONDITIONALLY REQUIRED Printer Description attribute specifies the supported  
1007 "material-temperature" values (or ranges of values) in degrees Celsius. This attribute MUST  
1008 be supported if the "material-temperature" member attribute (Section 8.1.1.15) is supported.

**1009 8.3.10 material-type-supported (1setOf type2 keyword)**

1010 This REQUIRED Printer Description attribute lists the supported "material-type" values for  
1011 the Printer.

**1012 8.3.11 materials-col-database (1setOf collection)**

1013 This RECOMMENDED Printer Description attribute lists the pre-configured materials for the  
1014 Printer. Each value contains the corresponding "materials-col" member attributes and will  
1015 typically reflect vendor and site ("third party") materials that are supported by the Printer.

1016 In order to optimize the total size of this attribute, Printers MAY omit member attributes that  
1017 allow the full range of supported values in a particular collection. For example, a Printer that  
1018 supports generic PLA filament can report a single collection value:

```
1019     materials-col-database =  
1020     { material-name="Generic PLA Filament" material-key="generic-pla"  
1021     material-diameter=285 material-temperature=215-235 }  
1022
```

1023 Such "wildcard" values can be combined with more precise collections that identify a specific  
1024 product, for example:

```
1025     materials-col-database =  
1026     { material-name="Generic PLA Filament" material-key="generic-pla"  
1027     material-diameter=285 material-temperature=215-235 },  
1028     { material-name="Example Corp Flexible Midnight Blue PLA" material-  
1029     key="com.example.flexible-midnight-blue" material-  
1030     color="com.example.midnight-blue_000027" material-diameter=285 material-  
1031     temperature=210-225 }
```

### 1032 **8.3.12 materials-col-default (1setOf collection)**

1033 This REQUIRED Printer Description attribute lists the default materials that will be used if  
1034 the "materials-col" Job Template attribute (Section 8.1.1) is not specified.

### 1035 **8.3.13 materials-col-ready (1setOf collection)**

1036 This REQUIRED Printer Description attribute lists the materials that have been loaded into  
1037 the Printer. Each value contains the corresponding "materials-col" member attributes.

### 1038 **8.3.14 materials-col-supported (1setOf type2 keyword)**

1039 This REQUIRED Printer Description attribute lists the "materials-col" member attributes that  
1040 are supported by the Printer. Printers MUST include the following values: 'material-fill-  
1041 density', 'material-key', 'material-name', 'material-purpose', 'material-shell-thickness', and  
1042 'material-type'.

### 1043 **8.3.15 max-materials-col-supported (integer(1:MAX))**

1044 This REQUIRED Printer Description attribute specifies the maximum number of values that  
1045 can be provided with the "materials-col" Job Template attribute (section 8.1.1).

### 1046 **8.3.16 multiple-object-handling-default (type2 keyword)**

1047 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
1048 "multiple-object-handling" value. Printers that support the 'application/pdf' Document format  
1049 MUST support this attribute.

### 1050 **8.3.17 multiple-object-handling-supported (1setOf type2 keyword)**

1051 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
1052 "multiple-object-handling" values. Printers that support the 'application/pdf' Document format  
1053 MUST support this attribute.  
1054

1055 **8.3.18 pdf-features-supported (1setOf type2 keyword)**

1056 This CONDITIONALLY REQUIRED Printer Description attribute lists the PDF features that  
1057 are supported by the Printer. Printers that support the 'application/pdf' Document format  
1058 MUST support this attribute.

1059 Values include:

1060 'prc': The Printer supports 3D objects in the Product Representation Compact  
1061 (PRC) format [ISO14739-1].

1062 'u3d': The Printer supports 3D objects in the Universal 3D (U3D) format [ECMA363].

1063 **[8.3.19 platform-shape \(type2 keyword\)](#)**

1064 [This RECOMMENDED Printer Description attribute describes the overall shape of the build](#)  
1065 [platform. Values include:](#)

1066 ['ellipse': The build platform is elliptical, forming a cylindrical build volume.](#)

1067 ['rectangle': The build platform is rectangular, forming a cubic build volume.](#)

1068 **8.3.20 platform-temperature-default (integer(-273:MAX))**

1069 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
1070 "platform-temperature" value. Printers that control the temperature of the Build Platform  
1071 MUST support this attribute.

1072 **8.3.21 platform-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-  
1073 273:MAX)))**

1074 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
1075 "platform-temperature" values and/or ranges. Printers that control the temperature of the  
1076 Build Platform MUST support this attribute.

1077 **8.3.22 print-accuracy-default (collection)**

1078 This REQUIRED Printer Description attribute specifies the default "print-accuracy" value.

1079 **8.3.23 print-accuracy-supported (collection)**

1080 This REQUIRED Printer Description attribute specifies the best "print-accuracy" value that  
1081 is supported by the Printer.

1082 **8.3.24 print-base-default (type2 keyword)**

1083 This REQUIRED Printer Description attribute specifies the default "print-base" value.

1084 **8.3.25 print-base-supported (1setOf type2 keyword)**

1085 This REQUIRED Printer Description attribute lists the supported "print-base" values.

1086 **8.3.26 print-objects-supported (1setOf type2 keyword)**1087 This CONDITIONALLY REQUIRED Printer Description attribute specifies which "print-  
1088 objects" member attributes are supported. Printers that support the 'application/pdf'  
1089 Document format MUST support this attribute.1090 **8.3.27 print-supports-default (type2 keyword)**

1091 This REQUIRED Printer Description attribute specifies the default "print-supports" value.

1092 **8.3.28 print-supports-supported (1setOf type2 keyword)**

1093 This REQUIRED Printer Description attribute lists the supported "print-supports" values.

1094 **8.3.29 printer-volume-humidity-default (integer(0:100) | no-value)**1095 This CONDITIONALLY REQUIRED attribute specifies the default relative humidity of the build  
1096 chamber as a percentage. Printers that support humidity control MUST support this attribute.1097 **8.3.30 printer-volume-humidity-supported (boolean)**1098 This CONDITIONALLY REQUIRED attribute specifies whether the "printer-volume-humidity"  
1099 Job Template attribute (section 8.1.8) is supported. Printers that support humidity control  
1100 MUST support this attribute.1101 **8.3.31 printer-volume-supported (collection)**1102 This REQUIRED Printer Description attribute specifies the maximum build volume supported  
1103 by the Printer. Table 15 lists the REQUIRED member attributes.1104 **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))

1105 **8.3.31.1 x-dimension (integer(1:MAX))**1106 This member attributes specifies the width of the build volume in hundredths of millimeters  
1107 (1/2540th of an inch).

1108 **8.3.31.2 y-dimension (integer(1:MAX))**

1109 This member attribute specifies the depth of the build volume in hundredths of millimeters  
1110 (1/2540th of an inch).

1111 **8.3.31.3 z-dimension (integer(1:MAX))**

1112 This member attribute specifies the height of the build volume in hundredths of millimeters  
1113 (1/2540th of an inch).

1114 **8.3.32 printer-volume-temperature-default (integer(-273:MAX) | no-value)**

1115 This CONDITIONALLY REQUIRED attribute contains the default temperature of the build  
1116 chamber in degrees Celsius, if configured. Printers that provide a temperature-controlled  
1117 build chamber MUST support this attribute.

1118 **8.3.33 printer-volume-temperature-supported (1setOf (integer(-273:MAX) |**  
1119 **rangeOfInteger(-273:MAX))**

1120 This CONDITIONALLY REQUIRED attribute lists the supported temperatures (or ranges of  
1121 temperatures) of the build chamber in degrees Celsius. Printers that provide a temperature-  
1122 controlled build chamber MUST support this attribute.

1123 **8.4 Printer Status Attributes**

1124 **8.4.1 printer-camera-image-uri (1setOf uri)**

1125 This Printer Status attribute lists the URIs for one or more resident camera snapshots. Each  
1126 URI corresponds to a separate resident camera. The images referenced by each URI can  
1127 change at any time so it is up to the Client to periodically poll for changes and for the Printer  
1128 to atomically update the images so that Clients can safely do so. The referenced images  
1129 MUST be PNG [RFC2083] or JPEG [JFIF] format.

1130 **8.4.2 printer-volume-humidity-current (integer(0:100) | unknown)**

1131 This CONDITIONALLY REQUIRED attribute reports the current relative humidity of the build  
1132 chamber as a percentage. Printers that support humidity control MUST support this attribute.

1133 **8.4.3 printer-volume-temperature-current (integer(-273:MAX) | unknown)**

1134 This CONDITIONALLY REQUIRED attribute reports the current temperature of the build  
1135 chamber in degrees Celsius, if known. Printers that provide a temperature-controlled build  
1136 chamber MUST support this attribute.

1137 **9. New Values for Existing Attributes**

1138 **9.1 ipp-features-supported (1setOf type2 keyword)**

1139 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-  
1140 supported" Printer Description attribute.

1141 **9.2 printer-state-reasons (1setOf type2 keyword)**

1142 This specification registers the following new values for the "printer-state-reasons" Printer  
1143 Status attribute:

1144 'camera-failure': A camera is no longer working.

1145 'chamber-cooling': A chamber is being cooled.

1146 'chamber-failure': A chamber has failed and requires maintenance or replacement.

1147 'chamber-heating': A chamber is being heated.

1148 'chamber-temperature-high': The temperature of a chamber is high.

1149 'chamber-temperature-low': The temperature of a chamber is low.

1150 'extruder-cooling': An extruder is being cooled.

1151 'extruder-failure': An extruder has failed and requires maintenance or replacement.

1152 'extruder-heating': An extruder is being heated.

1153 'extruder-jam': An extruder is jammed or clogged.

1154 'extruder-temperature-high': The temperature of an extruder is too high.

1155 'extruder-temperature-low': The temperature of an extruder is too low.

1156 'fan-failure': A fan has failed.

1157 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.

1158 'lamp-failure': A lamp has failed.

1159 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.

1160 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.

1161 'laser-failure': A laser has failed.

- 1162 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.
- 1163 'material-empty': One or more build materials have been exhausted.
- 1164 'material-low': One or more build materials may need replenishment soon.
- 1165 'material-needed': One or more build materials need to be loaded for a processing  
1166 Job.
- 1167 'motor-failure': A motor has failed.
- 1168 'platform-cooling': A Build Platform is being cooled.
- 1169 'platform-failure': A Build Platform has failed and requires maintenance or  
1170 replacement.
- 1171 'platform-heating': A Build Platform is being heated.
- 1172 'platform-temperature-high': The temperature of a Build Platform is too high.
- 1173 'platform-temperature-low': The temperature of a Build Platform is too low.  
1174



1175 **10. Conformance Requirements**

1176 **10.1 Printer Conformance Requirements**

1177 In order for a Printer to claim conformance to this specification, a Printer MUST support:

- 1178 1. The required discovery protocols in section 5;
- 1179 2. The required transports and resource paths in section 6.1;
- 1180 3. The required HTTP features in section 6.2;
- 1181 4. The required IPP operations in section 6.3;
- 1182 5. The required IPP attributes in sections 6.4 through 6.9;
- 1183 6. The required document formats in section 7;
- 1184 7. The additional values defined in section 9;
- 1185 8. The internationalization considerations in section 11; and
- 1186 9. The security considerations in section 12.

1187 **10.2 Client Conformance Requirements**

1188 In order for a Client to claim conformance to this specification, a Client MUST support:

- 1189 1. The required discovery protocols in section 5;
- 1190 2. The required transports and resource paths in section 6.1;
- 1191 3. The required HTTP features in section 6.2;
- 1192 4. The required IPP operations in section 6.3;
- 1193 5. The required IPP attributes in sections 6.4 through 6.9;
- 1194 6. The required document formats in section 7;
- 1195 7. The additional values defined in section 9;
- 1196 8. The internationalization considerations in section 11; and
- 1197 9. The security considerations in section 12.

1198

1199 **11. Internationalization Considerations**

1200 For interoperability and basic support for multiple languages, conforming implementations  
1201 MUST support:

- 1202 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)
- 1203 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 1204 2. The Unicode Format for Network Interchange [RFC5198] which requires
- 1205 transmission of well-formed UTF-8 strings and recommends transmission of
- 1206 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1207 Unicode NFC is defined as the result of performing Canonical Decomposition (into base  
1208 characters and combining marks) followed by Canonical Composition (into canonical  
1209 composed characters wherever Unicode has assigned them).

1210 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and  
1211 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in IPP  
1212 Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8 URIs  
1213 now 'hidden').

1214 Implementations of this specification SHOULD conform to the following standards on  
1215 processing of human-readable Unicode text strings, see:

- 1216 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical
- 1217 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping
- 1218 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]
- 1219 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences
- 1220 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization
- 1221 Unicode Character Encoding Model [UTR17] – multi-layer character model
- 1222 Unicode in XML and other Markup Languages [UTR20] – XML usage
- 1223 Unicode Character Property Model [UTR23] – character properties
- 1224 Unicode Conformance Model [UTR33] – Unicode conformance basis+
- 1225 Unicode Collation Algorithm [UTS10] – sorting
- 1226 Unicode Locale Data Markup Language [UTS35] – locale databases

1227 **12. Security Considerations**

1228 In addition to the security considerations described in the IPP/1.1: Model and Semantics  
1229 [RFC8011], the following sub-sections describe issues that are unique to 3D printing.

1230 Implementations of this specification SHOULD conform to the following standards on  
1231 processing of human-readable Unicode text strings, see:

1232       Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1233       Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

1234 **12.1 Confidentiality**

1235 Clients and Printers MUST provide confidentiality of data in transit using either an interface  
1236 providing physical security such as USB or using TLS encryption [RFC5246] over  
1237 unsecured/network connections,

1238 **12.2 Access Control**

1239 Because of the potential for abuse and misuse, Printers SHOULD provide access control  
1240 mechanisms including lists of allowed Clients, authentication, and authorization to site  
1241 defined policies.

1242 **12.3 Physical Safety**

1243 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such  
1244 as protective gates, covers, or interlocks.

1245 **12.4 Material Safety**

1246 Printers MUST restrict usage and combination of materials to those that can be safely  
1247 printed. Access controls (section 12.2) MAY be used to allow authorized End Users to  
1248 experiment with untested materials or combinations, but only when such materials or  
1249 combinations can reasonably be expected to not pose a safety risk.

1250 **12.5 Temperature Control**

1251 Printers MUST validate values provided by Clients and limit material, extruder, Build  
1252 Platform, and print chamber temperatures within designed limits to prevent unsafe operating  
1253 conditions, damage to the hardware, hazardous emissions, explosions, and/or fires.

1254

1255 **13. IANA and PWG Considerations**1256 **13.1 Attribute Registrations**

1257 The attributes defined in this specification will be published by IANA according to the  
 1258 procedures in IPP/1.1 Model and Semantics [RFC8011] section 7.2 in the following file:

1259 <http://www.iana.org/assignments/ipp-registrations>

1260 The registry entries will contain the following information:

Document Status attributes: -----	Reference
1261 materials-col-actual (1setOf collection)	[PWG5100.21]
1262 < member attributes are the same as materials-col >	[PWG5100.21]
1263 multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1264 platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1265 print-accuracy-actual (collection)	[PWG5100.21]
1266 < member attributes are the same as print-accuracy >	[PWG5100.21]
1267 print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1268 print-objects-actual (1setOf collection)	[PWG5100.21]
1269 < member attributes are the same as print-objects >	[PWG5100.21]
1270 print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1271	
1272	
1273	
Document Template attributes: -----	Reference
1274 materials-col (1setOf collection)	[PWG5100.21]
1275 material-amount (integer(0:MAX))	[PWG5100.21]
1276 material-amount-units (type2 keyword)	[PWG5100.21]
1277 material-color (type2 keyword)	[PWG5100.21]
1278 material-diameter (integer(0:MAX))	[PWG5100.21]
1279 material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1280 material-fill-density (integer(0:100))	[PWG5100.21]
1281 material-key (keyword)	[PWG5100.21]
1282 material-name (name (MAX))	[PWG5100.21]
1283 <a href="#">material-nozzle-diameter (integer(0:MAX))</a>	[PWG5100.21]
1284 material-purpose (1setOf type2 keyword)	[PWG5100.21]
1285 material-rate (integer(1:MAX))	[PWG5100.21]
1286 material-rate-units (type2 keyword)	[PWG5100.21]
1287 <a href="#">material-retraction (boolean)</a>	[PWG5100.21]
1288 material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1289 material-temperature (integer(-273:MAX)   rangeOfInteger(-273:MAX))	[PWG5100.21]
1290 material-type (type2 keyword   name (MAX))	[PWG5100.21]
1291 multiple-object-handling (type2 keyword)	[PWG5100.21]
1292 platform-temperature (integer(-273:MAX))	[PWG5100.21]
1293 print-accuracy (collection)	[PWG5100.21]
1294 accuracy-units (type2 keyword)	[PWG5100.21]
1295 x-accuracy (integer(0:MAX))	[PWG5100.21]
1296 y-accuracy (integer(0:MAX))	[PWG5100.21]
1297 z-accuracy (integer(0:MAX))	[PWG5100.21]
1298 print-base (type2 keyword)	[PWG5100.21]
1299 print-objects (1setOf collection)	[PWG5100.21]
1300	
1301	
1302	



1397	print-objects (1setOf collection)	[PWG5100.21]	Deleted: PWG5100.NN
1398	document-number (integer(1:MAX))	[PWG5100.21]	Deleted: PWG5100.NN
1399	object-offset (collection)	[PWG5100.21]	Deleted: PWG5100.NN
1400	x-offset (integer(0:MAX))	[PWG5100.21]	Deleted: PWG5100.NN
1401	y-offset (integer(0:MAX))	[PWG5100.21]	Deleted: PWG5100.NN
1402	z-offset (integer(0:MAX))	[PWG5100.21]	Deleted: PWG5100.NN
1403	object-size (collection)	[PWG5100.21]	Deleted: PWG5100.NN
1404	x-dimension (integer(1:MAX))	[PWG5100.21]	Deleted: PWG5100.NN
1405	y-dimension (integer(1:MAX))	[PWG5100.21]	Deleted: PWG5100.NN
1406	z-dimension (integer(1:MAX))	[PWG5100.21]	Deleted: PWG5100.NN
1407	object-uuid (uri)	[PWG5100.21]	Deleted: PWG5100.NN
1408	print-supports (type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1409	printer-volume-humidity (integer(0:100)   no-value)	[PWG5100.21]	Deleted: PWG5100.NN
1410	printer-volume-temperature (integer(-273:MAX)   no-value)	[PWG5100.21]	Deleted: PWG5100.NN
1411	-----	[PWG5100.21]	Deleted: PWG5100.NN
1412	Printer Description attributes:	Reference	Deleted: PWG5100.NN
1413	-----	-----	Deleted: PWG5100.NN
1414	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1415	material-amount-units-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: material-diameter-supported (1setOf (integer(0:MAX)   rangeOfInteger(0:MAX)))
1416	material-diameter-supported (1setOf (integer(0:MAX)   rangeOfInteger(0:MAX)))	[PWG5100.21]	Deleted: material-diameter-supported (1setOf (integer(0:MAX)   rangeOfInteger(0:MAX))) → [PWG5100.NN#PWG5100.21]
1417	material-nozzle-diameter-supported (1setOf (integer(0:MAX)   rangeOfInteger(0:MAX)))	[PWG5100.21]	Deleted: PWG5100.NN
1418	material-purposes-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1419	material-rate-supported (1setOf (integer(1:MAX)   rangeOfInteger(1:MAX)))	[PWG5100.21]	Deleted: PWG5100.NN
1420	material-rate-units-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1421	material-shell-thickness-supported (1setOf (integer(0:MAX)   rangeOfInteger(0:MAX)))	[PWG5100.21]	Deleted: PWG5100.NN
1422	material-temperature-supported (1setOf (integer(-273:MAX)   rangeOfInteger(-273:MAX)))	[PWG5100.21]	Deleted: PWG5100.NN
1423	material-type-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1424	materials-col-database (1setOf collection)	[PWG5100.21]	Deleted: PWG5100.NN
1425	< member attributes are the same as materials-col >	[PWG5100.21]	Deleted: PWG5100.NN
1426	materials-col-default (1setOf collection)	[PWG5100.21]	Deleted: PWG5100.NN
1427	< member attributes are the same as materials-col >	[PWG5100.21]	Deleted: PWG5100.NN
1428	materials-col-ready (1setOf collection)	[PWG5100.21]	Deleted: PWG5100.NN
1429	< member attributes are the same as materials-col >	[PWG5100.21]	Deleted: PWG5100.NN
1430	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1431	max-materials-col-supported (integer(1:MAX))	[PWG5100.21]	Deleted: PWG5100.NN
1432	multiple-object-handling-default (type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1433	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1434	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1435	platform-shape (type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1436	platform-temperature-default (integer(-273:MAX))	[PWG5100.21]	Deleted: PWG5100.NN
1437	platform-temperature-supported (1setOf (integer(-273:MAX)   rangeOfInteger(-273:MAX)))	[PWG5100.21]	Deleted: PWG5100.NN
1438	print-accuracy-supported (collection)	[PWG5100.21]	Deleted: PWG5100.NN
1439	< member attributes are the same as print-accuracy >	[PWG5100.21]	Deleted: PWG5100.NN
1440	print-base-default (type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1441	print-base-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1442	print-objects-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1443	print-supports-default (type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1444	print-supports-supported (1setOf type2 keyword)	[PWG5100.21]	Deleted: PWG5100.NN
1445			Deleted: PWG5100.NN
1446			Deleted: PWG5100.NN
1447			Deleted: PWG5100.NN
1448			Deleted: PWG5100.NN
1449			Deleted: PWG5100.NN
1450			Deleted: PWG5100.NN
1451			Deleted: PWG5100.NN











1869 Service Name: ipp3d  
 1870  
 1871 Transport Protocol(s): tcp  
 1872  
 1873 Assignee/Contact: Michael Sweet, msweet@apple.com  
 1874  
 1875 Description: 3D Print services (3D printers) using the Internet Printing  
 1876 Protocol over HTTPS.  
 1877  
 1878 Reference: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100_21.pdf)  
 1879 [5100\\_21.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100_21.pdf)  
 1880  
 1881 Port Number:  
 1882  
 1883 Service Code:  
 1884  
 1885 Known Unauthorized Uses:  
 1886  
 1887 Assignment Notes: Change controller is The Printer Working Group, c/o The  
 1888 IEEE Industry Standards and Technology Organization, 445 Hoes Lane,  
 1889 Piscataway, NJ 08854, USA

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2073 Michael Scrutton, Adobe Systems  
2074 Emmet Lalish, Microsoft Corporation  
2075

2077 **16. Object Definition Languages (ODLs)**

2078 This section provides information on several commonly used ODLs with either existing  
2079 (registered) or suggested MIME media types.

2080 **16.1 3D Manufacturing Format (3MF)**

2081 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that  
2082 provides geometry, material, and texture information necessary to support a wide variety of  
2083 3D printers. Materials can be named and composed within the geometry, facilitating multiple  
2084 material support in coordination with a Job Ticket.

2085 The registered MIME media type for the original Microsoft published specification is  
2086 "application/vnd.ms-3mfdocument". The MIME media type for the 3MF Consortium's  
2087 published specification is "model/3mf".

2088 **16.2 Additive Manufacturing Format (AMF)**

2089 AMF [ISO52915] is a relatively new format that was designed as a replacement for the  
2090 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-  
2091 available specification, but has several advantages over STL including:

- 2092 1. Shared vertices which eliminates holes and other breaks in the surface  
2093 geometry of objects,  
2094 2. Specification of multiple materials in a single file,  
2095 3. Curved surfaces can be specified, and  
2096 4. Coordinates use explicit units for proper output dimensions.

2097 The suggested (but not registered) MIME media type is 'model/amf'.

2098 **16.3 Portable Document Format (PDF)**

2099 PDF [ISO32000] is widely supported for 2D printing and has two 3D formats that are used  
2100 to embed 3D objects - PRC [ISO14739-1] and U3D [ECMA363]. The registered MIME media  
2101 type for PDF is "application/pdf".

2102 [For discussion: define a "model/pdf" MIME media type for PDFs containing 3D content?]

2103 **16.4 Standard Tessellation Language (STL)**

2104 STL [STLFORMAT] is widely supported by existing client software. The registered MIME  
2105 media type is 'application/sla'.

2106



2107 **17. Design Choices**

2108 This section documents some of the design choices that were made during the development  
2109 of this specification.

2110 **17.1 Units for Length Values**

2111 The default unit for most length values is hundredths of millimeters (1/2540th of an inch),  
2112 matching the units for 2D printing and providing a range of 0.01mm to 21.47km. This was  
2113 determined to be sufficient for the class of printers this specification targets.

2114 **17.2 Units for Thickness Values**

2115 The default unit for most thickness values is nanometers, which provides a range of  
2116 0.000001mm to 2.147m. This was determined to be sufficient for the class of printers this  
2117 specification targets.

2118 **17.3 Use of Celsius for Temperatures**

2119 The various integer attributes for temperature use degrees Celsius. This was done because  
2120 most existing printers and materials are specified using degrees Celsius. There is no  
2121 advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to perform  
2122 additional unit conversions could cause safety issues. All temperature attributes use a range  
2123 of -273 (absolute zero) to MAX (2147483647 - significantly hotter than our sun) to allow  
2124 flexibility.

2125 **17.4 Explicit Units for Other Values**

2126 Some attributes have a companion "xxx-units" attribute that specifies an explicit unit for the  
2127 given measurement(s). The initial list of unit values for each attribute has been limited to  
2128 those necessary for current printers and technologies at the time of writing of this  
2129 specification in order to minimize interoperability issues.

2130 **17.5 Intent vs. Process**

2131 The IPP Model [RFC8011], and more generally the PWG Semantic Model [PWG5108.1],  
2132 have long focused on Job Tickets specifying "what" is wanted for the printed output vs. "how"  
2133 that output is produced. This focus has served IPP well and allowed it to be used with wildly  
2134 different printing technologies.

2135 During the development of this specification, attributes that define a specific process or  
2136 technological parameter have been introduced and later replaced by intent-based  
2137 alternatives that allow an implementation to select suitable process-based parameters at

2138 print time, preserving the intrinsic value of such parameters without burdening the Client or  
2139 End User with such things.

2140 At the same time, some process parameters are needed for things like material specification.  
2141 For example, a particular brand of PLA may require a higher melting temperature - this  
2142 information might only be known to the End User, so the "materials-col" collection contains  
2143 an member attribute to convey this process-specific parameter. The Printer advertises  
2144 whether temperature is a valid material property in the "materials-col-supported" Printer  
2145 Description attribute.

2146 Finally, IPP does not prohibit the definition or use of process-based Job Template attributes  
2147 for specific implementations. Such extension attributes can be listed in the "job-creation-  
2148 attributes-supported" Printer Description attribute to notify Clients of their existence.

#### 2149 **17.6 Choosing a Required Document Format**

2150 One of the design consideration of this specification is to choose an open, freely available  
2151 file format for use as required document format. Having a required document format makes  
2152 interoperability significantly easier, and using an open and freely available format allows  
2153 developers of "consumer" printers to support IPP 3D. Several formats were considered,  
2154 including STL, AMF, PDF, and 3MF.

2155 While STL is a widely-implemented, open, and freely available file format, it lacks support  
2156 for multiple materials and colors/textures, and has technical issues that cause "holes" in  
2157 generated models.

2158 While AMF supports multiple materials and does not have the "holes" issue, it is not freely  
2159 available nor widely-implemented.

2160 PDF is the most capable 3D format but is not freely available and has the interoperability  
2161 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-  
2162 features-supported" Printer Description attribute (section 8.3.18) allows Clients to determine  
2163 whether a 3D PDF file can be printed by the Printer.

2164 3MF is open and freely available, supports multiple materials and color/textures, does not  
2165 have the "holes" issue of STL, and has a freely available open source implementation that  
2166 supports both creation and consumption of 3MF files.  
2167

2168 **18. Overview of Changes**

2169 **18.1 IPP 3D Printing Extensions v1.1**

2170 The following changes were made since v1.0 of this document:

- 2171 5. Made 3MF CONDITIONALLY REQUIRED for Printers that do Slicing,
- 2172 RECOMMEND support for a standard layered format otherwise.
- 2173 6. Added the CONDITIONALLY REQUIRED "material-nozzle-diameter" and
- 2174 "material-retraction" member attributes for the "materials-col" Job Template
- 2175 attribute.
- 2176 7. Added the RECOMMENDED "platform-shape" Printer Description attribute
- 2177 8. Added the CONDITIONALLY REQUIRED "printer-volume-humidity" and "printer-
- 2178 volume-temperature" Job Template attributes.
- 2179 9. Defined a naming convention for standard "material-type" values.
- 2180

2181 **19. Change History**

2182 **[19.1 April 26, 2018](#)**

2183 Initial revision.

## MIME Media Type Registration

The MIME media type defined in this specification will be published by IANA according to the procedures in Media Type Specifications and Registration Procedures [BCP13].

The registration template is as follows:

Type name: model

Subtype name: 3mf

Required parameters: N/A

Optional parameters: N/A

Encoding considerations: binary

Security considerations: 3MF files can be very large, particularly after decompression, which could fill a filesystem and cause a denial of service or system failure. This media type does not employ any sort of active or executable content. Neither privacy nor integrity protection is provided by the media type itself; if these protections are needed they must be implemented externally. Authentication, access control, and privacy/integrity are normally handled by the Internet Printing Protocol, Hyper-Text Transport Protocol, and Transport Layer Security.

Interoperability considerations:

Published specification: <http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf>

Applications that use this media type: 3D modeling and slicing software

Fragment identifier considerations:

Additional information:

Deprecated alias names for this type: N/A

Magic number(s): N/A

File extension(s): 3mf

Macintosh file type code(s): N/A

Person & email address to contact for further information: Michael Sweet, [msweet@apple.com](mailto:msweet@apple.com)

Intended usage: COMMON

Restrictions on usage: N/A

Author/Change controller: The Printer Working Group, c/o The IEEE  
Industry Standards and Technology Organization, 445 Hoes Lane,  
Piscataway, NJ 08854, USA

Provisional registration? (standards tree only): No

## **Semantic Model Registrations**

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

