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

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

This document is a PWG Working Draft. For a definition of a "PWG Working Draft", see:

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

This document is available electronically at:

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61 For additional information regarding the Printer Working Group visit:

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262 1. Introduction

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

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

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

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

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

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

282 2. Terminology

283 2.1 Conformance Terminology

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

289 2.2 Printing Terminology

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

Deleted: RFC8011

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

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

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

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

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

304 **2.3 Protocol Role Terminology**

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

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

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

312 **2.4 3D Printing Terminology**

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

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

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

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

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

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

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

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

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

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

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

336 **2.5 Other Terminology**

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

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

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

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

344 **2.6 Acronyms and Organizations**

345 *3D PDF Consortium*: <http://www.3dpdfconsortium.org/>

346 *3MF Consortium*: 3D Manufacturing Format Consortium, <http://www.3mf.io/>

347 *CNC*: Computer Numerical Control

348 *DLP*: Digital Light Processing

349 *FDM*: Fused Deposition Modeling

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

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

- 352 *ISO*: International Organization for Standardization, <http://www.iso.org/>
- 353 *ODL*: Object Definition Language
- 354 *PWG*: Printer Working Group, <http://www.pwg.org/>
- 355 *SD*: SD Card Association, <http://www.sdcard.org/>
- 356 *SDL*: Selective Deposition Lamination
- 357 *SL*: Stereo Lithography
- 358 *USB*: Universal Serial Bus, <http://www.usb.org/>
- 359

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.

394 3.1.3 Print a 3D Object with Multiple Materials

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

399 3.1.4 Print a Tool

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

404 3.1.5 View a 3D Object During Printing

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

407 3.2 Exceptions**408 3.2.1 Clogged Extruder**

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

412 3.2.2 Extruder Temperature Out of Range

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

417 3.2.3 Extruder Head Movement Issues

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

421 3.2.4 Filament Feed Jam

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

425 **3.2.5 Filament Feed Skip**

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

429 **3.2.6 Material Empty**

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

433 **3.2.7 Material Adhesion Issues**

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

438 **3.2.8 Build Platform Temperature Out of Range**

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

442 **3.2.9 Build Platform Not Clear**

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

447 **3.3 Out of Scope**

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

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

453

454 **3.4 Design Requirements**

455 The design requirements for this document are:

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

471 The design recommendations for this document are:

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

473

474 **4. 3D Print Service Model**

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

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

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

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

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

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

499

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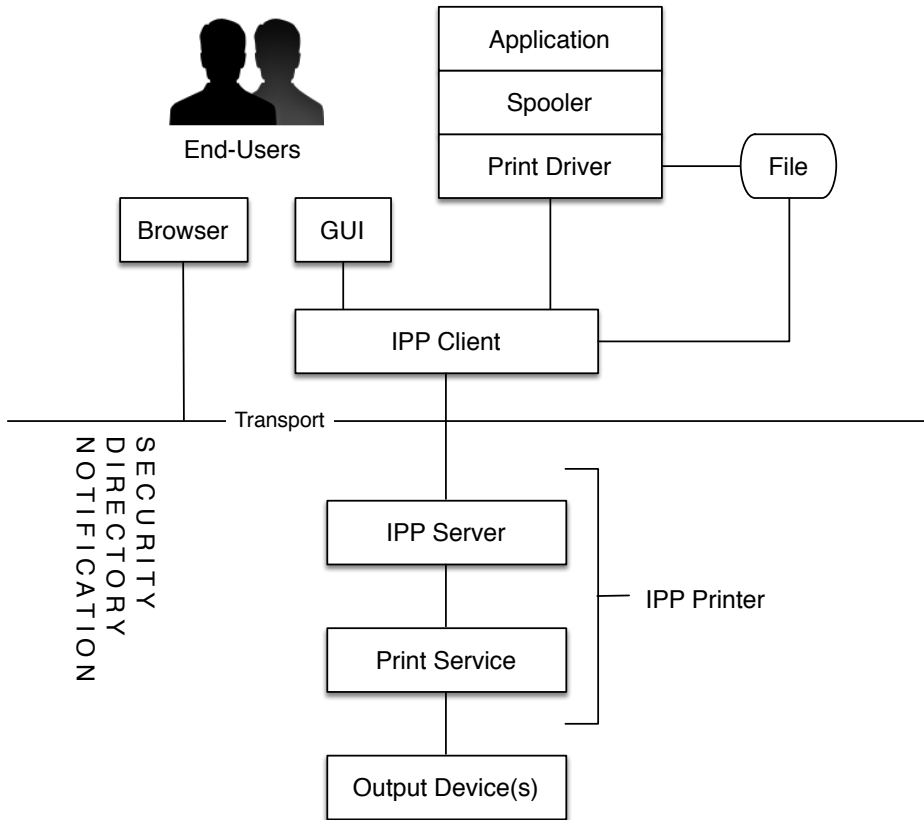


Figure 1 - Generalized IPP Model (RFC 8011)

501
502
503

504 4.1 3D Print Service

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

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512 4.2 3D Printer Subunits

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

515 **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

516 4.2.1 Finishing Devices

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

519 4.2.2 Input Trays/Rolls

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

521 4.2.3 Marker Supplies

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

525 4.2.4 Markers

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

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

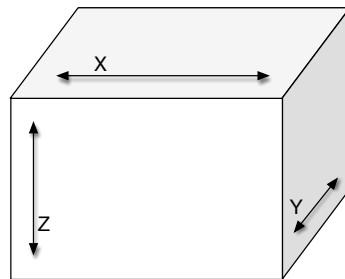
531 4.2.5 Media Paths

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

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

537 4.3 3D Printer Coordinate System

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



542

543

Figure 2 - 3D Build Volume

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

548 **4.4 Output Intent and Job Processing**

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

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

558 **4.5 Job Spooling**

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

562 **4.6 Multiple Document Jobs**

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

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

569 **4.7 Cloud-Based Printing**

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

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

577

578 5. Discovery Protocols

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

581 5.1 DNS Service Discovery (DNS-SD)

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

586 5.1.1 Service Instance Name

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

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

590 5.1.2 Service Type

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

592 5.1.3 TXT Record

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

596 **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

597 5.2 LDAP Discovery

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

601 5.2.1 printerIPPS3D Class

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

```
604 ( 1.3.18.0.2.24.46.2.1
605     NAME 'printerIPPS3D'
606     DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
607     AUXILIARY
608     SUP top
609     MAY ( printer-ipp-versions-supported $
610           printer-ipp-features-supported $
611           printer-multiple-document-jobs-supported )
612 )
```

613

614 **6. Protocol Binding**

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

618 **6.1 Transport and Resource Path**

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

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

626 **6.2 HTTP Features**

627 In addition to the IPP over HTTP conformance requirements defined in section 7.3 of IPP
628 2.0, 2.1, and 2.2 [PWG5100.12], Printers MUST support the following additional HTTP
629 headers and status codes defined in Hypertext Transfer Protocol – HTTP/1.1 [RFC7230].

630 **6.2.1 Host**

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

633 **6.2.2 If-Modified-Since, Last-Modified, and 304 Not Modified**

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

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

640 **6.2.3 Cache-Control**

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

646 **6.3 IPP Operations**

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

650 **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

651 **6.4 IPP Operation Attributes**

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

653 **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

654 **6.5 IPP Printer Description Attributes**

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

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

Attribute	Reference
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

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

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

660 Note 3: REQUIRED for Printers that control the material temperature during
661 printing.

662 Note 4: REQUIRED for Printers that have a temperature-controlled Build Platform.
663

664 **6.6 IPP Printer Status Attributes**

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

666 **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

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

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

670

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

Attribute	Source
job-printer-uri	RFC 8011
job-state	RFC 8011
job-state-message	RFC 8011
job-state-reasons	RFC 8011
job-uri	RFC 8011
job-uuid	PWG 5100.13
materials-col-actual	Section 8.2.3
multiple-object-handling-actual (note 1)	Section 8.2.4
platform-temperature-actual (note 2)	Section 8.2.6
print-accuracy-actual	Section 8.2.7
print-base-actual	Section 8.2.8
print-objects-actual (note 1)	Section 8.2.9
print-supports-actual	Section 8.2.10
time-at-completed	RFC 8011
time-at-creation	RFC 8011
time-at-processing	RFC 8011

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

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

684 6.9.1 job-id (integer)

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

690 6.9.2 job-uri (uri)

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

697 7. Document Formats

698 Printers that support Slicing MUST support Documents conforming to the 3MF [3MF]
 699 ("model/3mf") format and SHOULD support Documents conforming to the PDF [ISO32000]
 700 ("application/pdf") format containing U3D [U3D] or PRC [PRC] content. Printers that do not

701 support Slicing SHOULD support Documents conforming to a layered format such as PWG
702 Safe G-Code [PWGGCODE] and/or the 3MF Slice Extension [3MF-SLICE].

703 **8. New Attributes**

704 **8.1 Job Template Attributes**

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

707 **Table 10 - JPP 3D Job Template Attributes**

Deleted: New

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)

708 **8.1.1 chamber-humidity (integer(0:100) | no-value)**

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

712 **8.1.2 chamber-temperature (integer(-273:MAX) | no-value)**

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

716 **8.1.3 materials-col (1setOf collection)**

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

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

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

730

Table 11 - "materials-col" Member Attributes

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

731 8.1.3.1 material-amount (integer(0:MAX) | unknown)

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

736 8.1.3.2 material-amount-units (type2 keyword)

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

739 'g': Value is mass in grams.

740 'kg': Value is mass in kilograms.

741 'l': Value is volume in liters.

742 'm': Value is length in meters.

743 'ml': Value is volume in milliliters.

744 'mm': Value is length in millimeters.

745 8.1.3.3 material-color (type2 keyword)

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

748 8.1.3.4 material-diameter (integer(0:MAX))

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

752 8.1.3.5 material-diameter-tolerance (integer(0:MAX))

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

755 8.1.3.6 material-fill-density (integer(0:100))

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

758 8.1.3.7 material-key (keyword)

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

761 8.1.3.8 material-name (name(MAX))

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

763 8.1.3.9 material-nozzle-diameter (integer(0:MAX))

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

767 8.1.3.10 material-purpose (1setOf type2 keyword)

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

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

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

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

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

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

776 8.1.3.11 material-rate (integer(1:MAX))

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

779 8.1.3.12 material-rate-units (type2 keyword)

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

782 'mg_sec ': Value is milligrams per second.

783 'ml_sec ': Value is milliliters per second.

784 'mm_sec ': Value is millimeters per second.

785 8.1.3.13 material-retraction (boolean)

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

788 8.1.3.14 material-shell-thickness (integer(0:MAX))

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

791 8.1.3.15 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))

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

795 8.1.3.16 material-type (type2 keyword | name(MAX))

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

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

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

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

804 'chocolate': Chocolate.

805 'gold': Gold (metal).

806 'nylon': Nylon.

807 'pet': Polyethylene terephthalate (PET).

808 'photopolymer': Photopolymer (liquid) resin.

809 'pla': Polylactic Acid (PLA).

810 'pla-conductive': Conductive PLA.

811 'pla-dissolvable': Dissolvable PLA.

812 'pla-flexible': Flexible PLA.

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

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

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

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

817 'polycarbonate': Polycarbonate.

818 'silver': Silver (metal).

819 'titanium': Titanium (metal).

820 'wax': Wax.

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

829 8.1.4 multiple-object-handling (type2 keyword)

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

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

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

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

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

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

839 8.1.5 platform-temperature (integer(-273:MAX))

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

Deleted: RFC8011

844 **8.1.6 print-accuracy (collection)**

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

847 When enforcing attribute fidelity ("ipp-attribute-fidelity" with a value of 'true'), Printers only
848 reject "print-accuracy" values that are smaller than the "print-accuracy-supported" (section
849 8.3.27) value.

850 **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

851 **8.1.6.1 accuracy-units (type2 keyword)**

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

854 'mm': Accuracy numbers are in millimeters.

855 'um': Accuracy numbers are in micrometers.

856 'nm': Accuracy numbers are in nanometers.

857 **8.1.6.2 x-accuracy (integer(0:MAX))**

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

861 **8.1.6.3 y-accuracy (integer(0:MAX))**

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

865 **8.1.6.4 z-accuracy (integer(0:MAX))**

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

869 8.1.7 print-base (type2 keyword)

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

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

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

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

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

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

878 8.1.8 print-objects (1setOf collection)

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

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

884 **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

885

886 8.1.8.1 document-number (integer(1:MAX))

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

889 8.1.8.2 object-offset (collection)

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

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

894 **8.1.8.3 object-size (collection)**

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

898 **8.1.8.4 object-uuid (uri)**

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

901 **8.1.9 print-supports (type2 keyword)**

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

904 'none': Do not print supports.

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

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

907

908 8.2 Job Status Attributes

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

911 **Table 14 - JPP 3D "-actual" Job Status Attributes**

Job Status Attribute	Conformance
chamber-humidity-actual (1setOf integer(0:100))	RECOMMENDED
chamber-temperature-actual (1setOf integer(-273:MAX))	RECOMMENDED
materials-col-actual (1setOf collection)	REQUIRED
multiple-object-handling-actual (type2 keyword)	REQUIRED (note 1)
platform-temperature-actual (1setOf integer(-273:MAX))	REQUIRED (note 2)
print-accuracy-actual (collection)	REQUIRED
print-base-actual (1setOf type2 keyword)	REQUIRED
print-objects-actual (1setOf collection)	REQUIRED (note 1)
print-supports-actual (1setOf type2 keyword)	REQUIRED

Deleted: New

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

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

915 8.2.1 chamber-humidity-actual (1setOf integer(0:100))

916 [This Job Status attribute contains the chamber humidity values that were used throughout
917 the processing of the Job. Printers that support humidity control SHOULD support this
918 attribute.](#)

919 8.2.2 chamber-temperature-actual (1setOf integer(-273:MAX))

920 [This Job Status attribute contains the chamber temperature\(s\) that were used throughout
921 the processing of the Job. Printers that support a temperature-controlled build chamber
922 SHOULD support this attribute.](#)

923 8.2.3 materials-col-actual (1setOf collection)

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

926 8.2.4 multiple-object-handling-actual (type2 keyword)

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

931 8.2.5 print-accuracy-actual (collection)

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

933 8.2.6 platform-temperature-actual (1setOf integer(-273:MAX))

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

937 8.2.7 print-accuracy-actual (1setOf collection)

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

940 8.2.8 print-base-actual (1setOf type2 keyword)

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

943 8.2.9 print-objects-actual (1setOf collection)

944 This CONDITIONALLY REQUIRED Job Status attribute lists the objects that were
945 processed. Printers that support the 'application/pdf' document format MUST support this
946 attribute.

947 8.2.10 print-supports-actual (1setOf type2 keyword)

948 This REQUIRED Job Status attribute specifies whether supports were printed during the
949 processing of the Job.

950 8.3 Printer Description Attributes**951 8.3.1 accuracy-units-supported (1setOf type2 keyword)**

952 This REQUIRED Printer Description attribute specifies the supported "accuracy-units"
953 member attribute values.

954 8.3.2 chamber-humidity-default (integer(0:100) | no-value)

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

958 8.3.3 chamber-humidity-supported (boolean)

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

962 8.3.4 chamber-temperature-default (integer(-273:MAX) | no-value)

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

**966 8.3.5 chamber-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-
967 273:MAX)))**

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

971 8.3.6 material-amount-units-supported (1setOf type2 keyword)

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

975 8.3.7 material-diameter-supported (1setOf (integer | rangeOfInteger))

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

979 8.3.8 material-nozzle-diameter-supported (1setOf (integer | rangeOfInteger))

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

983 8.3.9 material-purpose-supported (1setOf type2 keyword)

984 This REQUIRED Printer Description attribute lists the supported "material-purpose" values
985 for the Printer.

986 8.3.10 material-rate-supported (1setOf (integer | rangeOfInteger))

987 This Printer Description attribute lists the supported "material-rate" values for the Printer.
988 This attribute MUST be supported if the "material-rate" member attribute (Section 8.1.3.11)
989 is supported.

990 8.3.11 material-rate-units-supported (1setOf type2 keyword)

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

**994 8.3.12 material-shell-thickness-supported (1setOf (integer(1:MAX) |
995 rangeOfInteger(1:MAX)))**

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

**998 8.3.13 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-
999 273:MAX)))**

1000 This CONDITIONALLY REQUIRED Printer Description attribute specifies the supported
1001 "material-temperature" values (or ranges of values) in degrees Celsius. This attribute MUST
1002 be supported if the "material-temperature" member attribute (Section 8.1.3.15) is supported.

1003 8.3.14 material-type-supported (1setOf type2 keyword)

1004 This REQUIRED Printer Description attribute lists the supported "material-type" values for
1005 the Printer.

1006 8.3.15 materials-col-database (1setOf collection)

1007 This RECOMMENDED Printer Description attribute lists the pre-configured materials for the
1008 Printer. Each value contains the corresponding "materials-col" member attributes and will
1009 typically reflect vendor and site ("third party") materials that are supported by the Printer.

1010 In order to optimize the total size of this attribute, Printers MAY omit member attributes that
1011 allow the full range of supported values in a particular collection. For example, a Printer that
1012 supports generic PLA filament can report a single collection value:

```
1013     materials-col-database =  
1014     { material-name="Generic PLA Filament" material-key="generic-pla"  
1015     material-diameter=285 material-temperature=215-235 }
```

1016 Such "wildcard" values can be combined with more precise collections that identify a specific
1017 product, for example:

```
1018     materials-col-database =  
1019     { material-name="Generic PLA Filament" material-key="generic-pla"  
1020     material-diameter=285 material-temperature=215-235 },  
1021     { material-name="Example Corp Flexible Midnight Blue PLA" material-  
1022     key="com.example.flexible-midnight-blue" material-  
1023     color="com.example.midnight-blue_000027" material-diameter=285 material-  
1024     temperature=210-225 }
```

1025 8.3.16 materials-col-default (1setOf collection)

1026 This REQUIRED Printer Description attribute lists the default materials that will be used if
1027 the "materials-col" Job Template attribute (Section 8.1.1) is not specified.

1028 8.3.17 materials-col-ready (1setOf collection)

1029 This REQUIRED Printer Description attribute lists the materials that have been loaded into
1030 the Printer. Each value contains the corresponding "materials-col" member attributes.

1031 8.3.18 materials-col-supported (1setOf type2 keyword)

1032 This REQUIRED Printer Description attribute lists the "materials-col" member attributes that
1033 are supported by the Printer. Printers MUST include the following values: 'material-fill-
1034 density', 'material-key', 'material-name', 'material-purpose', 'material-shell-thickness', and
1035 'material-type'.

1036 8.3.19 max-materials-col-supported (integer(1:MAX))

1037 This REQUIRED Printer Description attribute specifies the maximum number of values that
1038 can be provided with the "materials-col" Job Template attribute (section 8.1.1).

1039 8.3.20 multiple-object-handling-default (type2 keyword)

1040 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default
1041 "multiple-object-handling" value. Printers that support the 'application/pdf' Document format
1042 MUST support this attribute.

1043 8.3.21 multiple-object-handling-supported (1setOf type2 keyword)

1044 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported
1045 "multiple-object-handling" values. Printers that support the 'application/pdf' Document format
1046 MUST support this attribute.

1047 8.3.22 pdf-features-supported (1setOf type2 keyword)

1048 This CONDITIONALLY REQUIRED Printer Description attribute lists the PDF features that
1049 are supported by the Printer. Printers that support the 'application/pdf' Document format
1050 MUST support this attribute.

1051 Values include:

1052 'prc': The Printer supports 3D objects in the Product Representation Compact
1053 (PRC) format [ISO14739-1].

1054 'u3d': The Printer supports 3D objects in the Universal 3D (U3D) format
1055 [ECMA363].

1056 8.3.23 platform-shape (type2 keyword)

1057 This RECOMMENDED Printer Description attribute describes the overall shape of the build
1058 platform. Values include:

1059 'ellipse': The build platform is elliptical, forming a cylindrical build volume.

1060 'rectangle': The build platform is rectangular, forming a cubic build volume.

1061 8.3.24 platform-temperature-default (integer(-273:MAX))

1062 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default
1063 "platform-temperature" value. Printers that control the temperature of the Build Platform
1064 MUST support this attribute.

**1065 8.3.25 platform-temperature-supported (1setOf (integer(-273:MAX) |
1066 rangeOfInteger(-273:MAX)))**

1067 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported
1068 "platform-temperature" values and/or ranges. Printers that control the temperature of the
1069 Build Platform MUST support this attribute.

1070 8.3.26 print-accuracy-default (collection)

1071 This REQUIRED Printer Description attribute specifies the default "print-accuracy" value.

1072 8.3.27 print-accuracy-supported (collection)

1073 This REQUIRED Printer Description attribute specifies the best "print-accuracy" value that
1074 is supported by the Printer.

1075 8.3.28 print-base-default (type2 keyword)

1076 This REQUIRED Printer Description attribute specifies the default "print-base" value.

1077 8.3.29 print-base-supported (1setOf type2 keyword)

1078 This REQUIRED Printer Description attribute lists the supported "print-base" values.

1079 8.3.30 print-objects-supported (1setOf type2 keyword)

1080 This CONDITIONALLY REQUIRED Printer Description attribute specifies which "print-
1081 objects" member attributes are supported. Printers that support the 'application/pdf'
1082 Document format MUST support this attribute.

1083 8.3.31 print-supports-default (type2 keyword)

1084 This REQUIRED Printer Description attribute specifies the default "print-supports" value.

1085 **8.3.32 print-supports-supported (1setOf type2 keyword)**

1086 This REQUIRED Printer Description attribute lists the supported "print-supports" values.

1087 **8.3.33 printer-volume-supported (collection)**1088 This REQUIRED Printer Description attribute specifies the maximum build volume supported
1089 by the Printer. Table 15 lists the REQUIRED member attributes.1090 **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))

1091 **8.3.33.1 x-dimension (integer(1:MAX))**1092 This member attributes specifies the width of the build volume in hundredths of millimeters
1093 (1/2540th of an inch).1094 **8.3.33.2 y-dimension (integer(1:MAX))**1095 This member attributes specifies the depth of the build volume in hundredths of millimeters
1096 (1/2540th of an inch).1097 **8.3.33.3 z-dimension (integer(1:MAX))**1098 This member attributes specifies the height of the build volume in hundredths of millimeters
1099 (1/2540th of an inch).1100 **8.4 Printer Status Attributes**1101 **8.4.1 chamber-humidity-current (integer(0:100) | unknown)**1102 This Printer Status attribute reports the current relative humidity of the build chamber as a
1103 percentage. Printers that support the "chamber-humidity" Job Template attribute (section
1104 8.1.1) MUST support this attribute.1105 **8.4.2 chamber-temperature-current (integer(-273:MAX) | unknown)**1106 This Printer Status attribute reports the current temperature of the build chamber in degrees
1107 Celsius, if known. Printers that support the "chamber-temperature" Job Template attribute
1108 (section 8.1.2) MUST support this attribute.

1109 8.4.3 printer-camera-image-uri (1setOf uri)

1110 This Printer Status attribute lists the URIs for one or more resident camera snapshots. Each
1111 URI corresponds to a separate resident camera. The images referenced by each URI can
1112 change at any time so it is up to the Client to periodically poll for changes and for the Printer
1113 to atomically update the images so that Clients can safely do so. The referenced images
1114 MUST be PNG [RFC2083] or JPEG [JFIF] format.

1115 9. New Values for Existing Attributes**1116 9.1 ipp-features-supported (1setOf type2 keyword)**

1117 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-
1118 supported" Printer Description attribute.

1119 9.2 printer-state-reasons (1setOf type2 keyword)

1120 This specification registers the following new values for the "printer-state-reasons" Printer
1121 Status attribute:

- 1122 'camera-failure': A camera is no longer working.
- 1123 'chamber-cooling': A chamber is being cooled.
- 1124 'chamber-failure': A chamber has failed and requires maintenance or replacement.
- 1125 'chamber-heating': A chamber is being heated.
- 1126 'chamber-temperature-high': The temperature of a chamber is high.
- 1127 'chamber-temperature-low': The temperature of a chamber is low.
- 1128 'extruder-cooling': An extruder is being cooled.
- 1129 'extruder-failure': An extruder has failed and requires maintenance or replacement.
- 1130 'extruder-heating': An extruder is being heated.
- 1131 'extruder-jam': An extruder is jammed or clogged.
- 1132 'extruder-temperature-high': The temperature of an extruder is too high.
- 1133 'extruder-temperature-low': The temperature of an extruder is too low.
- 1134 'fan-failure': A fan has failed.

- 1135 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.
- 1136 'lamp-failure': A lamp has failed.
- 1137 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.
- 1138 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.
- 1139 'laser-failure': A laser has failed.
- 1140 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.
- 1141 'material-empty': One or more build materials have been exhausted.
- 1142 'material-low': One or more build materials may need replenishment soon.
- 1143 'material-needed': One or more build materials need to be loaded for a processing
1144 Job.
- 1145 'motor-failure': A motor has failed.
- 1146 'platform-cooling': A Build Platform is being cooled.
- 1147 'platform-failure': A Build Platform has failed and requires maintenance or
1148 replacement.
- 1149 'platform-heating': A Build Platform is being heated.
- 1150 'platform-temperature-high': The temperature of a Build Platform is too high.
- 1151 'platform-temperature-low': The temperature of a Build Platform is too low.
- 1152

1153 **10. Conformance Requirements**

1154 **10.1 Printer Conformance Requirements**

1155 In order for a Printer to claim conformance to this specification, a Printer MUST support:

- 1156 1. The required discovery protocols in section 5;
- 1157 2. The required transports and resource paths in section 6.1;
- 1158 3. The required HTTP features in section 6.2;
- 1159 4. The required IPP operations in section 6.3;
- 1160 5. The required IPP attributes in sections 6.4 through 6.9;
- 1161 6. The required document formats in section 7;
- 1162 7. The additional values defined in section 9;
- 1163 8. The internationalization considerations in section 11; and
- 1164 9. The security considerations in section 12.

1165 **10.2 Client Conformance Requirements**

1166 In order for a Client to claim conformance to this specification, a Client MUST support:

- 1167 1. The required discovery protocols in section 5;
- 1168 2. The required transports and resource paths in section 6.1;
- 1169 3. The required HTTP features in section 6.2;
- 1170 4. The required IPP operations in section 6.3;
- 1171 5. The required IPP attributes in sections 6.4 through 6.9;
- 1172 6. The required document formats in section 7;
- 1173 7. The additional values defined in section 9;
- 1174 8. The internationalization considerations in section 11; and
- 1175 9. The security considerations in section 12.

1176

1177 **11. Internationalization Considerations**

1178 For interoperability and basic support for multiple languages, conforming implementations
1179 MUST support:

- 1180 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)
1181 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 1182 2. The Unicode Format for Network Interchange [RFC5198] which requires
1183 transmission of well-formed UTF-8 strings and recommends transmission of
1184 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1185 Unicode NFC is defined as the result of performing Canonical Decomposition (into base
1186 characters and combining marks) followed by Canonical Composition (into canonical
1187 composed characters wherever Unicode has assigned them).

1188 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and
1189 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in IPP
1190 Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8 URIs
1191 now 'hidden').

1192 Implementations of this specification SHOULD conform to the following standards on
1193 processing of human-readable Unicode text strings, see:

1194 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical

1195 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping

1196 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]

1197 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences

1198 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization

1199 Unicode Character Encoding Model [UTR17] – multi-layer character model

1200 Unicode in XML and other Markup Languages [UTR20] – XML usage

1201 Unicode Character Property Model [UTR23] – character properties

1202 Unicode Conformance Model [UTR33] – Unicode conformance basis+

1203 Unicode Collation Algorithm [UTS10] – sorting

1204 Unicode Locale Data Markup Language [UTS35] – locale databases

1205 **12. Security Considerations**

1206 In addition to the security considerations described in the IPP/1.1: Model and Semantics
1207 [\[STD92\]](#), the following sub-sections describe issues that are unique to 3D printing.

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1208 Implementations of this specification SHOULD conform to the following standards on
1209 processing of human-readable Unicode text strings, see:

1210 Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1211 Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

1212 **12.1 Confidentiality**

1213 Clients and Printers MUST provide confidentiality of data in transit using either an interface
1214 providing physical security such as USB or using TLS encryption [RFC5246] over
1215 unsecured/network connections,

1216 **12.2 Access Control**

1217 Because of the potential for abuse and misuse, Printers SHOULD provide access control
1218 mechanisms including lists of allowed Clients, authentication, and authorization to site
1219 defined policies.

1220 **12.3 Physical Safety**

1221 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such
1222 as protective gates, covers, or interlocks.

1223 **12.4 Material Safety**

1224 Printers MUST restrict usage and combination of materials to those that can be safely
1225 printed. Access controls (section 12.2) MAY be used to allow authorized End Users to
1226 experiment with untested materials or combinations, but only when such materials or
1227 combinations can reasonably be expected to not pose a safety risk.

1228 **12.5 Temperature Control**

1229 Printers MUST validate values provided by Clients and limit material, extruder, Build
1230 Platform, and print chamber temperatures within designed limits to prevent unsafe operating
1231 conditions, damage to the hardware, hazardous emissions, explosions, and/or fires.

1232

1234 **13. IANA and PWG Considerations**1235 **13.1 Attribute Registrations**

1236 The attributes defined in this specification will be published by IANA according to the
 1237 procedures in IPP/1.1 Model and Semantics [STD92] section 7.2 in the following file:

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1238 <http://www.iana.org/assignments/ipp-registrations>

1239 The registry entries will contain the following information:

1240	Document Status attributes:	Reference
1241	-----	-----
1242	chamber-humidity-actual (1setOf integer(0:100))	[PWG5100.21]
1243	chamber-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1244	materials-col-actual (1setOf collection)	[PWG5100.21]
1245	< member attributes are the same as materials-col >	[PWG5100.21]
1246	multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1247	platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1248	print-accuracy-actual (collection)	[PWG5100.21]
1249	< member attributes are the same as print-accuracy >	[PWG5100.21]
1250	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1251	print-objects-actual (1setOf collection)	[PWG5100.21]
1252	< member attributes are the same as print-objects >	[PWG5100.21]
1253	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1254		
1255	Document Template attributes:	Reference
1256	-----	-----
1257	chamber-humidity (integer(0:100))	[PWG5100.21]
1258	chamber-temperature (integer(-273:MAX))	[PWG5100.21]
1259	materials-col (1setOf collection)	[PWG5100.21]
1260	material-amount (integer(0:MAX))	[PWG5100.21]
1261	material-amount-units (type2 keyword)	[PWG5100.21]
1262	material-color (type2 keyword)	[PWG5100.21]
1263	material-diameter (integer(0:MAX))	[PWG5100.21]
1264	material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1265	material-fill-density (integer(0:100))	[PWG5100.21]
1266	material-key (keyword)	[PWG5100.21]
1267	material-name (name(MAX))	[PWG5100.21]
1268	material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
1269	material-purpose (1setOf type2 keyword)	[PWG5100.21]
1270	material-rate (integer(1:MAX))	[PWG5100.21]
1271	material-rate-units (type2 keyword)	[PWG5100.21]
1272	material-retraction (boolean)	[PWG5100.21]
1273	material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1274	material-temperature (integer(-273:MAX) rangeOfInteger(-273:MAX))	[PWG5100.21]
1275		
1276	material-type (type2 keyword name(MAX))	[PWG5100.21]
1277	multiple-object-handling (type2 keyword)	[PWG5100.21]
1278	platform-temperature (integer(-273:MAX))	[PWG5100.21]
1279	print-accuracy (collection)	[PWG5100.21]
1280	accuracy-units (type2 keyword)	[PWG5100.21]
1281	x-accuracy (integer(0:MAX))	[PWG5100.21]

1283	y-accuracy (integer(0:MAX))	[PWG5100.21]
1284	z-accuracy (integer(0:MAX))	[PWG5100.21]
1285	print-base (type2 keyword)	[PWG5100.21]
1286	print-objects (1setOf collection)	[PWG5100.21]
1287	document-number (integer(1:MAX))	[PWG5100.21]
1288	object-offset (collection)	[PWG5100.21]
1289	x-offset (integer(0:MAX))	[PWG5100.21]
1290	y-offset (integer(0:MAX))	[PWG5100.21]
1291	z-offset (integer(0:MAX))	[PWG5100.21]
1292	object-size (collection)	[PWG5100.21]
1293	x-dimension (integer(1:MAX))	[PWG5100.21]
1294	y-dimension (integer(1:MAX))	[PWG5100.21]
1295	z-dimension (integer(1:MAX))	[PWG5100.21]
1296	object-uuid (uri)	[PWG5100.21]
1297	print-supports (type2 keyword)	[PWG5100.21]
1298		
1299	▼ Job Status attributes:	Reference
1300	-----	-----
1301	<u>chamber-humidity-actual (1setOf integer(0:100))</u>	<u>[PWG5100.21]</u>
1302	<u>chamber-temperature-actual (1setOf integer(-273:MAX))</u>	<u>[PWG5100.21]</u>
1303	materials-col-actual (1setOf collection)	[PWG5100.21]
1304	< member attributes are the same as materials-col >	[PWG5100.21]
1305	multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1306	platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1307	print-accuracy-actual (collection)	[PWG5100.21]
1308	< member attributes are the same as print-accuracy >	[PWG5100.21]
1309	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1310	print-objects-actual (1setOf collection)	[PWG5100.21]
1311	< member attributes are the same as print-objects >	[PWG5100.21]
1312	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1313		
1314	Job Template attributes:	Reference
1315	-----	-----
1316	<u>chamber-humidity (integer(0:100))</u>	<u>[PWG5100.21]</u>
1317	<u>chamber-temperature (integer(-273:MAX))</u>	<u>[PWG5100.21]</u>
1318	materials-col (1setOf collection)	[PWG5100.21]
1319	material-amount (integer(0:MAX))	[PWG5100.21]
1320	material-amount-units (type2 keyword)	[PWG5100.21]
1321	material-color (type2 keyword)	[PWG5100.21]
1322	material-diameter (integer(0:MAX))	[PWG5100.21]
1323	material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1324	material-fill-density (integer(0:100))	[PWG5100.21]
1325	material-key (keyword)	[PWG5100.21]
1326	material-name (name(MAX))	[PWG5100.21]
1327	material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
1328	material-purpose (1setOf type2 keyword)	[PWG5100.21]
1329	material-rate (integer(1:MAX))	[PWG5100.21]
1330	material-rate-units (type2 keyword)	[PWG5100.21]
1331	material-retraction (boolean)	[PWG5100.21]
1332	material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1333	material-temperature (integer(-273:MAX) rangeOfInteger(-273:MAX))	[PWG5100.21]
1334		[PWG5100.21]
1335	material-type (type2 keyword name(MAX))	[PWG5100.21]
1336	multiple-object-handling (type2 keyword)	[PWG5100.21]
1337	platform-temperature (integer(-273:MAX))	[PWG5100.21]
1338	print-accuracy (collection)	[PWG5100.21]

Deleted: printer-volume-humidity (integer(0:100) | no-value) → [PWG5100.21] §
 printer-volume-temperature (integer(-273:MAX) | no-value) → [PWG5100.21] §

1343	accuracy-units (type2 keyword)	[PWG5100.21]
1344	x-accuracy (integer(0:MAX))	[PWG5100.21]
1345	y-accuracy (integer(0:MAX))	[PWG5100.21]
1346	z-accuracy (integer(0:MAX))	[PWG5100.21]
1347	print-base (type2 keyword)	[PWG5100.21]
1348	print-objects (1setOf collection)	[PWG5100.21]
1349	document-number (integer(1:MAX))	[PWG5100.21]
1350	object-offset (collection)	[PWG5100.21]
1351	x-offset (integer(0:MAX))	[PWG5100.21]
1352	y-offset (integer(0:MAX))	[PWG5100.21]
1353	z-offset (integer(0:MAX))	[PWG5100.21]
1354	object-size (collection)	[PWG5100.21]
1355	x-dimension (integer(1:MAX))	[PWG5100.21]
1356	y-dimension (integer(1:MAX))	[PWG5100.21]
1357	z-dimension (integer(1:MAX))	[PWG5100.21]
1358	object-uuid (uri)	[PWG5100.21]
1359	print-supports (type2 keyword)	[PWG5100.21]
1360	Printer Description attributes:	Reference
1361	-----	-----
1362	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.21]
1363	chamber-humidity-default (integer(0:100) no-value)	[PWG5100.21]
1364	chamber-humidity-supported (boolean)	[PWG5100.21]
1365	chamber-temperature-default (integer(-273:MAX) no-value)	[PWG5100.21]
1366	chamber-temperature-supported (1setOf (integer(-273:MAX) rangeOfInteger(-273:MAX)))	[PWG5100.21]
1367	material-amount-units-supported (1setOf type2 keyword)	[PWG5100.21]
1368	material-diameter-supported (1setOf (integer(0:MAX) rangeOfInteger(0:MAX)))	[PWG5100.21]
1369	material-nozzle-diameter-supported (1setOf (integer(0:MAX) rangeOfInteger(0:MAX)))	[PWG5100.21]
1370	material-purpose-supported (1setOf type2 keyword)	[PWG5100.21]
1371	material-rate-supported (1setOf (integer(1:MAX) rangeOfInteger(1:MAX)))	[PWG5100.21]
1372	material-rate-units-supported (1setOf type2 keyword)	[PWG5100.21]
1373	material-shell-thickness-supported (1setOf (integer(0:MAX) rangeOfInteger(0:MAX)))	[PWG5100.21]
1374	material-temperature-supported (1setOf (integer(-273:MAX) rangeOfInteger(-273:MAX)))	[PWG5100.21]
1375	material-type-supported (1setOf type2 keyword)	[PWG5100.21]
1376	materials-col-database (1setOf collection)	[PWG5100.21]
1377	< member attributes are the same as materials-col >	[PWG5100.21]
1378	materials-col-default (1setOf collection)	[PWG5100.21]
1379	< member attributes are the same as materials-col >	[PWG5100.21]
1380	materials-col-ready (1setOf collection)	[PWG5100.21]
1381	< member attributes are the same as materials-col >	[PWG5100.21]
1382	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1383	max-materials-col-supported (integer(1:MAX))	[PWG5100.21]
1384	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1385	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1386	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1387	platform-shape (type2 keyword)	[PWG5100.21]
1388	platform-temperature-default (integer(-273:MAX))	[PWG5100.21]
1389	platform-temperature-supported (1setOf (integer(-273:MAX) rangeOfInteger(-273:MAX)))	[PWG5100.21]
1390		
1391		
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1396		
1397		
1398		

Deleted: printer-volume-humidity (integer(0:100) | no-value) → [PWG5100.21]§

Deleted: printer-volume-temperature (integer(-273:MAX) | no-value) → [PWG5100.21]§

Moved (insertion) [1]

Deleted: printer-volume

Deleted: →

Deleted: printer-volume

Moved (insertion) [2]

Deleted: printer-volume

Deleted: printer-volume

Deleted: →

```

1409 print-accuracy-supported (collection) [PWG5100.21]
1410 < member attributes are the same as print-accuracy > [PWG5100.21]
1411 print-base-default (type2 keyword) [PWG5100.21]
1412 print-base-supported (1setOf type2 keyword) [PWG5100.21]
1413 print-objects-supported (1setOf type2 keyword) [PWG5100.21]
1414 print-supports-default (type2 keyword) [PWG5100.21]
1415 print-supports-supported (1setOf type2 keyword) [PWG5100.21]
1416 printer-volume-supported (collection) [PWG5100.21]
1417   x-dimension (integer(1:MAX)) [PWG5100.21]
1418   y-dimension (integer(1:MAX)) [PWG5100.21]
1419   z-dimension (integer(1:MAX)) [PWG5100.21]
1420
1421 ▲ Printer Status attributes: Reference
1422 -----
1423 chamber-humidity-current \(integer\(0:100\) | unknown\) [PWG5100.21]
1424 chamber-temperature-current \(integer\(-273:MAX\) | unknown\) [PWG5100.21]
1425 printer-camera-image-uri (1setOf uri) [PWG5100.21]
    
```

Moved up [1]: printer-volume-humidity-default (integer(0:100) | no-value) → [PWG5100.21] §
 printer-volume-humidity-supported (boolean) → [PWG5100.21] §

Moved up [2]: printer-volume-temperature-default (integer(-273:MAX) | no-value) → [PWG5100.21] §
 printer-volume-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-273:MAX))) → [PWG5100.21] §

1426 13.2 Attribute Value Registrations

1427 The attributes defined in this specification will be published by IANA according to the
 1428 procedures in IPP/1.1 Model and Semantics [STD92] section 7.1 in the following file:

1429 <http://www.iana.org/assignments/ipp-registrations>

1430 The registry entries will contain the following information:

```

1431 Attributes (attribute syntax)
1432 Keyword Attribute Value Reference
1433 -----
1434 accuracy-units (type2 keyword) [PWG5100.21]
1435   mm [PWG5100.21]
1436   nm [PWG5100.21]
1437   um [PWG5100.21]
1438 accuracy-units-supported (1setOf type2 keyword) [PWG5100.21]
1439 < any accuracy-units values > [PWG5100.21]
1440 ipp-features-supported (1setOf type2 keyword) [PWG5100.13]
1441   ipp-3d [PWG5100.21]
1442 material-amount-units (type2 keyword) [PWG5100.21]
1443   g [PWG5100.21]
1444   kg [PWG5100.21]
1445   l [PWG5100.21]
1446   m [PWG5100.21]
1447   ml [PWG5100.21]
1448   mm [PWG5100.21]
1449 material-color (type2 keyword) [PWG5100.21]
1450 < any "media" color name > [PWG5100.21]
1451 material-purpose (1setOf type2 keyword) [PWG5100.21]
1452   all [PWG5100.21]
1453   base [PWG5100.21]
1454   in-fill [PWG5100.21]
1455   shell [PWG5100.21]
1456   support [PWG5100.21]
1457 material-rate-units (type2 keyword) [PWG5100.21]
    
```

Deleted: printer-volume-humidity-current (integer(0:100) | unknown) → [PWG5100.21] §
 printer-volume-temperature-current (integer(-273:MAX) | unknown) → [PWG5100.21] §

Deleted: RFC8011

1473	mg_second	[PWG5100.21]
1474	ml_second	[PWG5100.21]
1475	mm_second	[PWG5100.21]
1476	material-type (type2 keyword)	[PWG5100.21]
1477	abs	[PWG5100.21]
1478	abs-carbon-fiber	[PWG5100.21]
1479	abs-carbon-nanotube	[PWG5100.21]
1480	chocolate	[PWG5100.21]
1481	gold	[PWG5100.21]
1482	nylon	[PWG5100.21]
1483	pet	[PWG5100.21]
1484	photopolymer	[PWG5100.21]
1485	pla	[PWG5100.21]
1486	pla-conductive	[PWG5100.21]
1487	pla-dissolvable	[PWG5100.21]
1488	pla-flexible	[PWG5100.21]
1489	pla-magnetic	[PWG5100.21]
1490	pla-steel	[PWG5100.21]
1491	pla-stone	[PWG5100.21]
1492	pla-wood	[PWG5100.21]
1493	polycarbonate	[PWG5100.21]
1494	silver	[PWG5100.21]
1495	titanium	[PWG5100.21]
1496	wax	[PWG5100.21]
1497	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1498	< any materials-col member attribute name >	[PWG5100.21]
1499	multiple-object-handling (type2 keyword)	[PWG5100.21]
1500	auto	[PWG5100.21]
1501	best-fit	[PWG5100.21]
1502	best-quality	[PWG5100.21]
1503	best-speed	[PWG5100.21]
1504	one-at-a-time	[PWG5100.21]
1505	multiple-object-handling-actual (1setOf type2 keyword)	[PWG5100.21]
1506	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1507		[PWG5100.21]
1508	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1509	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1510		[PWG5100.21]
1511	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1512	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1513		[PWG5100.21]
1514	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1515	prc	[PWG5100.21]
1516	u3d	[PWG5100.21]
1517	platform-shape (type2 keyword)	[PWG5100.21]
1518	ellipse	[PWG5100.21]
1519	rectangle	[PWG5100.21]
1520	print-base (type2 keyword)	[PWG5100.21]
1521	brim	[PWG5100.21]
1522	none	[PWG5100.21]
1523	raft	[PWG5100.21]
1524	skirt	[PWG5100.21]
1525	standard	[PWG5100.21]
1526	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1527	< any print-base Job Template attribute value >	[PWG5100.21]
1528	print-base-default (type2 keyword)	[PWG5100.21]

1529	< any print-base Job Template attribute value >	[PWG5100.21]
1530	print-base-supported (1setOf type2 keyword)	[PWG5100.21]
1531	< any print-base Job Template attribute value >	[PWG5100.21]
1532	print-objects-supported (1setOf type2 keyword)	[PWG5100.21]
1533	< any print-objects member attribute name >	[PWG5100.21]
1534	print-supports (type2 keyword)	[PWG5100.21]
1535	material	[PWG5100.21]
1536	none	[PWG5100.21]
1537	standard	[PWG5100.21]
1538	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1539	< any print-supports Job Template attribute value >	[PWG5100.21]
1540	print-supports-default (type2 keyword)	[PWG5100.21]
1541	< any print-supports Job Template attribute value >	[PWG5100.21]
1542	print-supports-supported (1setOf type2 keyword)	[PWG5100.21]
1543	< any print-supports Job Template attribute value >	[PWG5100.21]
1544	printer-state-reasons (1setOf type2 keyword)	[RFC8011]
1545	camera-failure	[PWG5100.21]
1546	chamber-cooling	[PWG5100.21]
1547	chamber-failure	[PWG5100.21]
1548	chamber-heating	[PWG5100.21]
1549	chamber-temperature-high	[PWG5100.21]
1550	chamber-temperature-low	[PWG5100.21]
1551	extruder-cooling	[PWG5100.21]
1552	extruder-failure	[PWG5100.21]
1553	extruder-heating	[PWG5100.21]
1554	extruder-jam	[PWG5100.21]
1555	extruder-temperature-high	[PWG5100.21]
1556	extruder-temperature-low	[PWG5100.21]
1557	fan-failure	[PWG5100.21]
1558	lamp-at-eol	[PWG5100.21]
1559	lamp-failure	[PWG5100.21]
1560	lamp-near-eol	[PWG5100.21]
1561	laser-at-eol	[PWG5100.21]
1562	laser-failure	[PWG5100.21]
1563	laser-near-eol	[PWG5100.21]
1564	material-empty	[PWG5100.21]
1565	material-low	[PWG5100.21]
1566	material-needed	[PWG5100.21]
1567	motor-failure	[PWG5100.21]
1568	platform-cooling	[PWG5100.21]
1569	platform-failure	[PWG5100.21]
1570	platform-heating	[PWG5100.21]
1571	platform-temperature-high	[PWG5100.21]
1572	platform-temperature-low	[PWG5100.21]

1573 13.3 Service Type Registration

1574 The DNS-SD service type defined in this specification will be published by IANA according
 1575 to the procedures in Internet Assigned Numbers Authority (IANA) Procedures for the
 1576 Management of the Service Name and Transport Protocol Port Number Registry [BCP165].

1577 The registration template is as follows:

1578 Service Name: ipps-3d

1579
1580 Transport Protocol(s): tcp
1581
1582 Assignee/Contact: Michael Sweet, msweet@apple.com
1583
1584 Description: 3D Print services (3D printers) using the Internet Printing
1585 Protocol over HTTPS.
1586
1587 Reference: <http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf>
1588
1589
1590 Port Number:
1591
1592 Service Code:
1593
1594 Known Unauthorized Uses:
1595
1596 Assignment Notes: Change controller is The Printer Working Group, c/o The
1597 IEEE Industry Standards and Technology Organization, 445 Hoes Lane,
1598 Piscataway, NJ 08854, USA

1599 14. References

1600 14.1 Normative References

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1770 **16. Object Definition Languages (ODLs)**

1771 This section provides information on several commonly used ODLs with either existing
1772 (registered) or suggested MIME media types.

1773 **16.1 3D Manufacturing Format (3MF)**

1774 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that
1775 provides geometry, material, and texture information necessary to support a wide variety of
1776 3D printers. Materials can be named and composed within the geometry, facilitating multiple
1777 material support in coordination with a Job Ticket.

1778 The registered MIME media type for the original Microsoft published specification is
1779 "application/vnd.ms-3mfdocument". The MIME media type for the 3MF Consortium's
1780 published specification is "model/3mf".

1781 **16.2 Additive Manufacturing Format (AMF)**

1782 AMF [ISO52915] is a relatively new format that was designed as a replacement for the
1783 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-
1784 available specification, but has several advantages over STL including:

- 1785 1. Shared vertices which eliminates holes and other breaks in the surface
1786 geometry of objects,
- 1787 2. Specification of multiple materials in a single file,
- 1788 3. Curved surfaces can be specified, and
- 1789 4. Coordinates use explicit units for proper output dimensions.

1790 The suggested (but not registered) MIME media type is 'model/amf'.

1791 **16.3 Portable Document Format (PDF)**

1792 PDF [ISO32000] is widely supported for 2D printing and has two 3D formats that are used
1793 to embed 3D objects - PRC [ISO14739-1] and U3D [ECMA363]. The registered MIME media
1794 type for PDF is "application/pdf".

1795 [For discussion: define a "model/pdf" MIME media type for PDFs containing 3D content?]

1796 **16.4 Standard Tessellation Language (STL)**

1797 STL [STLFORMAT] is widely supported by existing client software. The registered MIME
1798 media type is 'application/sla'.

1799

1800 **17. Design Choices**

1801 This section documents some of the design choices that were made during the development
1802 of this specification.

1803 **17.1 Units for Length Values**

1804 The default unit for most length values is hundredths of millimeters (1/2540th of an inch),
1805 matching the units for 2D printing and providing a range of 0.01mm to 21.47km. This was
1806 determined to be sufficient for the class of printers this specification targets.

1807 **17.2 Units for Thickness Values**

1808 The default unit for most thickness values is nanometers, which provides a range of
1809 0.000001mm to 2.147m. This was determined to be sufficient for the class of printers this
1810 specification targets.

1811 **17.3 Use of Celsius for Temperatures**

1812 The various integer attributes for temperature use degrees Celsius. This was done because
1813 most existing printers and materials are specified using degrees Celsius. There is no
1814 advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to perform
1815 additional unit conversions could cause safety issues. All temperature attributes use a range
1816 of -273 (absolute zero) to MAX (2147483647 - significantly hotter than our sun) to allow
1817 flexibility.

1818 **17.4 Explicit Units for Other Values**

1819 Some attributes have a companion "xxx-units" attribute that specifies an explicit unit for the
1820 given measurement(s). The initial list of unit values for each attribute has been limited to
1821 those necessary for current printers and technologies at the time of writing of this
1822 specification in order to minimize interoperability issues.

1823 **17.5 Intent vs. Process**

1824 The IPP Model [RFC8011], and more generally the PWG Semantic Model [PWG5108.1],
1825 have long focused on Job Tickets specifying "what" is wanted for the printed output vs. "how"
1826 that output is produced. This focus has served IPP well and allowed it to be used with wildly
1827 different printing technologies.

1828 During the development of this specification, attributes that define a specific process or
1829 technological parameter have been introduced and later replaced by intent-based
1830 alternatives that allow an implementation to select suitable process-based parameters at

1831 print time, preserving the intrinsic value of such parameters without burdening the Client or
1832 End User with such things.

1833 At the same time, some process parameters are needed for things like material specification.
1834 For example, a particular brand of PLA may require a higher melting temperature - this
1835 information might only be known to the End User, so the "materials-col" collection contains
1836 an member attribute to convey this process-specific parameter. The Printer advertises
1837 whether temperature is a valid material property in the "materials-col-supported" Printer
1838 Description attribute.

1839 Finally, IPP does not prohibit the definition or use of process-based Job Template attributes
1840 for specific implementations. Such extension attributes can be listed in the "job-creation-
1841 attributes-supported" Printer Description attribute to notify Clients of their existence.

1842 **17.6 Choosing a Required Document Format**

1843 One of the design consideration of this specification is to choose an open, freely available
1844 file format for use as required document format. Having a required document format makes
1845 interoperability significantly easier, and using an open and freely available format allows
1846 developers of "consumer" printers to support IPP 3D. Several formats were considered,
1847 including STL, AMF, PDF, and 3MF.

1848 While STL is a widely-implemented, open, and freely available file format, it lacks support
1849 for multiple materials and colors/textures, and has technical issues that cause "holes" in
1850 generated models.

1851 While AMF supports multiple materials and does not have the "holes" issue, it is not freely
1852 available nor widely-implemented.

1853 PDF is the most capable 3D format but is not freely available and has the interoperability
1854 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-
1855 features-supported" Printer Description attribute (section 8.3.22) allows Clients to determine
1856 whether a 3D PDF file can be printed by the Printer.

1857 3MF is open and freely available, supports multiple materials and color/textures, does not
1858 have the "holes" issue of STL, and has a freely available open source implementation that
1859 supports both creation and consumption of 3MF files.
1860

1861 **18. Overview of Changes**

1862 **18.1 IPP 3D Printing Extensions v1.1**

1863 The following changes were made since v1.0 of this document:

- 1864 1. Made 3MF CONDITIONALLY REQUIRED for Printers that do Slicing,
1865 RECOMMEND support for a standard layered format otherwise.
- 1866 2. Added the CONDITIONALLY REQUIRED "material-nozzle-diameter" and
1867 "material-retraction" member attributes for the "materials-col" Job Template
1868 attribute.
- 1869 3. Added the RECOMMENDED "platform-shape" Printer Description attribute
- 1870 4. Added the CONDITIONALLY REQUIRED "~~chamber-humidity~~" and "~~chamber-~~
1871 temperature" Job Template attributes.
- 1872 5. Defined a naming convention for standard "material-type" values.
1873

Deleted: printer-volume

Deleted: printer-volume

1876 **19. Change History**

1877 **19.1 July 4, 2018**

- 1878 • Status: Prototype
- 1879 • RFC 8011 is now STD 92.
- 1880 • Added missing chamber-humidity-actual and chamber-temperature-actual attributes.
- 1881 • Updated IANA registrations.

1882 **19.2 June 5, 2018**

- 1883 • Renamed "printer-volume-xxx" to "chamber-xxx".
- 1884 • Added "chamber-humidity" to Table 10.
- 1885 • All new attributes that were CONDITIONALLY REQUIRED are now
1886 RECOMMENDED.
- 1887 • Added definition of material-type keyword format for standard materials.
- 1888 • Update Unicode reference now that v11 has been published.

1889 **19.3 April 26, 2018**

1890 Initial revision.