



The Printer Working Group

April 26, 2018  
Working Draft

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

Status: Initial

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

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

This document is available electronically at:

<https://ftp.pwg.org/pub/pwg/ipp/wd/wd-ipp3d11-20180426.docx>

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## 1. Introduction

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

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

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

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

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

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

## 2. Terminology

### 2.1 Conformance Terminology

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

### 2.2 Printing Terminology

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

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

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

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

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

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

## 300 **2.3 Protocol Role Terminology**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## 332 **2.5 Other Terminology**

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

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

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

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

## 340 **2.6 Acronyms and Organizations**

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

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

343 *CNC*: Computer Numerical Control

344 *DLP*: Digital Light Processing

345 *FDM*: Fused Deposition Modeling

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

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

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

349 *ODL*: Object Definition Language

350 *PWG*: Printer Working Group, <http://www.pwg.org/>  
351 *SD*: SD Card Association, <http://www.sdcard.org/>  
352 *SDL*: Selective Deposition Lamination  
353 *SL*: Stereo Lithography  
354 *USB*: Universal Serial Bus, <http://www.usb.org/>  
355

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

Existing specifications define the following:

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

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

#### 3.1 Use Cases

##### 3.1.1 Print a 3D Object

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

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

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

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

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

### 3.1.4 Print a Tool

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

### 3.1.5 View a 3D Object During Printing

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

## 3.2 Exceptions

### 3.2.1 Clogged Extruder

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

### 3.2.2 Extruder Temperature Out of Range

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

### 3.2.3 Extruder Head Movement Issues

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

### 3.2.4 Filament Feed Jam

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

### 3.2.5 Filament Feed Skip

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

### 3.2.6 Material Empty

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

### 3.2.7 Material Adhesion Issues

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

### 3.2.8 Build Platform Temperature Out of Range

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

### 3.2.9 Build Platform Not Clear

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

## 3.3 Out of Scope

The following are considered out of scope for this document:

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

### 3.4 Design Requirements

The design requirements for this document are:

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

The design recommendations for this document are:

1. Support 3D printing technologies other than FDM



## 4. 3D Print Service Model

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

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

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

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

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

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

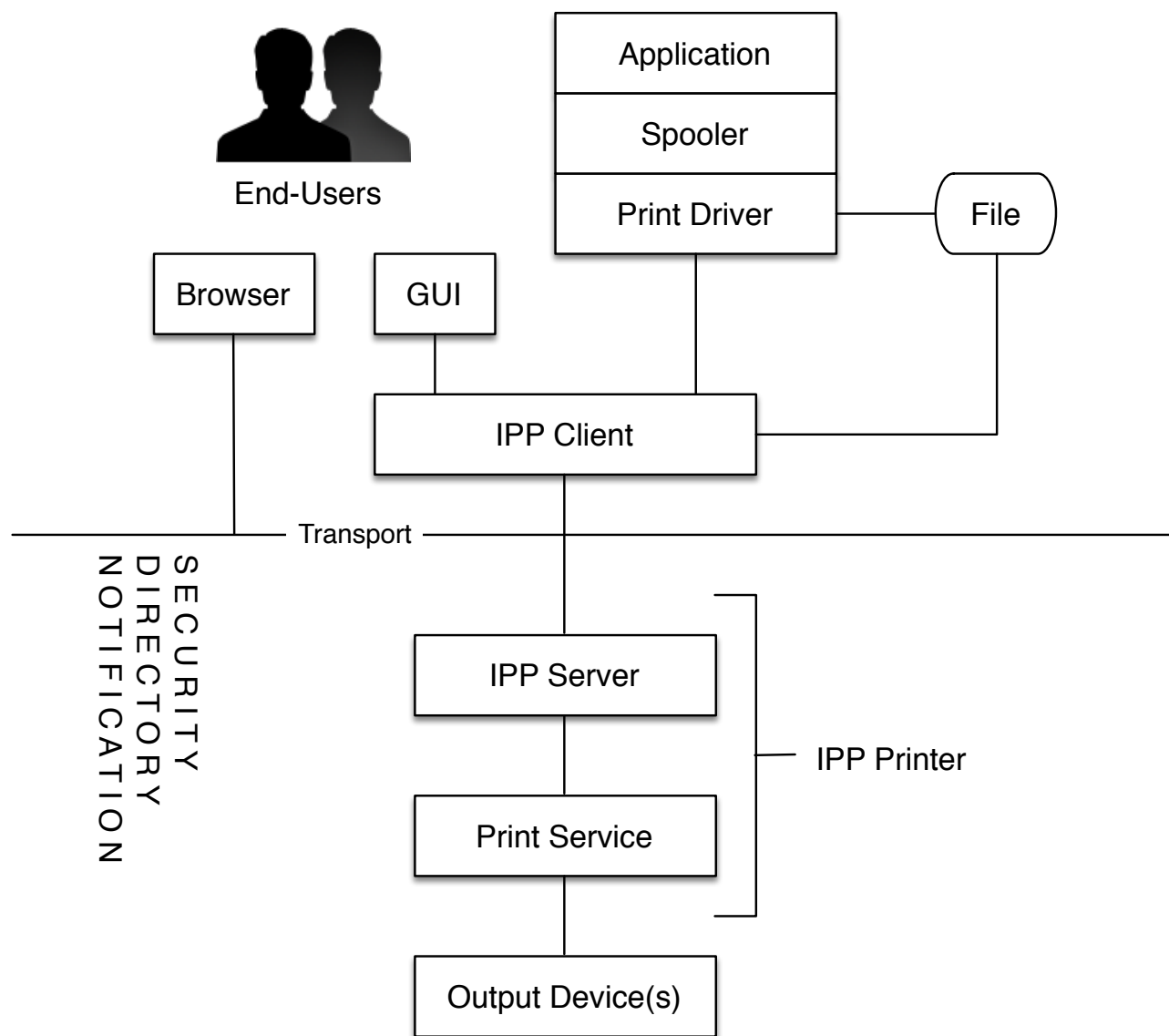


Figure 1 - Generalized IPP Model (RFC 8011)

## 4.1 3D Print Service

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

## 4.2 3D Printer Subunits

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

**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

### 4.2.1 Finishing Devices

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

### 4.2.2 Input Trays/Rolls

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

### 4.2.3 Marker Supplies

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

#### 4.2.4 Markers

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

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

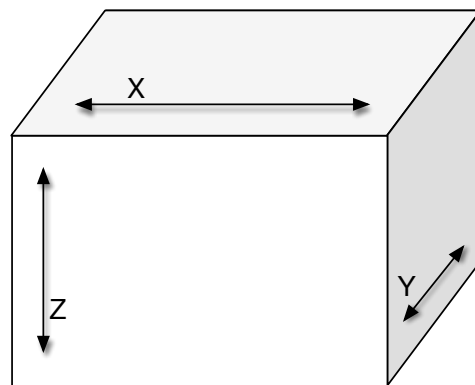
#### 4.2.5 Media Paths

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

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

### 4.3 3D Printer Coordinate System

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



**Figure 2 - 3D Build Volume**

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

## 4.4 Output Intent and Job Processing

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

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

## 4.5 Job Spooling

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

## 4.6 Multiple Document Jobs

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

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

## 4.7 Cloud-Based Printing

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

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

## 5. Discovery Protocols

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

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

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

#### 5.1.1 Service Instance Name

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

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

#### 5.1.2 Service Type

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

#### 5.1.3 TXT Record

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

**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

## 5.2 LDAP Discovery

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

### 5.2.1 printerIPPS3D Class

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

```
( 1.3.18.0.2.24.46.2.1
  NAME 'printerIPPS3D'
  DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
  AUXILIARY
  SUP top
  MAY ( printer-ipp-versions-supported $
        printer-ipp-features-supported $
        printer-multiple-document-jobs-supported )
)
```

## 6. Protocol Binding

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

### 6.1 Transport and Resource Path

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

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

### 6.2 HTTP Features

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

#### 6.2.1 Host

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

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

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

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

#### 6.2.3 Cache-Control

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



## 6.3 IPP Operations

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

**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

## 6.4 IPP Operation Attributes

Table 4 lists the REQUIRED operation attributes for a Printer.

**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

## 6.5 IPP Printer Description Attributes

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

651

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

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

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

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

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

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

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

## 6.6 IPP Printer Status Attributes

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

**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

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

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

## 6.7 IPP Job Template Attributes

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

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

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

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

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

## 6.8 IPP Job Description Attributes

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

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

Attribute	Source
job-name	RFC 8011

## 6.9 IPP Job Status Attributes

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

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

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

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

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

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

### 679 6.9.1 job-id (integer)

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

### 685 6.9.2 job-uri (uri)

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

## 692 7. Document Formats

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

## 8. New Attributes

### 8.1 Job Template Attributes

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

**Table 10 - New Job Template Attributes**

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

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

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

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

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

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

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

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

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

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

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



**725 8.1.3.1 material-amount (integer(0:MAX) | unknown)**

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

**730 8.1.3.2 material-amount-units (type2 keyword)**

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

733 'g': Value is mass in grams.

734 'kg': Value is mass in kilograms.

735 'l': Value is volume in liters.

736 'm': Value is length in meters.

737 'ml': Value is volume in milliliters.

738 'mm': Value is length in millimeters.

**739 8.1.3.3 material-color (type2 keyword)**

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

**742 8.1.3.4 material-diameter (integer(0:MAX))**

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

**746 8.1.3.5 material-diameter-tolerance (integer(0:MAX))**

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

**749 8.1.3.6 material-fill-density (integer(0:100))**

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

**752 8.1.3.7 material-key (keyword)**

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

**755 8.1.3.8 material-name (name(MAX))**

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

**757 8.1.3.9 material-nozzle-diameter (integer(0:MAX))**

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

**761 8.1.3.10 material-purpose (1setOf type2 keyword)**

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

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

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

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

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

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

**770 8.1.3.11 material-rate (integer(1:MAX))**

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

**773 8.1.3.12 material-rate-units (type2 keyword)**

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

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

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

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

**779 8.1.3.13 material-retraction (boolean)**

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

**782 8.1.3.14 material-shell-thickness (integer(0:MAX))**

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

**785 8.1.3.15 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))**

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

**789 8.1.3.16 material-type (type2 keyword | name(MAX))**

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

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

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

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

798 'chocolate': Chocolate.

799 'gold': Gold (metal).

800 'nylon': Nylon.

801 'pet': Polyethylene terephthalate (PET).

802 'photopolymer': Photopolymer (liquid) resin.

803 'pla': Polylactic Acid (PLA).

804 'pla-conductive': Conductive PLA.

805 'pla-dissolvable': Dissolvable PLA.

806 'pla-flexible': Flexible PLA.

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

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

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

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

811 'polycarbonate': Polycarbonate.

812 'silver': Silver (metal).

813 'titanium': Titanium (metal).

814 'wax': Wax.

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

#### 823 **8.1.4 multiple-object-handling (type2 keyword)**

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

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

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

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

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

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

#### 833 **8.1.5 platform-temperature (integer(-273:MAX))**

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

**8.1.6 print-accuracy (collection)**

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

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

**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

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

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

'mm': Accuracy numbers are in millimeters.

'um': Accuracy numbers are in micrometers.

'nm': Accuracy numbers are in nanometers.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**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

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

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

**8.1.8.2 object-offset (collection)**

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

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

#### 887 **8.1.8.3 object-size (collection)**

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

#### 891 **8.1.8.4 object-uuid (uri)**

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

#### 894 **8.1.9 print-supports (type2 keyword)**

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

897 'none': Do not print supports.

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

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

900

## 8.2 Job Status Attributes

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

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

Job Status Attribute	Conformance
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

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

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

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

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

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

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

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

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

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

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

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

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



### 924 **8.2.6 print-base-actual (1setOf type2 keyword)**

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

### 927 **8.2.7 print-objects-actual (1setOf collection)**

928 This CONDITIONALLY REQUIRED Job Status attribute lists the objects that were  
929 processed. Printers that support the 'application/pdf' document format MUST support this  
930 attribute.

### 931 **8.2.8 print-supports-actual (1setOf type2 keyword)**

932 This REQUIRED Job Status attribute specifies whether supports were printed during the  
933 processing of the Job.

## 934 **8.3 Printer Description Attributes**

### 935 **8.3.1 accuracy-units-supported (1setOf type2 keyword)**

936 This REQUIRED Printer Description attribute specifies the supported "accuracy-units"  
937 member attribute values.

### 938 **8.3.2 chamber-humidity-default (integer(0:100) | no-value)**

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

### 942 **8.3.3 chamber-humidity-supported (boolean)**

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

### 946 **8.3.4 chamber-temperature-default (integer(-273:MAX) | no-value)**

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

### 950 **8.3.5 chamber-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-** 951 **273:MAX)))**

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

**955 8.3.6 material-amount-units-supported (1setOf type2 keyword)**

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

**959 8.3.7 material-diameter-supported (1setOf (integer | rangeOfInteger))**

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

**963 8.3.8 material-nozzle-diameter-supported (1setOf (integer | rangeOfInteger))**

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

**967 8.3.9 material-purpose-supported (1setOf type2 keyword)**

968 This REQUIRED Printer Description attribute lists the supported "material-purpose" values  
969 for the Printer.

**970 8.3.10 material-rate-supported (1setOf (integer | rangeOfInteger))**

971 This Printer Description attribute lists the supported "material-rate" values for the Printer.  
972 This attribute MUST be supported if the "material-rate" member attribute (Section 8.1.3.11)  
973 is supported.

**974 8.3.11 material-rate-units-supported (1setOf type2 keyword)**

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

**978 8.3.12 material-shell-thickness-supported (1setOf (integer(1:MAX) |  
979 rangeOfInteger(1:MAX)))**

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

**982 8.3.13 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-  
983 273:MAX)))**

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

**987 8.3.14 material-type-supported (1setOf type2 keyword)**

988 This REQUIRED Printer Description attribute lists the supported "material-type" values for  
989 the Printer.

**990 8.3.15 materials-col-database (1setOf collection)**

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

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

```
997     materials-col-database =  
998     { material-name="Generic PLA Filament" material-key="generic-pla"  
999     material-diameter=285 material-temperature=215-235 }
```

1000 Such "wildcard" values can be combined with more precise collections that identify a specific  
1001 product, for example:

```
1002     materials-col-database =  
1003     { material-name="Generic PLA Filament" material-key="generic-pla"  
1004     material-diameter=285 material-temperature=215-235 },  
1005     { material-name="Example Corp Flexible Midnight Blue PLA" material-  
1006     key="com.example.flexible-midnight-blue" material-  
1007     color="com.example.midnight-blue_000027" material-diameter=285 material-  
1008     temperature=210-225 }
```

**1009 8.3.16 materials-col-default (1setOf collection)**

1010 This REQUIRED Printer Description attribute lists the default materials that will be used if  
1011 the "materials-col" Job Template attribute (Section 8.1.1) is not specified.

**1012 8.3.17 materials-col-ready (1setOf collection)**

1013 This REQUIRED Printer Description attribute lists the materials that have been loaded into  
1014 the Printer. Each value contains the corresponding "materials-col" member attributes.

**1015 8.3.18 materials-col-supported (1setOf type2 keyword)**

1016 This REQUIRED Printer Description attribute lists the "materials-col" member attributes that  
1017 are supported by the Printer. Printers MUST include the following values: 'material-fill-  
1018 density', 'material-key', 'material-name', 'material-purpose', 'material-shell-thickness', and  
1019 'material-type'.

**1020 8.3.19 max-materials-col-supported (integer(1:MAX))**

1021 This REQUIRED Printer Description attribute specifies the maximum number of values that  
1022 can be provided with the "materials-col" Job Template attribute (section 8.1.1).

**1023 8.3.20 multiple-object-handling-default (type2 keyword)**

1024 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
1025 "multiple-object-handling" value. Printers that support the 'application/pdf' Document format  
1026 MUST support this attribute.

**1027 8.3.21 multiple-object-handling-supported (1setOf type2 keyword)**

1028 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
1029 "multiple-object-handling" values. Printers that support the 'application/pdf' Document format  
1030 MUST support this attribute.

**1031 8.3.22 pdf-features-supported (1setOf type2 keyword)**

1032 This CONDITIONALLY REQUIRED Printer Description attribute lists the PDF features that  
1033 are supported by the Printer. Printers that support the 'application/pdf' Document format  
1034 MUST support this attribute.

1035 Values include:

1036 'prc': The Printer supports 3D objects in the Product Representation Compact  
1037 (PRC) format [ISO14739-1].

1038 'u3d': The Printer supports 3D objects in the Universal 3D (U3D) format [ECMA363].

**1039 8.3.23 platform-shape (type2 keyword)**

1040 This RECOMMENDED Printer Description attribute describes the overall shape of the build  
1041 platform. Values include:

1042 'ellipse': The build platform is elliptical, forming a cylindrical build volume.

1043 'rectangle': The build platform is rectangular, forming a cubic build volume.

**1044 8.3.24 platform-temperature-default (integer(-273:MAX))**

1045 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default  
1046 "platform-temperature" value. Printers that control the temperature of the Build Platform  
1047 MUST support this attribute.

1048 **8.3.25 platform-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-**  
 1049 **273:MAX)))**

1050 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported  
 1051 "platform-temperature" values and/or ranges. Printers that control the temperature of the  
 1052 Build Platform MUST support this attribute.

1053 **8.3.26 print-accuracy-default (collection)**

1054 This REQUIRED Printer Description attribute specifies the default "print-accuracy" value.

1055 **8.3.27 print-accuracy-supported (collection)**

1056 This REQUIRED Printer Description attribute specifies the best "print-accuracy" value that  
 1057 is supported by the Printer.

1058 **8.3.28 print-base-default (type2 keyword)**

1059 This REQUIRED Printer Description attribute specifies the default "print-base" value.

1060 **8.3.29 print-base-supported (1setOf type2 keyword)**

1061 This REQUIRED Printer Description attribute lists the supported "print-base" values.

1062 **8.3.30 print-objects-supported (1setOf type2 keyword)**

1063 This CONDITIONALLY REQUIRED Printer Description attribute specifies which "print-  
 1064 objects" member attributes are supported. Printers that support the 'application/pdf'  
 1065 Document format MUST support this attribute.

1066 **8.3.31 print-supports-default (type2 keyword)**

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

1068 **8.3.32 print-supports-supported (1setOf type2 keyword)**

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

1070 **8.3.33 printer-volume-supported (collection)**

1071 This REQUIRED Printer Description attribute specifies the maximum build volume supported  
 1072 by the Printer. Table 15 lists the REQUIRED member attributes.

1073 **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))

**1074 8.3.33.1 x-dimension (integer(1:MAX))**

1075 This member attributes specifies the width of the build volume in hundredths of millimeters  
1076 (1/2540th of an inch).

**1077 8.3.33.2 y-dimension (integer(1:MAX))**

1078 This member attributes specifies the depth of the build volume in hundredths of millimeters  
1079 (1/2540th of an inch).

**1080 8.3.33.3 z-dimension (integer(1:MAX))**

1081 This member attributes specifies the height of the build volume in hundredths of millimeters  
1082 (1/2540th of an inch).

**1083 8.4 Printer Status Attributes****1084 8.4.1 chamber-humidity-current (integer(0:100) | unknown)**

1085 This Printer Status attribute reports the current relative humidity of the build chamber as a  
1086 percentage. Printers that support the "chamber-humidity" Job Template attribute (section  
1087 8.1.1) MUST support this attribute.

**1088 8.4.2 chamber-temperature-current (integer(-273:MAX) | unknown)**

1089 This Printer Status attribute reports the current temperature of the build chamber in degrees  
1090 Celsius, if known. Printers that support the "chamber-temperature" Job Template attribute  
1091 (section 8.1.2) MUST support this attribute.

**1092 8.4.3 printer-camera-image-uri (1setOf uri)**

1093 This Printer Status attribute lists the URIs for one or more resident camera snapshots. Each  
1094 URI corresponds to a separate resident camera. The images referenced by each URI can  
1095 change at any time so it is up to the Client to periodically poll for changes and for the Printer  
1096 to atomically update the images so that Clients can safely do so. The referenced images  
1097 MUST be PNG [RFC2083] or JPEG [JFIF] format.

**1098 9. New Values for Existing Attributes****1099 9.1 ipp-features-supported (1setOf type2 keyword)**

1100 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-  
1101 supported" Printer Description attribute.

## 1102 9.2 printer-state-reasons (1setOf type2 keyword)

1103 This specification registers the following new values for the "printer-state-reasons" Printer  
1104 Status attribute:

1105 'camera-failure': A camera is no longer working.

1106 'chamber-cooling': A chamber is being cooled.

1107 'chamber-failure': A chamber has failed and requires maintenance or replacement.

1108 'chamber-heating': A chamber is being heated.

1109 'chamber-temperature-high': The temperature of a chamber is high.

1110 'chamber-temperature-low': The temperature of a chamber is low.

1111 'extruder-cooling': An extruder is being cooled.

1112 'extruder-failure': An extruder has failed and requires maintenance or replacement.

1113 'extruder-heating': An extruder is being heated.

1114 'extruder-jam': An extruder is jammed or clogged.

1115 'extruder-temperature-high': The temperature of an extruder is too high.

1116 'extruder-temperature-low': The temperature of an extruder is too low.

1117 'fan-failure': A fan has failed.

1118 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.

1119 'lamp-failure': A lamp has failed.

1120 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.

1121 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.

1122 'laser-failure': A laser has failed.

1123 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.

1124 'material-empty': One or more build materials have been exhausted.

1125 'material-low': One or more build materials may need replenishment soon.

1126 'material-needed': One or more build materials need to be loaded for a processing  
1127 Job.

- 1128 'motor-failure': A motor has failed.
- 1129 'platform-cooling': A Build Platform is being cooled.
- 1130 'platform-failure': A Build Platform has failed and requires maintenance or  
1131 replacement.
- 1132 'platform-heating': A Build Platform is being heated.
- 1133 'platform-temperature-high': The temperature of a Build Platform is too high.
- 1134 'platform-temperature-low': The temperature of a Build Platform is too low.  
1135



## 10. Conformance Requirements

### 10.1 Printer Conformance Requirements

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

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

### 10.2 Client Conformance Requirements

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

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

## 11. Internationalization Considerations

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

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

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

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

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

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

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

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

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

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

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

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

Unicode Character Property Model [UTR23] – character properties

Unicode Conformance Model [UTR33] – Unicode conformance basis+

Unicode Collation Algorithm [UTS10] – sorting

Unicode Locale Data Markup Language [UTS35] – locale databases

## 12. Security Considerations

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

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

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

Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

### 12.1 Confidentiality

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

### 12.2 Access Control

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

### 12.3 Physical Safety

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

### 12.4 Material Safety

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

### 12.5 Temperature Control

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

## 13. IANA and PWG Considerations

### 13.1 Attribute Registrations

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

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

The registry entries will contain the following information:

Document Status attributes:	Reference
-----	-----
materials-col-actual (1setOf collection)	[PWG5100.21]
< member attributes are the same as materials-col >	[PWG5100.21]
multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
print-accuracy-actual (collection)	[PWG5100.21]
< member attributes are the same as print-accuracy >	[PWG5100.21]
print-base-actual (1setOf type2 keyword)	[PWG5100.21]
print-objects-actual (1setOf collection)	[PWG5100.21]
< member attributes are the same as print-objects >	[PWG5100.21]
print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
Document Template attributes:	Reference
-----	-----
materials-col (1setOf collection)	[PWG5100.21]
material-amount (integer(0:MAX))	[PWG5100.21]
material-amount-units (type2 keyword)	[PWG5100.21]
material-color (type2 keyword)	[PWG5100.21]
material-diameter (integer(0:MAX))	[PWG5100.21]
material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
material-fill-density (integer(0:100))	[PWG5100.21]
material-key (keyword)	[PWG5100.21]
material-name (name(MAX))	[PWG5100.21]
material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
material-purpose (1setOf type2 keyword)	[PWG5100.21]
material-rate (integer(1:MAX))	[PWG5100.21]
material-rate-units (type2 keyword)	[PWG5100.21]
material-retraction (boolean)	[PWG5100.21]
material-shell-thickness (integer(0:MAX))	[PWG5100.21]
material-temperature (integer(-273:MAX)   rangeOfInteger(-273:MAX))	[PWG5100.21]
material-type (type2 keyword   name(MAX))	[PWG5100.21]
multiple-object-handling (type2 keyword)	[PWG5100.21]
platform-temperature (integer(-273:MAX))	[PWG5100.21]
print-accuracy (collection)	[PWG5100.21]
accuracy-units (type2 keyword)	[PWG5100.21]
x-accuracy (integer(0:MAX))	[PWG5100.21]
y-accuracy (integer(0:MAX))	[PWG5100.21]
z-accuracy (integer(0:MAX))	[PWG5100.21]
print-base (type2 keyword)	[PWG5100.21]
print-objects (1setOf collection)	[PWG5100.21]

1264	document-number (integer(1:MAX))	[PWG5100.21]
1265	object-offset (collection)	[PWG5100.21]
1266	x-offset (integer(0:MAX))	[PWG5100.21]
1267	y-offset (integer(0:MAX))	[PWG5100.21]
1268	z-offset (integer(0:MAX))	[PWG5100.21]
1269	object-size (collection)	[PWG5100.21]
1270	x-dimension (integer(1:MAX))	[PWG5100.21]
1271	y-dimension (integer(1:MAX))	[PWG5100.21]
1272	z-dimension (integer(1:MAX))	[PWG5100.21]
1273	object-uuid (uri)	[PWG5100.21]
1274	print-supports (type2 keyword)	[PWG5100.21]
1275	printer-volume-humidity (integer(0:100)   no-value)	[PWG5100.21]
1276	printer-volume-temperature (integer(-273:MAX)   no-value)	[PWG5100.21]
1277		
1278		
1279	Job Status attributes:	Reference
1280	-----	-----
1281	materials-col-actual (1setOf collection)	[PWG5100.21]
1282	< member attributes are the same as materials-col >	[PWG5100.21]
1283	multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1284	platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1285	print-accuracy-actual (collection)	[PWG5100.21]
1286	< member attributes are the same as print-accuracy >	[PWG5100.21]
1287	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1288	print-objects-actual (1setOf collection)	[PWG5100.21]
1289	< member attributes are the same as print-objects >	[PWG5100.21]
1290	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1291		
1292	Job Template attributes:	Reference
1293	-----	-----
1294	materials-col (1setOf collection)	[PWG5100.21]
1295	material-amount (integer(0:MAX))	[PWG5100.21]
1296	material-amount-units (type2 keyword)	[PWG5100.21]
1297	material-color (type2 keyword)	[PWG5100.21]
1298	material-diameter (integer(0:MAX))	[PWG5100.21]
1299	material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1300	material-fill-density (integer(0:100))	[PWG5100.21]
1301	material-key (keyword)	[PWG5100.21]
1302	material-name (name(MAX))	[PWG5100.21]
1303	material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
1304	material-purpose (1setOf type2 keyword)	[PWG5100.21]
1305	material-rate (integer(1:MAX))	[PWG5100.21]
1306	material-rate-units (type2 keyword)	[PWG5100.21]
1307	material-retraction (boolean)	[PWG5100.21]
1308	material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1309	material-temperature (integer(-273:MAX)   rangeOfInteger(-273:MAX))	[PWG5100.21]
1310		
1311	material-type (type2 keyword   name(MAX))	[PWG5100.21]
1312	multiple-object-handling (type2 keyword)	[PWG5100.21]
1313	platform-temperature (integer(-273:MAX))	[PWG5100.21]
1314	print-accuracy (collection)	[PWG5100.21]
1315	accuracy-units (type2 keyword)	[PWG5100.21]
1316	x-accuracy (integer(0:MAX))	[PWG5100.21]
1317	y-accuracy (integer(0:MAX))	[PWG5100.21]
1318	z-accuracy (integer(0:MAX))	[PWG5100.21]
1319	print-base (type2 keyword)	[PWG5100.21]

1320	print-objects (1setOf collection)	[PWG5100.21]
1321	document-number (integer(1:MAX))	[PWG5100.21]
1322	object-offset (collection)	[PWG5100.21]
1323	x-offset (integer(0:MAX))	[PWG5100.21]
1324	y-offset (integer(0:MAX))	[PWG5100.21]
1325	z-offset (integer(0:MAX))	[PWG5100.21]
1326	object-size (collection)	[PWG5100.21]
1327	x-dimension (integer(1:MAX))	[PWG5100.21]
1328	y-dimension (integer(1:MAX))	[PWG5100.21]
1329	z-dimension (integer(1:MAX))	[PWG5100.21]
1330	object-uuid (uri)	[PWG5100.21]
1331	print-supports (type2 keyword)	[PWG5100.21]
1332	printer-volume-humidity (integer(0:100)   no-value)	[PWG5100.21]
1333	printer-volume-temperature (integer(-273:MAX)   no-value)	
1334		[PWG5100.21]
1335		
1336	Printer Description attributes:	Reference
1337	-----	-----
1338	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.21]
1339	material-amount-units-supported (1setOf type2 keyword)	[PWG5100.21]
1340	material-diameter-supported (1setOf (integer(0:MAX)	
1341	rangeOfInteger(0:MAX)))	[PWG5100.21]
1342	material-nozzle-diameter-supported (1setOf (integer(0:MAX)	
1343	rangeOfInteger(0:MAX)))	[PWG5100.21]
1344	material-purpose-supported (1setOf type2 keyword)	[PWG5100.21]
1345	material-rate-supported (1setOf (integer(1:MAX)   rangeOfInteger(1:MAX)))	
1346		[PWG5100.21]
1347	material-rate-units-supported (1setOf type2 keyword)	[PWG5100.21]
1348	material-shell-thickness-supported (1setOf (integer(0:MAX)	
1349	rangeOfInteger(0:MAX)))	[PWG5100.21]
1350	material-temperature-supported (1setOf (integer(-273:MAX)	
1351	rangeOfInteger(-273:MAX)))	[PWG5100.21]
1352	material-type-supported (1setOf type2 keyword)	[PWG5100.21]
1353	materials-col-database (1setOf collection)	[PWG5100.21]
1354	< member attributes are the same as materials-col >	[PWG5100.21]
1355	materials-col-default (1setOf collection)	[PWG5100.21]
1356	< member attributes are the same as materials-col >	[PWG5100.21]
1357	materials-col-ready (1setOf collection)	[PWG5100.21]
1358	< member attributes are the same as materials-col >	[PWG5100.21]
1359	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1360	max-materials-col-supported (integer(1:MAX))	[PWG5100.21]
1361	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1362	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1363	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1364	platform-shape (type2 keyword)	[PWG5100.21]
1365	platform-temperature-default (integer(-273:MAX))	[PWG5100.21]
1366	platform-temperature-supported (1setOf (integer(-273:MAX)	
1367	rangeOfInteger(-273:MAX)))	[PWG5100.21]
1368	print-accuracy-supported (collection)	[PWG5100.21]
1369	< member attributes are the same as print-accuracy >	[PWG5100.21]
1370	print-base-default (type2 keyword)	[PWG5100.21]
1371	print-base-supported (1setOf type2 keyword)	[PWG5100.21]
1372	print-objects-supported (1setOf type2 keyword)	[PWG5100.21]
1373	print-supports-default (type2 keyword)	[PWG5100.21]
1374	print-supports-supported (1setOf type2 keyword)	[PWG5100.21]

```

1375 printer-volume-humidity-default (integer(0:100) | no-value)
1376                                     [PWG5100.21]
1377 printer-volume-humidity-supported (boolean) [PWG5100.21]
1378 printer-volume-supported (collection) [PWG5100.21]
1379     x-dimension (integer(1:MAX)) [PWG5100.21]
1380     y-dimension (integer(1:MAX)) [PWG5100.21]
1381     z-dimension (integer(1:MAX)) [PWG5100.21]
1382 printer-volume-temperature-default (integer(-273:MAX) | no-value)
1383                                     [PWG5100.21]
1384 printer-volume-temperature-supported (1setOf (integer(-273:MAX) |
1385 rangeOfInteger(-273:MAX)) [PWG5100.21]
1386
1387 Printer Status attributes: Reference
1388 -----
1389 printer-camera-image-uri (1setOf uri) [PWG5100.21]
1390 printer-volume-humidity-current (integer(0:100) | unknown)
1391                                     [PWG5100.21]
1392 printer-volume-temperature-current (integer(-273:MAX) | unknown)
1393                                     [PWG5100.21]

```

## 1394 13.2 Attribute Value Registrations

1395 The attributes defined in this specification will be published by IANA according to the  
 1396 procedures in IPP/1.1 Model and Semantics [RFC8011] section 7.1 in the following file:

1397 <http://www.iana.org/assignments/ipp-registrations>

1398 The registry entries will contain the following information:

```

1399 Attributes (attribute syntax)
1400 Keyword Attribute Value Reference
1401 -----
1402 accuracy-units (type2 keyword) [PWG5100.21]
1403     mm [PWG5100.21]
1404     nm [PWG5100.21]
1405     um [PWG5100.21]
1406 accuracy-units-supported (1setOf type2 keyword) [PWG5100.21]
1407     < any accuracy-units values > [PWG5100.21]
1408 ipp-features-supported (1setOf type2 keyword) [PWG5100.13]
1409     ipp-3d [PWG5100.21]
1410 material-amount-units (type2 keyword) [PWG5100.21]
1411     g [PWG5100.21]
1412     kg [PWG5100.21]
1413     l [PWG5100.21]
1414     m [PWG5100.21]
1415     ml [PWG5100.21]
1416     mm [PWG5100.21]
1417 material-color (type2 keyword) [PWG5100.21]
1418     < any "media" color name > [PWG5100.21]
1419 material-purpose (1setOf type2 keyword) [PWG5100.21]
1420     all [PWG5100.21]
1421     base [PWG5100.21]
1422     in-fill [PWG5100.21]
1423     shell [PWG5100.21]

```

1424	support	[PWG5100.21]
1425	material-rate-units (type2 keyword)	[PWG5100.21]
1426	mg_second	[PWG5100.21]
1427	ml_second	[PWG5100.21]
1428	mm_second	[PWG5100.21]
1429	material-type (type2 keyword)	[PWG5100.21]
1430	abs	[PWG5100.21]
1431	abs-carbon-fiber	[PWG5100.21]
1432	abs-carbon-nanotube	[PWG5100.21]
1433	chocolate	[PWG5100.21]
1434	gold	[PWG5100.21]
1435	nylon	[PWG5100.21]
1436	pet	[PWG5100.21]
1437	photopolymer	[PWG5100.21]
1438	pla	[PWG5100.21]
1439	pla-conductive	[PWG5100.21]
1440	pla-dissolvable	[PWG5100.21]
1441	pla-flexible	[PWG5100.21]
1442	pla-magnetic	[PWG5100.21]
1443	pla-steel	[PWG5100.21]
1444	pla-stone	[PWG5100.21]
1445	pla-wood	[PWG5100.21]
1446	polycarbonate	[PWG5100.21]
1447	silver	[PWG5100.21]
1448	titanium	[PWG5100.21]
1449	wax	[PWG5100.21]
1450	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1451	< any materials-col member attribute name >	[PWG5100.21]
1452	multiple-object-handling (type2 keyword)	[PWG5100.21]
1453	auto	[PWG5100.21]
1454	best-fit	[PWG5100.21]
1455	best-quality	[PWG5100.21]
1456	best-speed	[PWG5100.21]
1457	one-at-a-time	[PWG5100.21]
1458	multiple-object-handling-actual (1setOf type2 keyword)	[PWG5100.21]
1459	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1460		[PWG5100.21]
1461	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1462	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1463		[PWG5100.21]
1464	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1465	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1466		[PWG5100.21]
1467	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1468	prc	[PWG5100.21]
1469	u3d	[PWG5100.21]
1470	platform-shape (type2 keyword)	[PWG5100.21]
1471	ellipse	[PWG5100.21]
1472	rectangle	[PWG5100.21]
1473	print-base (type2 keyword)	[PWG5100.21]
1474	brim	[PWG5100.21]
1475	none	[PWG5100.21]
1476	raft	[PWG5100.21]
1477	skirt	[PWG5100.21]
1478	standard	[PWG5100.21]
1479	print-base-actual (1setOf type2 keyword)	[PWG5100.21]



```

1480     < any print-base Job Template attribute value > [PWG5100.21]
1481     print-base-default (type2 keyword) [PWG5100.21]
1482     < any print-base Job Template attribute value > [PWG5100.21]
1483     print-base-supported (1setOf type2 keyword) [PWG5100.21]
1484     < any print-base Job Template attribute value > [PWG5100.21]
1485     print-objects-supported (1setOf type2 keyword) [PWG5100.21]
1486     < any print-objects member attribute name > [PWG5100.21]
1487     print-supports (type2 keyword) [PWG5100.21]
1488         material [PWG5100.21]
1489         none [PWG5100.21]
1490         standard [PWG5100.21]
1491     print-supports-actual (1setOf type2 keyword) [PWG5100.21]
1492     < any print-supports Job Template attribute value > [PWG5100.21]
1493     print-supports-default (type2 keyword) [PWG5100.21]
1494     < any print-supports Job Template attribute value > [PWG5100.21]
1495     print-supports-supported (1setOf type2 keyword) [PWG5100.21]
1496     < any print-supports Job Template attribute value > [PWG5100.21]
1497     printer-state-reasons (1setOf type2 keyword) [RFC8011]
1498         camera-failure [PWG5100.21]
1499         chamber-cooling [PWG5100.21]
1500         chamber-failure [PWG5100.21]
1501         chamber-heating [PWG5100.21]
1502         chamber-temperature-high [PWG5100.21]
1503         chamber-temperature-low [PWG5100.21]
1504         extruder-cooling [PWG5100.21]
1505         extruder-failure [PWG5100.21]
1506         extruder-heating [PWG5100.21]
1507         extruder-jam [PWG5100.21]
1508         extruder-temperature-high [PWG5100.21]
1509         extruder-temperature-low [PWG5100.21]
1510         fan-failure [PWG5100.21]
1511         lamp-at-eol [PWG5100.21]
1512         lamp-failure [PWG5100.21]
1513         lamp-near-eol [PWG5100.21]
1514         laser-at-eol [PWG5100.21]
1515         laser-failure [PWG5100.21]
1516         laser-near-eol [PWG5100.21]
1517         material-empty [PWG5100.21]
1518         material-low [PWG5100.21]
1519         material-needed [PWG5100.21]
1520         motor-failure [PWG5100.21]
1521         platform-cooling [PWG5100.21]
1522         platform-failure [PWG5100.21]
1523         platform-heating [PWG5100.21]
1524         platform-temperature-high [PWG5100.21]
1525         platform-temperature-low [PWG5100.21]

```

### 1526 13.3 Service Type Registration

1527 The DNS-SD service type defined in this specification will be published by IANA according  
 1528 to the procedures in Internet Assigned Numbers Authority (IANA) Procedures for the  
 1529 Management of the Service Name and Transport Protocol Port Number Registry [BCP165].

1530 The registration template is as follows:

1531 Service Name: ipp3d  
 1532  
 1533 Transport Protocol(s): tcp  
 1534  
 1535 Assignee/Contact: Michael Sweet, msweet@apple.com  
 1536  
 1537 Description: 3D Print services (3D printers) using the Internet Printing  
 1538 Protocol over HTTPS.  
 1539  
 1540 Reference: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf)  
 1541 [5100.21.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf)  
 1542  
 1543 Port Number:  
 1544  
 1545 Service Code:  
 1546  
 1547 Known Unauthorized Uses:  
 1548  
 1549 Assignment Notes: Change controller is The Printer Working Group, c/o The  
 1550 IEEE Industry Standards and Technology Organization, 445 Hoes Lane,  
 1551 Piscataway, NJ 08854, USA

## 1552 14. References

### 1553 14.1 Normative References

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1576		<a href="http://ftp.pwg.org/pub/pwg/candidates/cs-ippdocobject10-20031031-5100.5.pdf">ippdocobject10-20031031-5100.5.pdf</a>
1577	[PWG5100.11]	T. Hastings, D. Fullman, "IPP Job and Printer Extensions - Set 2
1578		(JPS2)", PWG 5100.11-2010, October 2010,
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1580		<a href="http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-20101030-5100.11.pdf">20101030-5100.11.pdf</a>
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1582		5100.12-2015, October 2015,
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## 16. Object Definition Languages (ODLs)

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

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

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

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

### 16.2 Additive Manufacturing Format (AMF)

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

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

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

### 16.3 Portable Document Format (PDF)

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

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

### 16.4 Standard Tessellation Language (STL)

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



## 17. Design Choices

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

### 17.1 Units for Length Values

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

### 17.2 Units for Thickness Values

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

### 17.3 Use of Celsius for Temperatures

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

### 17.4 Explicit Units for Other Values

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

### 17.5 Intent vs. Process

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

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

1779 print time, preserving the intrinsic value of such parameters without burdening the Client or  
1780 End User with such things.

1781 At the same time, some process parameters are needed for things like material specification.  
1782 For example, a particular brand of PLA may require a higher melting temperature - this  
1783 information might only be known to the End User, so the "materials-col" collection contains  
1784 an member attribute to convey this process-specific parameter. The Printer advertises  
1785 whether temperature is a valid material property in the "materials-col-supported" Printer  
1786 Description attribute.

1787 Finally, IPP does not prohibit the definition or use of process-based Job Template attributes  
1788 for specific implementations. Such extension attributes can be listed in the "job-creation-  
1789 attributes-supported" Printer Description attribute to notify Clients of their existence.

## 1790 **17.6 Choosing a Required Document Format**

1791 One of the design consideration of this specification is to choose an open, freely available  
1792 file format for use as required document format. Having a required document format makes  
1793 interoperability significantly easier, and using an open and freely available format allows  
1794 developers of "consumer" printers to support IPP 3D. Several formats were considered,  
1795 including STL, AMF, PDF, and 3MF.

1796 While STL is a widely-implemented, open, and freely available file format, it lacks support  
1797 for multiple materials and colors/textures, and has technical issues that cause "holes" in  
1798 generated models.

1799 While AMF supports multiple materials and does not have the "holes" issue, it is not freely  
1800 available nor widely-implemented.

1801 PDF is the most capable 3D format but is not freely available and has the interoperability  
1802 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-  
1803 features-supported" Printer Description attribute (section 8.3.22) allows Clients to determine  
1804 whether a 3D PDF file can be printed by the Printer.

1805 3MF is open and freely available, supports multiple materials and color/textures, does not  
1806 have the "holes" issue of STL, and has a freely available open source implementation that  
1807 supports both creation and consumption of 3MF files.  
1808

## 18. Overview of Changes

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

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

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

1822 **19. Change History**

1823 **19.1 June 5, 2018**

- 1824 • Renamed "printer-volume-xxx" to "chamber-xxx".
- 1825 • Added "chamber-humidity" to Table 10.
- 1826 • All new attributes that were CONDITIONALLY REQUIRED are now  
1827 RECOMMENDED.
- 1828 • Added definition of material-type keyword format for standard materials.
- 1829 • Update Unicode reference now that v11 has been published.

1830 **19.2 April 26, 2018**

1831 Initial revision.