



The Printer Working Group

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Working Draft

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IPP 3D Printing Extensions (3D)

Status: Prototype

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

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

This document is available electronically at:

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52 order to meet this objective, the PWG will document the results of their work as open
53 standards that define print related protocols, interfaces, procedures and conventions.
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55 interoperability provided by voluntary conformance to these standards.

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57 technically competent, has multiple, independent and interoperable implementations with
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68 About the Internet Printing Protocol Workgroup

69 The Internet Printing Protocol (IPP) workgroup has developed a modern, full-featured
70 network printing protocol, which is now the industry standard. IPP allows a print client to
71 query a printer for its supported capabilities, features, and parameters to allow the
72 selection of an appropriate printer for each print job. IPP also provides job information prior
73 to, during, and at the end of job processing.

74 For additional information regarding IPP visit:

75 <http://www.pwg.org/ipp/>

76 Implementers of this specification are encouraged to join the IPP mailing list in order to
77 participate in any discussions of the specification. Suggested additions, changes, or
78 clarification to this specification, should be sent to the IPP mailing list for consideration.

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270 **1. Introduction**

271 This specification defines an extension to the Internet Printing Protocol (IPP) that supports
272 printing of physical objects by Additive Manufacturing devices such as three-dimensional
273 (3D) printers.

274 The primary focus of this specification is on popular Fused Deposition Modeling (FDM)
275 devices that melt and extrude ABS and/or PLA filaments in layers to produce a physical,
276 3D object. However, the same attributes can be used for other types of 3D printers that
277 use different methods and materials such as Laser Sintering of powdered materials and
278 curing of liquids using ultraviolet light.

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

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

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

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

290 **2. Terminology**

291 **2.1 Conformance Terminology**

292 Capitalized terms, such as MUST, MUST NOT, RECOMMENDED, REQUIRED, SHOULD,
293 SHOULD NOT, MAY, and OPTIONAL, have special meaning relating to conformance as
294 defined in Key words for use in RFCs to Indicate Requirement Levels [RFC2119]. The
295 term CONDITIONALLY REQUIRED is additionally defined for a conformance requirement
296 that applies when a specified condition is true.

297 **2.2 Printing Terminology**

298 Normative definitions and semantics of printing terms are imported from IETF Printer MIB
299 v2 [RFC3805], IETF Finisher MIB [RFC3806], and IETF Internet Printing Protocol/1.1:
300 Model and Semantics [RFC2911].

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

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

306 *Logical Device*: a print server, software service, or gateway that processes jobs and either
307 forwards or stores the processed job or uses one or more Physical Devices to render
308 output.

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

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

312 **2.3 Protocol Role Terminology**

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

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

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

320 **2.4 3D Printing Terminology**

321 *Additive Manufacturing*: A 3D printing process where material is progressively added to
322 produce the final output.

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

325 *Digital Light Processing*: A 3D printing process that uses light with a negative image to
326 selectively cure layers of a liquid material.

327 *Fused Deposition Modeling*: A 3D printing process that extrudes a molten material to draw
328 layers.

329 *Laser Sintering*: A 3D printing process that uses a laser to melt and fuse layers of
330 powdered materials.

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

333 *Selective Deposition Lamination*: A 3D printing process that laminates cut sheets of
334 material.

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

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

339 **2.5 Acronyms and Organizations**

340 *CNC*: Computer Numerical Control

341 *DLP*: Digital Light Processing

342 *FDM*: Fused Deposition Modeling

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

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

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

346 *ODL*: Object Definition Language

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

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

349 *SDL*: Selective Deposition Lamination

350 *SL*: Stereo Lithography

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

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353 **3. Rationale for IPP 3D Printing Extensions**

354 Existing specifications define the following:

- 355 1. IPP/2.0 Second Edition [PWG5100.12] defines version 2.0, 2.1, and 2.2 of the
356 Internet Printing Protocol which defines a standard operating and data model,
357 interface protocol, and extension mechanism to support traditional Printers;
- 358 2. IPP Everywhere [PWG5100.14] defines a profile of existing IPP specifications,
359 standard Job Template attributes, and standard document formats;
- 360 3. IPP Shared Infrastructure Extensions (INFRA) [PWG5100.18] defines an
361 interface for printing through shared services based in infrastructure such as
362 Cloud servers;
- 363 4. The 3D Manufacturing Format Core Specification & Reference Guide v1.0 [3MF]
364 defines an XML schema and file format for describing 3D objects with one or
365 more materials.

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

369 **3.1 Use Cases**

370 **3.1.1 Print a 3D Object**

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

374 **3.1.2 Print a 3D Object Using Loaded Materials**

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

378 **3.1.3 Print a 3D Object with Multiple Materials**

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

383 **3.1.4 Print a Tool**

384 Jane wants to print an adjustable wrench. Because the wrench contains interlocking
385 pieces that must be printed accurately for it to work properly, Jane specifies the required
386 dimensional accuracy with the software on her Client device prior to submitting the print.

387 The Printer then validates that it can support the required accuracy before accepting the
388 Job.

389 **3.1.5 View a 3D Object During Printing**

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

392 **3.2 Exceptions**

393 **3.2.1 Clogged Extruder**

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

397 **3.2.2 Extruder Temperature Out of Range**

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

402 **3.2.3 Extruder Head Movement Issues**

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

406 **3.2.4 Filament Feed Jam**

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

410 **3.2.5 Filament Feed Skip**

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

414 **3.2.6 Material Empty**

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

418 3.2.7 Material Adhesion Issues

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

423 3.2.8 Print Bed Temperature Out of Range

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

427 3.2.9 Print Bed Not Clear

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

432 3.3 Out of Scope

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

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

438

439 **3.4 Design Requirements**

440 The design requirements for this document are:

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

456 The design recommendations for this document are:

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

458

459 **4. 3D Print Service Model**

460 The IPP/1.1 Model and Semantics [RFC2911], the IETF Printer MIB [RFC3805], and the
461 IETF Finisher MIB [RFC3806] already define a comprehensive model for the operation and
462 data elements of a typical 2D printer. Figure 1 shows the generalized IPP model. The IPP
463 Server provides the external network interface for IPP Clients, while the Print Service
464 manages and processes Jobs and communicates with the Output Device(s) and their sub-
465 units.

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

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

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

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

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

486

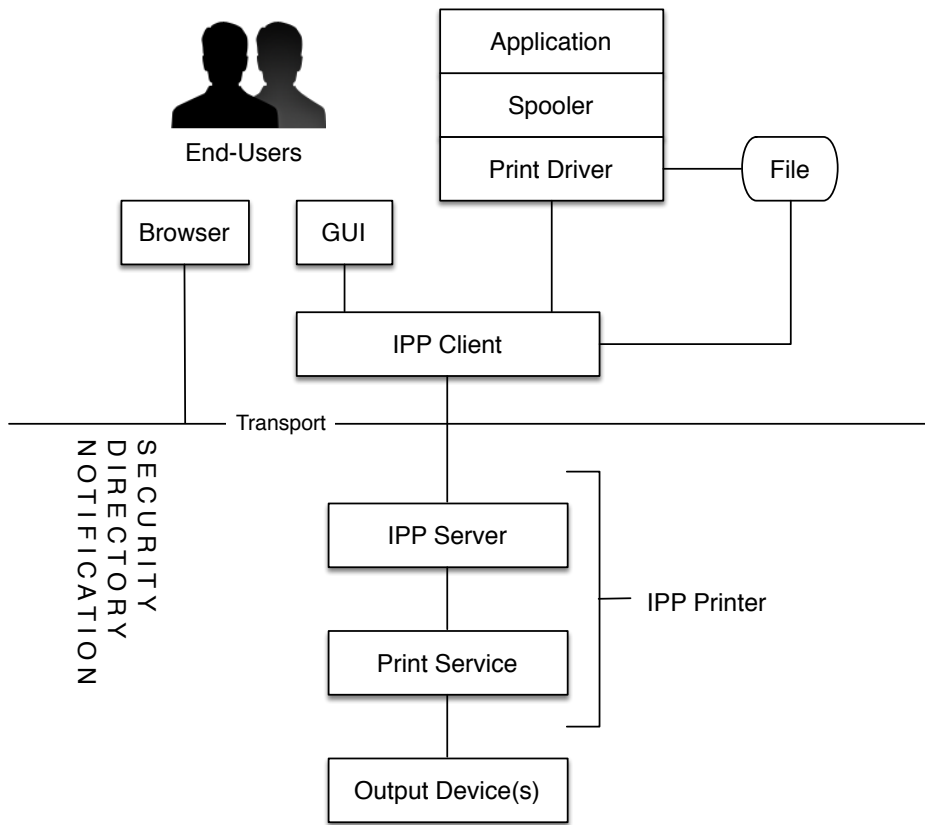


Figure 1 - Generalized IPP Model (RFC 2911)

487

488

489

490 4.1 3D Print Service

491 3D printing uses a variation of the traditional Print service that maintains state and
 492 capability information specific to 3D printing. The 3D Print service supports all of the same
 493 operations of the Print service described in [RFC2911] except for the Print-Job and Print-
 494 URI operations which are compound requests that are not used in newer IPP services.
 495 Similarly, the 3D Print service uses a superset of the Print service attributes except where
 496 such attributes are not applicable, for example the "media" attributes for a 3D printer that
 497 does not use media sheets. Attributes specific to the 3D Print Service are defined in
 498 section 8.

Deleted: 7

499 4.2 3D Printer Subunits

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

502 **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

503 4.2.1 Finishing Devices

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

506 4.2.2 Input Trays/Rolls

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

508 4.2.3 Marker Supplies

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

512 4.2.4 Markers

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

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

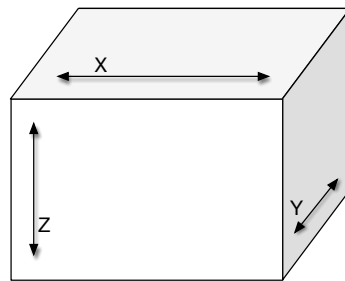
518 4.2.5 Media Paths

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

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

525 4.3 3D Printer Coordinate System

526 3D printers operate in three dimensions and thus have three axis of movement. For the
527 purposes of IPP, the build volume is defined as a rectangular prism (Figure 2) with the X
528 axis representing the width, the Y axis representing the depth, and the Z axis representing
529 the height. The origin is implementation-specific.



530

531

Figure 2 - 3D Build Volume

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

536 **4.4 Output Intent and Job Processing**

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

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

547 **4.5 Job Spooling**

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

551 **4.6 Multiple Document Jobs**

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

556 The "multiple-object-handling" (section [8.1.2](#)) Job Template attribute controls whether the
557 Printer performs this optimization.

Deleted: 7.1.2

558 **4.7 Cloud-Based Printing**

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

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

566

568 **5. Discovery Protocols**

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

571 **5.1 DNS Service Discovery (DNS-SD)**

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

576 **5.1.1 Service Instance Name**

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

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

580 **5.1.2 Service Type**

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

Deleted: mDNS

582 **5.1.3 TXT Record**

583

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

Deleted: Table 2

590

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

591 5.2 LDAP Discovery

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

595 5.2.1 printerIPPS3D Class

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

```

598 ( 1.3.18.0.2.24.46.??? <ASSIGN OID HERE>
599   NAME 'printerIPPS3D'
600   DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
601   AUXILIARY
602   SUP top
603   MAY ( printer-ipp-versions-supported $
604         printer-ipp-features-supported $
605         printer-multiple-document-jobs-supported )
606 )
607
```


608 **6. Protocol Binding**

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

612 **6.1 Transport and Resource Path**

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

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

620 **6.2 HTTP Features**

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

624 **6.2.1 Host**

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

627 **6.2.2 If-Modified-Since, Last-Modified, and 304 Not Modified**

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

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

634 **6.2.3 Cache-Control**

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

642 **6.3 IPP Operations**

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

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

Code	Operation Name	Reference
0x0004	Validate-Job	RFC 2911
0x0005	Create-Job	RFC 2911
0x0006	Send-Document	RFC 2911
0x0008	Cancel-Job	RFC 2911
0x0009	Get-Job-Attributes	RFC 2911
0x000A	Get-Jobs	RFC 2911
0x000B	Get-Printer-Attributes	RFC 2911
0x0039	Cancel-My-Jobs	PWG 5100.11
0x003B	Close-Job	PWG 5100.11
0x003C	Identify-Printer	PWG 5100.13

Deleted: Required

648 **6.4 IPP Operation Attributes**

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

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

Attribute	Reference
compression	RFC 2911
document-format	RFC 2911
document-name	RFC 2911, PWG 5100.5
first-index	PWG 5100.13
identify-actions	PWG 5100.13
ipp-attribute-fidelity	RFC 2911
job-ids	PWG 5100.11
job-mandatory-attributes	PWG 5100.7
job-name	RFC 2911
last-document	RFC 2911
limit	RFC 2911
requesting-user-name	RFC 2911
requesting-user-uri	PWG 5100.13
which-jobs	RFC 2911, PWG 5100.11

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Deleted: document-password

... [4]

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 2911
charset-supported	RFC 2911
compression-supported	RFC 2911
document-format-default	RFC 2911
document-format-supported	RFC 2911
generated-natural-language-supported	RFC 2911
identify-actions-default	PWG 5100.13
identify-actions-supported	PWG 5100.13
ipp-features-supported	PWG 5100.13
ipp-versions-supported	RFC 2911
job-constraints-supported	PWG 5100.13
job-creation-attributes-supported	PWG 5100.11
job-ids-supported	PWG 5100.11
job-resolvers-supported	PWG 5100.13
material-diameter-supported (note 2)	Section 8.3.3
material-purpose-supported	Section 8.3.4
material-rate-supported	Section 8.3.5
material-rate-units-supported	Section 8.3.6
material-shell-thickness-supported	Section 8.3.7
material-temperature-supported (note 3)	Section 8.3.7
material-type-supported	Section 8.3.9
materials-col-default	Section 8.3.11
materials-col-ready	Section 8.3.12
materials-col-supported	Section 8.3.13
multiple-document-jobs-supported	RFC 2911
multiple-object-handling-default	Section 8.3.14
multiple-object-handling-supported	Section 8.3.15
multiple-operation-timeout	RFC 2911
multiple-operation-timeout-action	PWG 5100.13
natural-language-configured	RFC 2911
operations-supported	RFC 2911
print-accuracy-default	Section 8.3.17
print-accuracy-supported	Section 8.3.18
print-objects-supported	Section 8.3.19
print-quality-default	RFC 2911
print-quality-supported	RFC 2911
print-rafts-default	Section 8.3.20

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Deleted: document-password-supported ... [5]

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print-rafts-supported	Section 8.3.21
print-supports-default	Section 8.3.22
print-supports-supported	Section 8.3.23
printer-bed-temperature-default (note 4)	Section 8.3.24
printer-bed-temperature-supported (note 4)	Section 8.3.25
printer-geo-location	PWG 5100.13
printer-get-attributes-supported	PWG 5100.13
printer-icons (note 1)	PWG 5100.13
printer-info	RFC 2911
printer-location	RFC 2911
printer-make-and-model	RFC 2911
printer-more-info	RFC 2911
printer-name	RFC 2911
printer-organization	PWG 5100.13
printer-organizational-unit	PWG 5100.13
printer-volume-supported	Section 8.3.27
printer-xri-supported (note 1)	RFC 3380
queued-job-count	RFC 2911
which-jobs-supported	PWG 5100.11
xri-authentication-supported	RFC 3380
xri-security-supported	RFC 3380
xri-uri-scheme-supported	RFC 3380

- Deleted: 8.3.19
- Deleted: 8.3.20
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- Note 1: URIs SHOULD use Host value from HTTP header (section ~~6.2.1~~) and MUST NOT use link-local addresses (~~section 8.4 of [PWG5100.14]~~).
- Note 2: ~~REQUIRED~~ for Printers that use filament-based materials.
- Note 3: ~~REQUIRED~~ for Printers that control the material temperature during printing.
- Note 4: ~~REQUIRED~~ for Printers that have a temperature-controlled build platform.

- Deleted: 7.1.1
- Deleted: (section)
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692 **6.6 IPP Printer Status Attributes**

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

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

Attribute	Reference
printer-config-change-date-time	PWG 5100.13
printer-camera-image-uri (notes 1, 2)	Section 8.3.26
printer-config-change-time	PWG 5100.13
printer-is-accepting-jobs	RFC 2911
printer-state	RFC 2911
printer-state-change-date-time	RFC 3995
printer-state-change-time	RFC 3995
printer-state-message	RFC 2911
printer-state-reasons	RFC 2911
printer-up-time	RFC 2911
printer-uri-supported (note 1)	RFC 2911
printer-uuid	PWG 5100.13
queued-job-count	RFC 2911
uri-security-supported	RFC 2911
uri-authentication-supported	RFC 2911

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

697 Note 2: REQUIRED for Printers that have one or more cameras.
 698

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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 2911
multiple-object-handling (note 1)	Section 8.1.2
print-accuracy	Section 8.1.3
print-objects (note 1)	Section 8.1.4
print-quality	RFC 2911
print-rafts	Section 8.1.5
print-supports	Section 8.1.6
printer-bed-temperature (note 2)	Section 8.1.7

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 2911

6.9 IPP Job Status Attributes

Table 9 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 2911
date-time-at-creation	RFC 2911
date-time-at-processing	RFC 2911
document-format-supplied	PWG 5100.7
document-name-supplied	PWG 5100.7
job-id	RFC 2911
job-originating-user-name	RFC 2911
job-printer-up-time	RFC 2911
job-printer-uri	RFC 2911

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job-state	RFC 2911
job-state-message	RFC 2911
job-state-reasons	RFC 2911
job-uri	RFC 2911
job-uuid	PWG 5100.13
materials-col-actual	Section 1.1
print-objects-actual (note 1)	Section 1.1
time-at-completed	RFC 2911
time-at-creation	RFC 2911
time-at-processing	RFC 2911

Deleted: 9.2.1

Deleted: 9.2.2

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

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733 6.9.1 job-id (integer)

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

739 6.9.2 job-uri (uri)

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

746 7. Document Formats

747 Printers MUST support Documents conforming to the 3MF [3MF] ("model/3mf") format and
 748 SHOULD support Documents conforming to the PDF [ISO32000] ("application/pdf") format
 749 containing U3D or PRC content.

753 **8. New Attributes**754 **8.1 Job Template Attributes**

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

757 **Table 10. - New Job Template Attributes**

Job Template	Printer: Default	Printer: Supported
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)
print-accuracy (collection)	print-accuracy-default (collection)	accuracy-units-supported (1setOf type2 keyword) print-accuracy-supported (collection)
print-objects (1setOf collection)	N/A	print-objects-supported (boolean)
print-rafts (type2 keyword)	print-rafts-default (type2 keyword)	print-rafts-supported (1setOf type2 keyword)
print-supports (type2 keyword)	print-supports-default (type2 keyword)	print-supports-supported (1setOf type2 keyword)
printer-bed-temperature (integer no-value)	printer-bed-temperature-default (integer no-value)	printer-bed-temperature-supported (1setOf (integer rangeOfInteger) no-value)

758 **8.1.1 materials-col (1setOf collection)**

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

764 The Printer advertises which "materials-col" member attributes are supported in the
 765 "materials-col-supported" (section 8.3.13) Printer Description attribute. The Printer lists
 766 only those member attributes that are applicable to the technology being used for printing.

Deleted: Table 2

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772 The Client typically supplies "materials-col" values matching those returned in the
 773 "materials-col-database" (section 8.3.1) or "materials-col-ready" (section 8.3.12) Printer
 774 Description attributes, although specifying the "material-name" or "material-key" member
 775 attribute from either of these Printer Description attributes is enough to specify the default
 776 values for the named material. Table 11 lists the member attributes.

Deleted: 7.3.1

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Table 11 - "materials-col" Member Attributes

Deleted: 12

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-fill-density	N/A
material-key	materials-col-database materials-col-ready
material-name	materials-col-database materials-col-ready
material-purpose	material-purpose-supported
material-rate	material-rate-supported
material-rate-units	material-rate-units-supported
material-shell-thickness	material-shell-thickness-supported
material-temperate	material-temperature-supported
material-type	material-type-supported

778 **8.1.1.1 material-amount (integer(0:MAX) | unknown)**

779 This RECOMMENDED member attribute provides the estimated amount of material that is
 780 available ("materials-col-database" and "materials-col-ready" values), the estimated
 781 amount of material that is required ("materials-col" values), or the actual amount of
 782 material that has been used ("materials-col-actual" values).

783 **8.1.1.2 material-amount-units (type2 keyword)**

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

- 786 'g': Value is mass in grams.
- 787 'kg': Value is mass in kilograms.
- 788 'l': Value is volume in liters.
- 789 'm': Value is length in meters.
- 790 'ml': Value is volume in milliliters.

795 'mm': Value is length in millimeters.

796 **8.1.1.3 material-color (type2 keyword)**

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

799 **8.1.1.4 material-diameter (integer(0:MAX))**

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

803 **8.1.1.5 material-fill-density (integer(0:100))**

804 This REQUIRED member attribute specifies the desired density of filled interior regions in
805 percent.

806 **8.1.1.6 material-key (keyword)**

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

809 **8.1.1.7 material-name (name(MAX))**

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

811 **8.1.1.8 material-purpose (1setOf type2 keyword)**

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

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

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

816 'raft': The material will be used to print a raft under the printed object.

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

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

819 **8.1.1.9 material-rate (integer(1:MAX))**

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

8.1.1.10 material-rate-units (type2 keyword)

823 This member attribute provides the units for the "material-rate" member attribute. Values
824 include:

825 'mg_sec': Value is milligrams per second.

826 'ml_sec': Value is milliliters per second.

827 'mm_sec': Value is millimeters per second.

8.1.1.11 material-shell-thickness (integer(0:MAX))

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

8.1.1.12 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))

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

8.1.1.13 material-type (type2 keyword | name(MAX))

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

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

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

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

844 'chocolate': Chocolate.

845 'gold': Gold (metal).

846 'nylon': Nylon.

847 'pet': Polyethylene terephthalate (PET).

848 'photopolymer': Photopolymer (liquid) resin.

849 'pla': Polylactic Acid (PLA).

- 850 'pla-conductive': Conductive PLA.
851 'pla-dissolvable': Dissolvable PLA.
852 'pla-flexible': Flexible PLA.
853 'pla-magnetic': PLA with embedded iron particles.
854 'pla-steel': PLA with embedded steel particles.
855 'pla-stone': PLA with embedded stone chips.
856 'pla-wood': PLA with embedded wood fibers.
857 'polycarbonate': Polycarbonate.
858 'silver': Silver (metal).
859 'titanium': Titanium (metal).
860 'wax': Wax.

861 **8.1.2 multiple-object-handling (type2 keyword)**

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

- 866 'auto': Automatically determine the best way to print multiple objects in a Job.
867 'best-fit': Fit as many objects as possible within the build volume.
868 'best-quality': Optimize the number of objects for print quality.
869 'best-speed': Optimize the number of objects for print speed.
870 'one-at-a-time': Print one object at a time.
871

8.1.3 print-accuracy (collection)

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

Deleted: required

When enforcing attribute fidelity ("ipp-attribute-fidelity" with a value of 'true'), Printers only reject "print-accuracy" values that are smaller than the "print-accuracy-supported" (section 8.3.18) value.

Table 12 - REQUIRED "print-accuracy" Member Attributes

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

8.1.3.1 accuracy-units (type2 keyword)

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

'mm': Accuracy numbers are in millimeters.

'um': Accuracy numbers are in micrometers.

'nm': Accuracy numbers are in nanometers.

8.1.3.2 x-accuracy (integer(0:MAX))

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

Deleted: e "x-accuracy (integer(0:MAX))"

8.1.3.3 y-accuracy (integer(0:MAX))

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

8.1.3.4 z-accuracy (integer(0:MAX))

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

8.1.4 print-objects (1setOf collection)

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

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

Table 13 - REQUIRED "print-objects" Member Attributes

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

8.1.4.1 document-number (integer(1:MAX))

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

8.1.4.2 object-offset (collection)

This member attribute specifies the offset to apply to the object. The "x-offset ([integer\(0:MAX\)](#))", "y-offset ([integer\(0:MAX\)](#))", and "z-offset ([integer\(0:MAX\)](#))" member attributes specify the offsets from the left, front, and build platform respectively in hundredths of millimeters (1/2540th of an inch).

8.1.4.3 object-size (collection)

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

8.1.4.4 object-uuid (uri)

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

Deleted: , "y-accuracy (integer(0:MAX))", and "z-accuracy (integer(0:MAX))" member attributes specify the general positioning and feature accuracy required in each axis. The "accuracy-units (type2 keyword)" member attribute specifies the units for the accuracy numbers. Keyword values inc... [6]

929 8.1.5 print-rafts (type2 keyword)

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

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

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

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

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

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

938 8.1.6 print-supports (type2 keyword)

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

941 'none': Do not print supports.

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

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

944 8.1.7 printer-bed-temperature (integer(-273:MAX))

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

948

8.2 Job Status Attributes

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

Table 14 - New "-actual" Job Status Attributes

Job Status Attribute	Conformance
materials-col-actual (1setOf collection)	REQUIRED
multiple-object-handling-actual (type2 keyword)	REQUIRED (note 1)
print-accuracy-actual (collection)	REQUIRED
print-objects-actual (1setOf collection)	REQUIRED (note 1)
print-rafts-actual (1setOf type2 keyword)	REQUIRED
print-supports-actual (1setOf type2 keyword)	REQUIRED
printer-bed-temperature-actual (1setOf integer(-273:MAX))	REQUIRED (note 2)

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

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

8.3 Printer Description Attributes

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

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

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

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

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

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

8.3.4 material-purpose-supported (1setOf type2 keyword)

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

Deleted: <#>materials-col-actual (1setOf collection) (... [7])

Deleted: 9.1.1.2

Deleted: 9.1.1.4

974 **8.3.5 material-rate-supported (1setOf (integer | rangeOfInteger)**

975 This Printer Description attribute lists the supported "material-rate" values for the Printer.
 976 This attribute MUST be supported if the "material-rate" member attribute (Section [8.1.1.9](#))
 977 is supported.

Deleted: 9.1.1.9

978 **8.3.6 material-rate-units-supported (1setOf type2 keyword)**

979 This Printer Description attribute lists the supported "material-rate-units" values for the
 980 Printer. This attribute MUST be supported if the "material-rate-units" member attribute
 981 (Section [8.1.1.10](#)) is supported.

Deleted: 9.1.1.10

982 **8.3.7 material-shell-thickness-supported (1setOf (integer(1:MAX) |
 983 rangeOfInteger(1:MAX)))**

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

986 **8.3.8 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-
 987 273:MAX)))**

988 This CONDITIONALLY REQUIRED Printer Description attribute specifies the supported
 989 "material-temperature" values (or ranges of values) in degrees Celsius. This attribute
 990 MUST be supported if the "material-temperature" member attribute (Section [8.1.1.12](#)) is
 991 supported.

Deleted: 9.1.1.12

992 **8.3.9 material-type-supported (1setOf type2 keyword)**

993 This REQUIRED Printer Description attribute lists the supported "material-type" values for
 994 the Printer.

995 **8.3.10 materials-col-database (1setOf collection)**

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

1000 In order to optimize the total size of this attribute, Printers MAY omit member attributes that
 1001 allow the full range of supported values in a particular collection. For example, a Printer
 1002 that supports generic PLA filament can report a single collection value:

```
1003     materials-col-database =
1004     { material-name="Generic PLA Filament" material-key="generic-pla"
1005     material-diameter=285 material-temperature=215-235 }
```

1010 Such "wildcard" values can be combined with more precise collections that identify a
1011 specific product, for example:

```
1012     materials-col-database =  
1013     { material-name="Generic PLA Filament" material-key="generic-pla"  
1014     material-diameter=285 material-temperature=215-235 },  
1015     { material-name="Example Corp Flexible Midnight Blue PLA" material-  
1016     key="com.example.flexible-midnight-blue" material-  
1017     color="com.example.midnight-blue_000027" material-diameter=285 material-  
1018     temperature=210-225 }
```

1019 **8.3.11 materials-col-default (1setOf collection)**

1020 This REQUIRED Printer Description attribute lists the default materials that will be used if
1021 the "materials-col" Job Template attribute (Section 8.1.1) is not specified.

Deleted: 9.1.1

1022 **8.3.12 materials-col-ready (1setOf collection)**

1023 This REQUIRED Printer Description attribute lists the materials that have been loaded into
1024 the Printer. Each value contains the corresponding "materials-col" member attributes.

1025 **8.3.13 materials-col-supported (1setOf type2 keyword)**

1026 This REQUIRED Printer Description attribute lists the "materials-col" member attributes
1027 that are supported by the Printer. Printers MUST include the following values: 'material-fill-
1028 density', 'material-key', 'material-name', 'material-purpose', 'material-shell-thickness', and
1029 'material-type'.

1030 **8.3.14 multiple-object-handling-default (type2 keyword)**

1031 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default
1032 "multiple-object-handling" value. Printers that support the 'application/pdf' Document format
1033 MUST support this attribute.

1034 **8.3.15 multiple-object-handling-supported (1setOf type2 keyword)**

1035 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported
1036 "multiple-object-handling" values. Printers that support the 'application/pdf' Document
1037 format MUST support this attribute.
1038

1040 **8.3.16 pdf-features-supported (1setOf type2 keyword)**

1041 This CONDITIONALLY REQUIRED Printer Description attribute lists the PDF features that
 1042 are supported by the Printer. Printers that support the 'application/pdf' Document format
 1043 MUST support this attribute.

1044 Values include:

1045 'prc': The Printer supports 3D objects in the Product Representation Compact (PRC)
 1046 format [ISO14739-1].

1047 'u3d': The Printer supports 3D objects in the Universal 3D (U3D) format [ECMA363].

1048 **8.3.17 print-accuracy-default (collection)**

1049 This REQUIRED Printer Description attribute specifies the default "print-accuracy" value.

1050 **8.3.18 print-accuracy-supported (collection)**

1051 This REQUIRED Printer Description attribute specifies the best "print-accuracy" value that
 1052 is supported by the Printer.

1053 **8.3.19 print-objects-supported (1setOf type2 keyword)**

1054 This CONDITIONALLY REQUIRED Printer Description attribute specifies which "print-
 1055 objects" member attributes are supported. Printers that support the 'application/pdf'
 1056 Document format MUST support this attribute.

1057 **8.3.20 print-rafts-default (type2 keyword)**

1058 This REQUIRED Printer Description attribute specifies the default "print-rafts" value.

1059 **8.3.21 print-rafts-supported (1setOf type2 keyword)**

1060 This REQUIRED Printer Description attribute lists the supported "print-rafts" values.

1061 **8.3.22 print-supports-default (type2 keyword)**

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

1063 **8.3.23 print-supports-supported (1setOf type2 keyword)**

1064 This REQUIRED Printer Description attribute lists the supported "print-supports" values.

Deleted: supported accuracies. The "x-accuracy (1setOf (integer(1:MAX) | rangeOfinteger(1:MAX)))", "y-accuracy (1setOf (integer(1:MAX) | rangeOfinteger(1:MAX)))", and "z-accuracy (1setOf (integer(1:MAX) | rangeOfinteger(1:MAX)))" member attributes specify the values (or ranges of values) that are supported.

1071 **8.3.24 printer-bed-temperature-default (integer(-273:MAX))**

1072 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default
1073 "printer-bed-temperature" value. Printers that control the temperature of the Build Platform
1074 MUST support this attribute.

1075 **8.3.25 printer-bed-temperature-supported (1setOf (integer(-273:MAX) |
1076 rangeOfInteger(-273:MAX))**

1077 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported
1078 "printer-bed-temperature" values and/or ranges. Printers that control the temperature of
1079 the Build Platform MUST support this attribute.

1080 **8.3.26 printer-camera-image-uri (1setOf uri)**

1081 This Printer Description attribute lists the URIs for one or more resident camera snapshots.
1082 Each URI corresponds to a separate resident camera. The images referenced by each
1083 URI can change at any time so it is up to the Client to periodically poll for changes and for
1084 the Printer to atomically update the images so that Clients can safely do so.

1085 **8.3.27 printer-volume-supported (collection)**

1086 This REQUIRED Printer Description attribute specifies the maximum build volume
1087 supported by the Printer. [Table 15 lists the REQUIRED member attributes.](#)

1088 **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))1089 **8.3.27.1 x-dimension (integer(1:MAX))**

1090 This member attributes specifies the width of the build volume in hundredths of millimeters
1091 (1/2540th of an inch).

1092 **8.3.27.2 y-dimension (integer(1:MAX))**

1093 This member attributes specifies the depth of the build volume in hundredths of millimeters
1094 (1/2540th of an inch).

1095 **8.3.27.3 z-dimension (integer(1:MAX))**

1096 This member attributes specifies the height of the build volume in hundredths of
1097 millimeters (1/2540th of an inch).

Deleted: e "x-dimension (integer(1:MAX))", "y-dimension (integer(1:MAX))", and "z-dimension (integer(1:MAX))"

Deleted: specify

Deleted: size

Deleted: along each axis

1103 9. New Values for Existing Attributes

1104 9.1 ipp-features-supported (1setOf type2 keyword)

1105 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-
1106 supported" Printer Description attribute.

1107 9.2 printer-state-reasons (1setOf type2 keyword)

1108 This specification registers the following new values for the "printer-state-reasons" Printer
1109 Status attribute:

- 1110 'camera-failure': A camera is no longer working.
- 1111 'chamber-cooling': A chamber is being cooled.
- 1112 'chamber-heating': A chamber is being heated.
- 1113 'chamber-temperature-high': The temperature of a chamber is high.
- 1114 'chamber-temperature-low': The temperature of a chamber is low.
- 1115 'extruder-cooling': An extruder is being cooled.
- 1116 'extruder-failure': An extruder has failed and requires maintenance or replacement.
- 1117 'extruder-heating': An extruder is being heated.
- 1118 'extruder-jam': An extruder is jammed or clogged.
- 1119 'extruder-temperature-high': The temperature of an extruder is too high.
- 1120 'extruder-temperature-low': The temperature of an extruder is too low.
- 1121 'fan-failure': A fan has failed.
- 1122 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.
- 1123 'lamp-failure': A lamp has failed.
- 1124 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.
- 1125 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.
- 1126 'laser-failure': A laser has failed.
- 1127 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.

- 1128 'material-empty': One or more build materials have been exhausted.
- 1129 'material-low': One or more build materials may need replenishment soon.
- 1130 'material-needed': One or more build materials need to be loaded for a processing Job.
- 1131 'motor-failure': A motor has failed.
- 1132

1133 **10. Conformance Requirements**

1134 **10.1 Printer Conformance Requirements**

1135 In order for a Printer to claim conformance to this specification, a Printer MUST support:

- 1136 1. The required discovery protocols in section 5;
- 1137 2. The required transports and resource paths in section 6.1;
- 1138 3. The required HTTP features in section 6.2;
- 1139 4. The required IPP operations in section 6.3;
- 1140 5. The required IPP attributes in sections 6.4 through 6.9;
- 1141 6. The required document formats in section 7;
- 1142 7. The additional values defined in section 9;
- 1143 8. The internationalization considerations in section 11; and
- 1144 9. The security considerations in section 12.

1145 **10.2 Client Conformance Requirements**

1146 In order for a Client to claim conformance to this specification, a Client MUST support:

- 1147 1. The required discovery protocols in section 5;
- 1148 2. The required transports and resource paths in section 6.1;
- 1149 3. The required HTTP features in section 6.2;
- 1150 4. The required IPP operations in section 6.3;
- 1151 5. The required IPP attributes in sections 6.4 through 6.9;
- 1152 6. The required document formats in section 7;
- 1153 7. The additional values defined in section 9;
- 1154 8. The internationalization considerations in section 11; and
- 1155 9. The security considerations in section 12.

1156

1157 **11. Internationalization Considerations**

1158 For interoperability and basic support for multiple languages, conforming implementations
1159 MUST support:

- 1160 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)
1161 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 1162 2. The Unicode Format for Network Interchange [RFC5198] which requires
1163 transmission of well-formed UTF-8 strings and recommends transmission of
1164 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1165 Unicode NFC is defined as the result of performing Canonical Decomposition (into base
1166 characters and combining marks) followed by Canonical Composition (into canonical
1167 composed characters wherever Unicode has assigned them).

1168 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and
1169 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in
1170 IPP Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8
1171 URIs now 'hidden').

1172 Implementations of this specification SHOULD conform to the following standards on
1173 processing of human-readable Unicode text strings, see:

1174 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical

1175 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping

1176 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]

1177 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences

1178 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization

1179 Unicode Character Encoding Model [UTR17] – multi-layer character model

1180 Unicode in XML and other Markup Languages [UTR20] – XML usage

1181 Unicode Character Property Model [UTR23] – character properties

1182 Unicode Conformance Model [UTR33] – Unicode conformance basis+

1183 Unicode Collation Algorithm [UTS10] – sorting

1184 Unicode Locale Data Markup Language [UTS35] – locale databases

1185 **12. Security Considerations**

1186 In addition to the security considerations described in the IPP/1.1: Model and Semantics
1187 [RFC2911], the following sub-sections describe issues that are unique to 3D printing.

1188 Implementations of this specification SHOULD conform to the following standards on
1189 processing of human-readable Unicode text strings, see:

1190 Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1191 Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

1192 **12.1 Confidentiality**

1193 Clients and Printers MUST provide confidentiality of data in transit using either an interface
1194 providing physical security such as USB or using TLS encryption [RFC5246] over
1195 unsecured/network connections,

1196 **12.2 Access Control**

1197 Because of the potential for abuse and misuse, Printers SHOULD provide access control
1198 mechanisms including lists of allowed Clients, authentication, and authorization to site
1199 defined policies.

1200 **12.3 Physical Safety**

1201 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such
1202 as protective gates, covers, or interlocks.

1203 **12.4 Material Safety**

1204 Printers MUST restrict usage and combination of materials to those that can be safely
1205 printed. Access controls (section [12.2](#)) MAY be used to allow authorized End Users to
1206 experiment with untested materials or combinations, but only when such materials or
1207 combinations can reasonably be expected to not pose a safety risk.

Deleted: 11.1

1208 **12.5 Temperature Control**

1209 Printers MUST validate values provided by Clients and limit material, extruder, build
1210 platform, and print chamber temperatures within designed limits to prevent unsafe
1211 operating conditions, damage to the hardware, hazardous emissions, explosions, and/or
1212 fires.

1213

1215 **13. IANA and PWG Considerations**1216 **13.1 Attribute Registrations**

1217 The attributes defined in this specification will be published by IANA according to the
 1218 procedures in IPP/1.1 Model and Semantics [RFC2911] section 6.2 in the following file:

1219 <http://www.iana.org/assignments/ipp-registrations>

Field Code Changed

1220 The registry entries will contain the following information:

1221	Job Status attributes:	Reference
1222	-----	-----
1223	materials-col-actual (lsetOf collection)	[PWG5100.NN]
1224	< member attributes are the same as materials-col >	[PWG5100.NN]
1225	<u>multiple-object-handling-actual (type2 keyword)</u>	<u>[PWG5100.NN]</u>
1226	<u>print-accuracy-actual (collection)</u>	<u>[PWG5100.NN]</u>
1227	< member attributes are the same as print-accuracy >	[PWG5100.NN]
1228	print-objects-actual (lsetOf collection)	[PWG5100.NN]
1229	< member attributes are the same as print-objects >	[PWG5100.NN]
1230	<u>print-rafts-actual (lsetOf type2 keyword)</u>	<u>[PWG5100.NN]</u>
1231	<u>print-supports-actual (lsetOf type2 keyword)</u>	<u>[PWG5100.NN]</u>
1232	<u>printer-bed-temperature-actual (lsetOf integer(-273:MAX))</u>	<u>[PWG5100.NN]</u>
1233		
1234	Job Template attributes:	Reference
1235	-----	-----
1236	materials-col (lsetOf collection)	[PWG5100.NN]
1237	material-amount (integer(0:MAX))	[PWG5100.NN]
1238	material-amount-units (type2 keyword)	[PWG5100.NN]
1239	material-color (type2 keyword)	[PWG5100.NN]
1240	material-diameter (integer(1:MAX))	[PWG5100.NN]
1241	material-fill-density (integer(0:100))	[PWG5100.NN]
1242	material-key (keyword)	[PWG5100.NN]
1243	material-name (name(MAX))	[PWG5100.NN]
1244	material-purpose (lsetOf type2 keyword)	[PWG5100.NN]
1245	material-rate (integer(1:MAX))	[PWG5100.NN]
1246	material-rate-units (type2 keyword)	[PWG5100.NN]
1247	material-shell-thickness (integer(0:MAX))	[PWG5100.NN]
1248	material-temperature (integer(-273:MAX) rangeOfInteger(-273:MAX))	[PWG5100.NN]
1249		
1250	material-type (type2 keyword name(MAX))	[PWG5100.NN]
1251	multiple-object-handling (type2 keyword)	[PWG5100.NN]
1252	print-accuracy (collection)	[PWG5100.NN]
1253	accuracy-units (type2 keyword)	[PWG5100.NN]
1254	x-accuracy (integer(0:MAX))	[PWG5100.NN]
1255	y-accuracy (integer(0:MAX))	[PWG5100.NN]
1256	z-accuracy (integer(0:MAX))	[PWG5100.NN]
1257	print-objects (lsetOf collection)	[PWG5100.NN]
1258	document-number (integer(1:MAX))	[PWG5100.NN]
1259	object-offset (collection)	[PWG5100.NN]
1260	x-offset (integer(0:MAX))	[PWG5100.NN]
1261	y-offset (integer(0:MAX))	[PWG5100.NN]
1262	z-offset (integer(0:MAX))	[PWG5100.NN]

1263	object-size (collection)	[PWG5100.NN]
1264	x-dimension (integer(1:MAX))	[PWG5100.NN]
1265	y-dimension (integer(1:MAX))	[PWG5100.NN]
1266	z-dimension (integer(1:MAX))	[PWG5100.NN]
1267	object-uuid (uri)	[PWG5100.NN]
1268	print-rafts (type2 keyword)	[PWG5100.NN]
1269	print-supports (type2 keyword)	[PWG5100.NN]
1270	printer-bed-temperature (integer(-273:MAX))	[PWG5100.NN]
1271		
1272	Printer Description attributes:	Reference
1273	-----	-----
1274	accuracy-units-supported (lsetOf type2 keyword)	[PWG5100.NN]
1275	material-amount-units-supported (lsetOf type2 keyword)	[PWG5100.NN]
1276	material-diameter-supported (lsetOf (integer(0:MAX)	
1277	rangeOfInteger(0:MAX)))	[PWG5100.NN]
1278	material-purpose-supported (lsetOf type2 keyword)	[PWG5100.NN]
1279	material-rate-supported (lsetOf (integer(1:MAX)	
1280	rangeOfInteger(1:MAX)))	[PWG5100.NN]
1281	material-rate-units-supported (lsetOf type2 keyword)	[PWG5100.NN]
1282	material-shell-thickness-supported (lsetOf (integer(0:MAX)	
1283	rangeOfInteger(0:MAX)))	[PWG5100.NN]
1284	material-temperature-supported (lsetOf (integer(-273:MAX)	
1285	rangeOfInteger(-273:MAX)))	[PWG5100.NN]
1286	material-type-supported (lsetOf type2 keyword)	[PWG5100.NN]
1287	materials-col-database (lsetOf collection)	[PWG5100.NN]
1288	< member attributes are the same as materials-col >	[PWG5100.NN]
1289	materials-col-default (lsetOf collection)	[PWG5100.NN]
1290	< member attributes are the same as materials-col >	[PWG5100.NN]
1291	materials-col-ready (lsetOf collection)	[PWG5100.NN]
1292	< member attributes are the same as materials-col >	[PWG5100.NN]
1293	materials-col-supported (lsetOf type2 keyword)	[PWG5100.NN]
1294	multiple-object-handling-default (type2 keyword)	[PWG5100.NN]
1295	multiple-object-handling-supported (lsetOf type2 keyword)	[PWG5100.NN]
1296	pdf-features-supported (lsetOf type2 keyword)	[PWG5100.NN]
1297	print-accuracy-supported (collection)	[PWG5100.NN]
1298	< member attributes are the same as print-accuracy >	[PWG5100.NN]
1299	print-objects-supported (lsetOf type2 keyword)	[PWG5100.NN]
1300	print-rafts-default (type2 keyword)	[PWG5100.NN]
1301	print-rafts-supported (lsetOf type2 keyword)	[PWG5100.NN]
1302	print-supports-default (type2 keyword)	[PWG5100.NN]
1303	print-supports-supported (lsetOf type2 keyword)	[PWG5100.NN]
1304	printer-bed-temperature-default (integer(-273:MAX))	[PWG5100.NN]
1305	printer-bed-temperature-supported (lsetOf (integer(-273:MAX)	
1306	rangeOfInteger(-273:MAX)))	[PWG5100.NN]
1307	printer-camera-image-uri (lsetOf uri)	[PWG5100.NN]
1308	printer-volume-supported (collection)	[PWG5100.NN]
1309	x-dimension (integer(1:MAX))	[PWG5100.NN]
1310	y-dimension (integer(1:MAX))	[PWG5100.NN]
1311	z-dimension (integer(1:MAX))	[PWG5100.NN]

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Deleted: x-accuracy (lsetOf (integer(0:MAX) | rangeOfInteger(0:MAX))) . [PWG5100.NN] ... [8]

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1312 13.2 Attribute Value Registrations

1313 The attributes defined in this specification will be published by IANA according to the
 1314 procedures in IPP/1.1 Model and Semantics [RFC2911] section 6.1 in the following file:

1324

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

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1325

The registry entries will contain the following information:

1326	Attributes (attribute syntax)	Reference
1327	Keyword Attribute Value	Reference
1328	-----	-----
1329	accuracy-units (type2 keyword)	[PWG5100.NN]
1330	mm	[PWG5100.NN]
1331	nm	[PWG5100.NN]
1332	um	[PWG5100.NN]
1333	accuracy-units-supported (lsetOf type2 keyword)	[PWG5100.NN]
1334	< any accuracy-units values >	[PWG5100.NN]
1335	ipp-features-supported (lsetOf type2 keyword)	[PWG5100.13]
1336	ipp-3d	[PWG5100.NN]
1337	material-amount-units (type2 keyword)	[PWG5100.NN]
1338	g	[PWG5100.NN]
1339	kg	[PWG5100.NN]
1340	l	[PWG5100.NN]
1341	m	[PWG5100.NN]
1342	ml	[PWG5100.NN]
1343	mm	[PWG5100.NN]
1344	material-color (type2 keyword)	[PWG5100.NN]
1345	< any "media" color name >	[PWG5100.NN]
1346	material-purpose (lsetOf type2 keyword)	[PWG5100.NN]
1347	all	[PWG5100.NN]
1348	in-fill	[PWG5100.NN]
1349	raft	[PWG5100.NN]
1350	shell	[PWG5100.NN]
1351	support	[PWG5100.NN]
1352	material-rate-units (type2 keyword)	[PWG5100.NN]
1353	mg_second	[PWG5100.NN]
1354	ml_second	[PWG5100.NN]
1355	mm_second	[PWG5100.NN]
1356	material-type (type2 keyword)	[PWG5100.NN]
1357	abs	[PWG5100.NN]
1358	abs-carbon-fiber	[PWG5100.NN]
1359	abs-carbon-nanotube	[PWG5100.NN]
1360	chocolate	[PWG5100.NN]
1361	gold	[PWG5100.NN]
1362	nylon	[PWG5100.NN]
1363	pet	[PWG5100.NN]
1364	photopolymer	[PWG5100.NN]
1365	pla	[PWG5100.NN]
1366	pla-conductive	[PWG5100.NN]
1367	pla-dissolvable	[PWG5100.NN]
1368	pla-flexible	[PWG5100.NN]
1369	pla-magnetic	[PWG5100.NN]
1370	pla-steel	[PWG5100.NN]
1371	pla-stone	[PWG5100.NN]
1372	pla-wood	[PWG5100.NN]
1373	polycarbonate	[PWG5100.NN]
1374	silver	[PWG5100.NN]
1375	titanium	[PWG5100.NN]
1376	wax	[PWG5100.NN]

1377	materials-col-supported (1setOf type2 keyword)	[PWG5100.NN]
1378	< any materials-col member attribute name >	[PWG5100.NN]
1379	multiple-object-handling (type2 keyword)	[PWG5100.NN]
1380	auto	[PWG5100.NN]
1381	best-fit	[PWG5100.NN]
1382	best-quality	[PWG5100.NN]
1383	best-speed	[PWG5100.NN]
1384	one-at-a-time	[PWG5100.NN]
1385	pdf-features-supported (1setOf type2 keyword)	[PWG5100.NN]
1386	prc	[PWG5100.NN]
1387	u3d	[PWG5100.NN]
1388	print-objects-supported (1setOf type2 keyword)	[PWG5100.NN]
1389	< any print-objects member attribute name >	[PWG5100.NN]
1390	print-rafts (type2 keyword)	[PWG5100.NN]
1391	brim	[PWG5100.NN]
1392	none	[PWG5100.NN]
1393	raft	[PWG5100.NN]
1394	skirt	[PWG5100.NN]
1395	standard	[PWG5100.NN]
1396	print-supports (type2 keyword)	[PWG5100.NN]
1397	material	[PWG5100.NN]
1398	none	[PWG5100.NN]
1399	standard	[PWG5100.NN]
1400	printer-state-reasons (1setOf type2 keyword)	[RFC2911]
1401	camera-failure	[PWG5100.NN]
1402	chamber-cooling	[PWG5100.NN]
1403	chamber-heating	[PWG5100.NN]
1404	chamber-temperature-high	[PWG5100.NN]
1405	chamber-temperature-low	[PWG5100.NN]
1406	extruder-cooling	[PWG5100.NN]
1407	extruder-failure	[PWG5100.NN]
1408	extruder-heating	[PWG5100.NN]
1409	extruder-jam	[PWG5100.NN]
1410	extruder-temperature-high	[PWG5100.NN]
1411	extruder-temperature-low	[PWG5100.NN]
1412	fan-failure	[PWG5100.NN]
1413	lamp-at-eol	[PWG5100.NN]
1414	lamp-failure	[PWG5100.NN]
1415	lamp-near-eol	[PWG5100.NN]
1416	laser-at-eol	[PWG5100.NN]
1417	laser-failure	[PWG5100.NN]
1418	laser-near-eol	[PWG5100.NN]
1419	material-empty	[PWG5100.NN]
1420	material-low	[PWG5100.NN]
1421	material-needed	[PWG5100.NN]
1422	motor-failure	[PWG5100.NN]

1423 13.3 Service Type Registration

1424 The DNS-SD service type defined in this specification will be published by IANA according
 1425 to the procedures in Internet Assigned Numbers Authority (IANA) Procedures for the
 1426 Management of the Service Name and Transport Protocol Port Number Registry
 1427 [BCP165].

1428 The registration template is as follows:

1429 Service Name: ipp3d
1430
1431 Transport Protocol(s): tcp
1432
1433 Assignee/Contact: Michael Sweet, msweet@apple.com
1434
1435 Description: 3D Print services (3D printers) using the Internet Printing
1436 Protocol over HTTPS.
1437
1438 Reference: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-5100.NN.pdf)
1439 5100.NN.pdf
1440
1441 Port Number:
1442
1443 Service Code:
1444
1445 Known Unauthorized Uses:
1446
1447 Assignment Notes: Change controller is The Printer Working Group, c/o The
1448 IEEE Industry Standards and Technology Organization, 445 Hoes Lane,
1449 Piscataway, NJ 08854, USA

1450 13.4 MIME Media Type Registration

1451 The MIME media type defined in this specification will be published by IANA according to
1452 the procedures in Media Type Specifications and Registration Procedures [BCP13].

1453 The registration template is as follows:

1454 Type name: media
1455
1456 Subtype name: 3mf
1457
1458 Required parameters: N/A
1459
1460 Optional parameters: N/A
1461
1462 Encoding considerations: binary
1463
1464 Security considerations: 3MF files can be very large, particularly after
1465 decompression, which could fill a filesystem and cause a denial of service
1466 or system failure. This media type does not employ any sort of active or
1467 executable content. Neither privacy nor integrity protection is provided
1468 by the media type itself; if these protections are needed they must be
1469 implemented externally. Authentication, access control, and
1470 privacy/integrity are normally handled by the Internet Printing Protocol,
1471 Hyper-Text Transport Protocol, and Transport Layer Security.
1472
1473 Interoperability considerations:
1474
1475 Published specification: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-5100.NN.pdf)
1476 YYYYMMDD-5100.NN.pdf

1477
1478 Applications that use this media type: 3D modeling and slicing software
1479
1480 Fragment identifier considerations:
1481
1482 Additional information:
1483
1484 Deprecated alias names for this type: N/A
1485
1486 Magic number(s): N/A
1487
1488 File extension(s): 3mf
1489
1490 Macintosh file type code(s): N/A
1491
1492 Person & email address to contact for further information: Michael Sweet,
1493 msweet@apple.com
1494
1495 Intended usage: COMMON
1496
1497 Restrictions on usage: N/A
1498
1499 Author/Change controller: The Printer Working Group, c/o The IEEE Industry
1500 Standards and Technology Organization, 445 Hoes Lane, Piscataway, NJ
1501 08854, USA
1502
1503 Provisional registration? (standards tree only): No

1504 **13.5 Semantic Model Registrations**

1505 The IPP attributes, values, and operations defined in this specification and listed in the
1506 preceding sections will be added to the PWG Semantic Model XML schema using the
1507 method defined in section 21 of [PWG5108.07].
1508

1509 **14. References**1510 **14.1 Normative References**

- 1511 [3MF] "3D Manufacturing Format Core Specification & Reference Guide
1512 v1.0", [http://www.3mf.io/wp-](http://www.3mf.io/wp-content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf)
1513 [content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf](http://www.3mf.io/wp-content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf)
- 1514 [BONJOUR] Apple Inc., "Bonjour Printing Specification Version 1.2", July 2013,
1515 <http://developer.apple.com/bonjour/>
- 1516 [ISO10646] "Information technology -- Universal Coded Character Set (UCS)",
1517 ISO/IEC 10646:2011
- 1518 [ISO32000] "Document management — Portable document format — Part 1: PDF
1519 1.7", ISO 32000-2008
- 1520 [ISO52915] "Standard Specification for Additive Manufacturing File Format (AMF)
1521 Version 1.1", ISO/ASTM 52915, 2013
- 1522 [PWG5100.5] D. Carney, T. Hastings, P. Zehler, "IPP: Document Object", PWG
1523 5100.5-2003, October 2003, [http://ftp.pwg.org/pub/pwg/candidates/cs-](http://ftp.pwg.org/pub/pwg/candidates/cs-ippdocobject10-20031031-5100.5.pdf)
1524 [ippdocobject10-20031031-5100.5.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippdocobject10-20031031-5100.5.pdf)
- 1525 [PWG5100.11] T. Hastings, D. Fullman, "IPP Job and Printer Extensions - Set 2
1526 (JPS2)", PWG 5100.11-2010, October 2010,
1527 [http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-20101030-5100.11.pdf)
1528 [20101030-5100.11.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-20101030-5100.11.pdf)
- 1529 [PWG5100.12] M. Sweet, I. McDonald, "IPP Version 2.0, 2.1, and 2.2", PWG
1530 5100.12-2015, October 2015,
1531 <http://ftp.pwg.org/pub/pwg/standards/std-ipp20-20151030-5100.12.pdf>
- 1532 [PWG5100.13] M. Sweet, I. McDonald, "IPP Job and Printer Extensions - Set 3
1533 (JPS3)", PWG 5100.13-2012, July 2012,
1534 [http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext3v10-](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext3v10-20120727-5100.13.pdf)
1535 [20120727-5100.13.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext3v10-20120727-5100.13.pdf)
- 1536 [PWG5100.14] M. Sweet, I. McDonald, A. Mitchell, J. Hutchings, "IPP Everywhere",
1537 PWG 5100.14-2013, January 2013,
1538 [http://ftp.pwg.org/pub/pwg/candidates/cs-ippeve10-20130128-](http://ftp.pwg.org/pub/pwg/candidates/cs-ippeve10-20130128-5100.14.pdf)
1539 [5100.14.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippeve10-20130128-5100.14.pdf)
- 1540 [PWG5100.18] M. Sweet, I. McDonald, "IPP Shared Infrastructure Extensions
1541 (INFRA)", PWG 5100.18-2015, June 2015,

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Field Code Changed

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Field Code Changed

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Field Code Changed

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1542		http://ftp.pwg.org/pub/pwg/candidates/cs-ippinfra10-20150619-5100.18.pdf	Field Code Changed
1543			
1544	[PWG5108.01]	W. Wagner, P. Zehler, "MFD Model and Common Semantics", PWG 5108.01-2011, April 2011, http://ftp.pwg.org/pub/pwg/candidates/cs-sm20-mfdmodel10-20110415-5108.1.pdf	Field Code Changed
1545			
1546			
1547	[PWG5108.07]	P. Zehler, "PWG Print Job Ticket and Associated Capabilities Version 1.0 (PJT)", PWG 5108.07-2012, August 2012, http://ftp.pwg.org/pub/pwg/candidates/cs-sm20-pjt10-20120801-5108.07.pdf	Field Code Changed
1548			
1549			
1550			
1551	[RFC2911]	T. Hastings, R. Herriot, R. deBry, S. Isaacson, P. Powell, "Internet Printing Protocol/1.1: Model and Semantics", RFC 2911, September 2000, http://tools.ietf.org/html/rfc2911	Field Code Changed
1552			
1553			
1554	[RFC3805]	R. Bergman, H. Lewis, I. McDonald, "Printer MIB v2", RFC 3805, June 2004, http://tools.ietf.org/html/rfc3805	Field Code Changed
1555			
1556	[RFC3806]	R. Bergman, H. Lewis, I. McDonald, "Printer Finishing MIB", RFC 3806, June 2004, http://tools.ietf.org/html/rfc3806	Field Code Changed
1557			
1558	[RFC5198]	J. Klensin, M. Padlipsky, "Unicode Format for Network Interchange", RFC 5198, March 2008, http://tools.ietf.org/html/rfc5198	Field Code Changed
1559			
1560	[RFC5246]	T.Dierks, E. Rescorla, "Transport Layer Security 1.2", RFC 5246, August 2008, http://tools.ietf.org/html/rfc5246	Field Code Changed
1561			
1562	[RFC6762]	S. Cheshire, M. Krochmal, "Multicast DNS", RFC 6762, February 2013, http://tools.ietf.org/html/rfc6762	Field Code Changed
1563			
1564	[RFC6763]	S. Cheshire, M. Krochmal, "DNS-Based Service Discovery", RFC 6763, February 2013, http://tools.ietf.org/html/rfc6763	Field Code Changed
1565			
1566	[STD63]	F. Yergeau, "UTF-8, a transformation format of ISO 10646", RFC 3629/STD 63, November 2003, http://tools.ietf.org/html/rfc3629	Field Code Changed
1567			
1568	[UAX9]	Unicode Consortium, "Unicode Bidirectional Algorithm", UAX#9, June 2014, http://www.unicode.org/reports/tr9/tr9-31.html	Field Code Changed
1569			
1570			
1571	[UAX14]	Unicode Consortium, "Unicode Line Breaking Algorithm", UAX#14, June 2014, http://www.unicode.org/reports/tr14/tr14-33.html	Field Code Changed
1572			
1573			
1574	[UAX15]	Unicode Consortium, "Normalization Forms", UAX#15, June 2014, http://www.unicode.org/reports/tr15/tr15-41.html	Field Code Changed
1575			

- 1576 [UAX29] Unicode Consortium, "Unicode Text Segmentation", UAX#29, June
1577 2014,
1578 <http://www.unicode.org/reports/tr29/tr29-25.html>
- 1579 [UAX31] Unicode Consortium, "Unicode Identifier and Pattern Syntax",
1580 UAX#31, June 2014,
1581 <http://www.unicode.org/reports/tr31/tr31-21.html>
- 1582 [UNICODE] Unicode Consortium, "Unicode Standard", Version 9.0.0, June 2016,
1583 <http://www.unicode.org/versions/Unicode9.0.0/>
- 1584 [UTS10] Unicode Consortium, "Unicode Collation Algorithm", UTS#10, June
1585 2014,
1586 <http://www.unicode.org/reports/tr10/tr10-30.html>
- 1587 [UTS35] Unicode Consortium, "Unicode Locale Data Markup Language",
1588 UTS#35, September 2014,
1589 <http://www.unicode.org/reports/tr35/tr35-37/tr35.html>
- 1590 [UTS39] Unicode Consortium, "Unicode Security Mechanisms", UTS#39,
1591 September 2014,
1592 <http://www.unicode.org/reports/tr39/tr39-9.html>

1593 14.2 Informative References

- 1594 [BCP13] N. Freed, J. Klensin, T. Hansen, "Media Type Specifications and
1595 Registration Procedures", BCP 13, RFC 6838,
1596 <http://tools.ietf.org/html/rfc6838>
- 1597 [BCP165] M. Cotton, L. Eggert, J. Touch, M. Westerlund, S. Cheshire, "Internet
1598 Assigned Numbers Authority (IANA) Procedures for the Management
1599 of the Service Name and Transport Protocol Port Number Registry",
1600 BCP 165, RFC 6335, <http://tools.ietf.org/html/rfc6335>
- 1601 [IPPSAMPLE] "ISTO-PWG IPP Sample Code Repository",
1602 <https://github.com/istopwg/ippsample>
- 1603 [STLFORMAT] 3D Systems, Inc., "SLC File Specification", 1994
- 1604 [UNISECFAQ] Unicode Consortium "Unicode Security FAQ", November 2013,
1605 <http://www.unicode.org/faq/security.html>
- 1606 [UTR17] Unicode Consortium "Unicode Character Encoding Model", UTR#17,
1607 November 2008,
1608 <http://www.unicode.org/reports/tr17/tr17-7.html>

Field Code Changed

Field Code Changed

Field Code Changed

Field Code Changed

Field Code Changed

Field Code Changed

Field Code Changed

Field Code Changed

Field Code Changed

Field Code Changed

- 1609 [UTR20] Unicode Consortium “Unicode in XML and other Markup Languages”,
1610 UTR#20, January 2013,
1611 <http://www.unicode.org/reports/tr20/tr20-9.html>
- 1612 [UTR23] Unicode Consortium “Unicode Character Property Model”, UTR#23,
1613 November 2008,
1614 <http://www.unicode.org/reports/tr23/tr23-9.html>
- 1615 [UTR33] Unicode Consortium “Unicode Conformance Model”, UTR#33,
1616 November 2008,
1617 <http://www.unicode.org/reports/tr33/tr33-5.html>

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1618 15. Author's Address

1619 Primary author:

1620 Michael Sweet
1621 Apple Inc.
1622 1 Infinite Loop
1623 MS 111-HOMC
1624 Cupertino, CA 95014
1625 msweet@apple.com

1626 The authors would also like to thank the following individuals for their contributions to this
1627 standard:

1628 Olliver Schinagl, Ultimaker B.V.
1629 Michael Scrutton, Adobe Systems
1630 Emmet Lalish, Microsoft Corporation

1631

1632 **16. Object Definition Languages (ODLs)**

1633 This section provides information on several commonly used ODLs with either existing
1634 (registered) or suggested MIME media types.

1635 **16.1 3D Manufacturing Format (3MF)**

1636 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that
1637 provides geometry, material, and texture information necessary to support a wide variety of
1638 3D printers. Materials can be named and composed within the geometry, facilitating
1639 multiple material support in coordination with a Job Ticket.

1640 The registered MIME media type for the original Microsoft published specification is
1641 "application/vnd.ms-3mfdocument". The suggested (but not registered) MIME media type
1642 for the 3MF Consortium's published specification is "model/3mf".

1643 **16.2 Additive Manufacturing Format (AMF)**

1644 AMF [ISO52915] is a relatively new format that was designed as a replacement for the
1645 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-
1646 available specification, but has several advantages over STL including:

- 1647 1. Shared vertices which eliminates holes and other breaks in the surface
1648 geometry of objects,
- 1649 2. Specification of multiple materials in a single file,
- 1650 3. Curved surfaces can be specified, and
- 1651 4. Coordinates use explicit units for proper output dimensions.

1652 The suggested (but not registered) MIME media type is 'model/amf'.

1653 **16.3 Portable Document Format (PDF)**

1654 PDF [ISO32000] is widely supported for 2D printing and has two 3D formats that are used
1655 to embed 3D objects - PRC [ISO14739-1] and U3D [ECMA363]. The registered MIME
1656 media type for PDF is "application/pdf".

1657 [For discussion: define a "model/pdf" MIME media type for PDFs containing 3D content?]

1658 **16.4 Standard Tessellation Language (STL)**

1659 STL [STLFORMAT] is widely supported by existing client software. The registered MIME
1660 media type is 'application/sla'.

1661

1662 **17. Design Choices**

1663 This section documents some of the design choices that were made during the
1664 development of this specification.

1665 **17.1 Units for Length Values**

1666 The default unit for most length values is hundredths of millimeters (1/2540th of an inch),
1667 matching the units for 2D printing and providing a range of 0.01mm to 21.47km. This was
1668 determined to be sufficient for the class of printers this specification targets.

1669 **17.2 Units for Thickness Values**

1670 The default unit for most thickness values is nanometers, which provides a range of
1671 0.000001mm to 2.147m. This was determined to be sufficient for the class of printers this
1672 specification targets.

1673 **17.3 Use of Celsius for Temperatures**

1674 The various integer attributes for temperature use degrees Celsius. This was done
1675 because most existing printers and materials are specified using degrees Celsius. There is
1676 no advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to
1677 perform additional unit conversions could cause safety issues. All temperature attributes
1678 use a range of -273 (absolute zero) to MAX (2147483647 - significantly hotter than our
1679 sun) to allow flexibility.

1680 **17.4 Explicit Units for Other Values**

1681 Some attributes have a companion "xxx-units" attribute that specifies an explicit unit for the
1682 given measurement(s). The initial list of unit values for each attribute has been limited to
1683 those necessary for current printers and technologies at the time of writing of this
1684 specification in order to minimize interoperability issues.

1685 **17.5 Intent vs. Process**

1686 The IPP Model [RFC2911], and more generally the PWG Semantic Model [PWG5108.1],
1687 have long focused on Job Tickets specifying "what" is wanted for the printed output vs.
1688 "how" that output is produced. This focus has served IPP well and allowed it to be used
1689 with wildly different printing technologies.

1690 During the development of this specification, attributes that define a specific process or
1691 technological parameter have been introduced and later replaced by intent-based
1692 alternatives that allow an implementation to select suitable process-based parameters at

1693 print time, preserving the intrinsic value of such parameters without burdening the Client or
1694 End User with such things.

1695 At the same time, some process parameters are needed for things like material
1696 specification. For example, a particular brand of PLA may require a higher melting
1697 temperature - this information might only be known to the End User, so the "materials-col"
1698 collection contains an member attribute to convey this process-specific parameter. The
1699 Printer advertises whether temperature is a valid material property in the "materials-col-
1700 supported" Printer Description attribute.

1701 Finally, IPP does not prohibit the definition or use of process-based Job Template
1702 attributes for specific implementations. Such extension attributes can be listed in the "job-
1703 creation-attributes-supported" Printer Description attribute to notify Clients of their
1704 existence.

1705 **17.6 Choosing a Required Document Format**

1706 One of the design consideration of this specification is to choose an open, freely available
1707 file format for use as required document format. Having a required document format
1708 makes interoperability significantly easier, and using an open and freely available format
1709 allows developers of "consumer" printers to support IPP 3D. Several formats were
1710 considered, including STL, AMF, PDF, and 3MF.

1711 While STL is a widely-implemented, open, and freely available file format, it lacks support
1712 for multiple materials and colors/textures, and has technical issues that cause "holes" in
1713 generated models.

1714 While AMF supports multiple materials and does not have the "holes" issue, it is not freely
1715 available nor widely-implemented.

1716 PDF is the most capable 3D format but is not freely available and has the interoperability
1717 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-
1718 features-supported" Printer Description attribute (section 8.3.16) allows Clients to
1719 determine whether a 3D PDF file can be printed by the Printer.

1720 3MF is open and freely available, supports multiple materials and color/textures, does not
1721 have the "holes" issue of STL, and has a freely available open source implementation that
1722 supports both creation and consumption of 3MF files.
1723

1724 18. Change History

1725 18.1 August 24, 2016

- 1726 1. Section 5.1.2: "over DNS-SD"
- 1727 2. Section 6.4: Dropped document-password from required operation attributes
- 1728 3. Section 6.5: Dropped document-password-supported from required Printer
- 1729 Description attributes, fixed section reference for material-shell-thickness, fixed
- 1730 note 1 reference for link-local addresses.
- 1731 4. Section 6.7: Fixed section references.
- 1732 5. Section 8.1: Updated print-accuracy -supported attributes.
- 1733 6. Section 8.1.3: Broke up print-accuracy member attributes into subsections.
- 1734 7. Section 8.1.4: Added table listing member attributes.
- 1735 8. Sections 8.1.4.x: Added syntax to each of the sub-member attributes.
- 1736 9. Section 8.2: Reworked as table listing the member attributes.
- 1737 10. Section 8.3.18: Reworded as the best supported "print-accuracy" value.
- 1738 11. Section 8.3.27: Broke up member attributes into subsections.
- 1739 12. Section 17.3: Mentioned the range for temperature values.

1740 18.2 August 16, 2016

- 1741 1. Section 1: Added informative reference to IPP sample code.
- 1742 2. Section 6.2: Fixed reference to HTTP/1.1 spec.
- 1743 3. Section 6.2.2: "camera image" instead of "ICC profile".
- 1744 4. Table 5: Added missing print-accuracy-default attribute, fix link-local rule to point
- 1745 to PWG5100.14.
- 1746 5. Table 6: Add missing reference for printer-camera-image-uri attribute, drop note
- 1747 3.
- 1748 6. Section 8.1.1.4: Use nanometers for material-diameter, just like material-shell-
- 1749 thickness.
- 1750 7. Section 8.1.1.10: Added '_sec' to material-rate-units values.
- 1751 8. Section 8.1.3: Added accuracy-units member attribute.
- 1752 9. Section 8.3.x: Added missing print-accuracy-default attribute.
- 1753 10. Section 8.3.x: Added accuracy-units-supported attribute.
- 1754 11. Section 8.3.6: Fix reference to "material-shell-thickness" member attribute.
- 1755 12. Section 8.3.11: Required.
- 1756 13. Section 8.3.13: List required values.
- 1757 14. Section 10.x: Fix spelling of "attribute" and section reference for document
- 1758 formats.
- 1759 15. Section 13: Updated registration information.
- 1760 16. Section 14.1: Updated Unicode reference to v9.0.0.
- 1761 17. Section 14.2: Added informative reference to IPP sample code.
- 1762 18. Section 17: Update and talk about length, thickness, and explicit unit attribute
- 1763 values.

1764 18.3 July 14, 2016

- 1765 1. Updated with conformance requirements.
- 1766 2. Added a new Protocol Binding section that outlines the core IPP and HTTP
- 1767 requirements.
- 1768 3. Section 8.1.x: Made materials-col, print-rafts, and print-supports REQUIRED,
- 1769 print-objects and multiple-object-handling CONDITIONALLY REQUIRED for
- 1770 PDF printers, added printer-bed-temperature and made it CONDITIONALLY
- 1771 REQUIRED for printers with a temperature-controlled build platform.
- 1772 4. Table 3: The supported values for print-accuracy are in print-accuracy-
- 1773 supported, not x/y/z-accuracy-supported.
- 1774 5. Section 8.1.4: Changed print-accuracy to use hundredths of millimeters for the
- 1775 units, with 0 being <0.01mm.
- 1776 6. Section 8.2: The -actual attributes are all Job Status (read-only)
- 1777 7. Section 8.3.16: Changed to use hundredths of millimeters for units.
- 1778 8. Section 8.3.x: Add printer-bed-temperature-default and -supported.

1779 18.4 April 30, 2016

- 1780 1. Status: Prototype
- 1781 2. Section 3.1.x: Added a new use case for tool printing where precision is needed.
- 1782 3. Section 3.3 and 3.4: Updated list of design requirements and out-of-scope items
- 1783 based on April 2016 F2F discussions.
- 1784 4. New Section 5 for transport and resource path requirements.
- 1785 5. Section 6.1: No longer reference Bonjour Printing spec, but instead define
- 1786 everything here. Service type is now "_ippes-3d_tcp".
- 1787 6. Section 6.2: Fill in LDAP information.
- 1788 7. Section 8.1: Drop print-quality-details, add print-accuracy, make print-objects a
- 1789 1setOf collection
- 1790 8. Section 8.1.1: Add material-fill-density and material-shell-thickness member
- 1791 attributes
- 1792 9. Section 8.1.3: Change to 1setOf collection and define member attributes for
- 1793 dimensions, offset, UUID, and document number.
- 1794 10. Section 8.2: Add print-objects-actual
- 1795 11. Section 8.3: Add material-thickness-supported, print-accuracy-supported, and
- 1796 drop print-quality-details-xxx
- 1797 12. Section 8.3.17: print-objects-supported is now a 1setOf type2 keyword
- 1798 13. Section 8.3.23: Dimensions are in hundredths of millimeters
- 1799 14. Section 10: Filled in conformance requirements
- 1800 15. Section 12.1: Talk about confidentiality
- 1801 16. Section 13: Filled in IANA considerations
- 1802 17. Section 17: Talk about use of PWG units (hundredths of millimeters) and
- 1803 nanometers.

1804 18.5 April 20, 2016

- 1805 1. Section 4.2: Add note that not all subunits are exposed, input tray/roll, trimmers
- 1806 are All.
- 1807 2. Section 4.3: Update Figure 2
- 1808 3. Section 4.6: Fix section reference
- 1809 4. Section 5: Drop SLP
- 1810 5. Section 5.1: Update to use _ipp3d._tcp, define TXT record
- 1811 6. Section 5.2: Drop SLP
- 1812 7. Section 7.1.4: Clarify keyword value definitions.

1813 18.6 March 3, 2016

- 1814 1. Added background on choice of 3MF vs. PDF.
- 1815 2. Added PDF to list of ODLs.
- 1816 3. Added pdf-features-supported attribute.

1817 18.7 February 17, 2016

- 1818 1. Global: "Document" instead of "document".
- 1819 2. Added discovery protocols and document formats sections, with requirements.
- 1820 3. Section 1: Reworded, added discovery and standard ODL discussion.
- 1821 4. Section 1.1: Dropped
- 1822 5. Section 4.2: Reworked subunits to be abstract views necessary for maintenance
- 1823 and status monitoring, entirely matching up with the Printer and Finisher MIBs
- 1824 6. Section 4.3: Replace Figure 2 with a depiction of the build volume, explain IPP
- 1825 coordinate system for build volume
- 1826 7. Section 4.4: Reword and drop mention of temperatures as intent.
- 1827 8. Section 5.1.x: Drop all of the process attributes (thickness, fill percent, speed,
- 1828 temperatures), add new print-quality-details attribute
- 1829 9. Section 5.1.1: Reference materials-col-supported, materials-col.material-name is
- 1830 enough in job ticket to use existing -database or -ready.
- 1831 10. Section 5.1.2: Added multiple-object-handling attribute
- 1832 11. Section 5.1.1.10: Clarified this is the printing temperature.
- 1833 12. Section 5.1.1.11: Dropped "filament", "powder", etc., talk about localization of
- 1834 values, and make "keyword | name".
- 1835 13. Section 5.3.x: Drop all of the process attributes, add new multiple-object-
- 1836 handling-xxx and print-quality-details-xxx attributes
- 1837 14. Section 5.4.x: Dropped
- 1838 15. Section 11.x: Updated references, moved STL to informative section, added
- 1839 PDF 1.7 (ISO 32000)
- 1840 16. Section 14.3: Added section on process vs intent

1841 18.8 February 1, 2016

- 1842 1. Updated front matter for working draft
1843 2. Fixed one remaining use of "white paper"

1844 18.9 January 28, 2016

- 1845 1. Updated to working draft template.
1846 2. Fixed document URLs.
1847 3. Global: "white paper" changed to "specification" as needed.
1848 4. Abstract: "this specification", extension to IPP Everywhere as well.
1849 5. Section 4: "3D Print Service Model", remove old intro text
1850 6. Dropped tables 1-3, instead just say "same as 2D print service" and mention that
1851 certain Job Template attributes such as "media" are not applicable to most 3D
1852 printers.
1853 7. Table 4: Added section references, reordered so that all RFC 3805 subunits are
1854 listed first.
1855 8. Section 4.x: Reword in places now that this is a specification.
1856 9. Section 5: Added subunit collection attributes
1857 10. Section 6: Add registration (instead of just suggestion)
1858 11. Added Section 14 on design choices

1859 18.10 November 16, 2015

- 1860 1. Section 1: Fix typos
1861 2. Section 3: Updated rationale to talk about 3MF instead of AMF and STL
1862 3. Section 4: Added new subsection on the 3D Print Service and the operations
1863 and attributes that are used.
1864 4. Section 4.3: Added Chambers to list of subunits since we are providing access
1865 to the temperature.
1866 5. Section 5.1.1: Added table listing all member attributes.
1867 6. Section 5.1.1.x: Added sections on material-amount, material-amount-units,
1868 material-diameter, material-rate, material-rate-units
1869 7. Section 5.1.1.x: Renamed "material-use" to "material-purpose" to avoid
1870 confusion with "material-amount-xxx".
1871 8. Section 5.3: Add new materials-col member attribute -supported attributes
1872 9. Section 7.1: Note existing MS 3DMF MIME media type
1873 10. Global: printer-bed-xxx -> printer-platform-xxx
1874 11. Global: Add range for all temperature attributes (-273:MAX)

1875 18.11 October 29, 2015

- 1876 1. Greatly expanded the discussion of how current solutions work and the IPP
1877 model
1878 2. Added discussion points for amount of material used

- 1879 3. Added materials-col-actual Job Description attribute
- 1880 4. Added 3MF description and reference
- 1881 5. Fixed link to IPP Everywhere in references

1882 18.12 August 12, 2015

- 1883 1. Dropped “0.1” from the title
- 1884 2. Various typographical changes
- 1885 3. Section 2.2: Added ODL acronym
- 1886 4. Table 1: Added reference column
- 1887 5. Figure 1: Updated figure to show Z increasing downward (direction of build platform movement)
- 1888 6. Section 4.x: Added sub-section on output intent.
- 1890 7. Section 5.1: Added table listing Job Template and corresponding -default and -supported attributes.
- 1891 8. Section 5.1.1.4: Added more types of filament, solid wax, and clarification on the names used for material type keywords.
- 1892 9. Section 5.1.1.5: Made material-use 1setOf, added 'all' value.
- 1894 10. Updated printer-bed-temperature-supported and printer-chamber-temperature-supported to allow 'no-value' values.
- 1896 11. Section 9.x: Added subsections on specific 3D printing security considerations.

1898 18.13 July 29, 2015

- 1899 1. Dropped all references to X3G and G-code.
- 1900 2. Reworked materials-col to specify materials but not temperatures and other physical properties
- 1901 3. Added “material-use” member attribute to assign materials to specific uses.
- 1902 4. Supports and rafts pick materials based on “material-use” values and not indices.
- 1903 5. Added reference to IPP INFRA
- 1904 6. Added printer-camera-image-uri Printer Description attribute.

1907 18.14 April 13, 2015

- 1908 1. Updated front matter to incorporate new IEEE-ISTO boilerplate for a contributed white paper.

1910 18.15 April 5, 2015

- 1911 1. Updated front matter to remove IEEE-ISTO boilerplate.
- 1912 2. Fixed various typos
- 1913 3. Clarified that SLC files are commonly known as STL files.
- 1914 4. Clarified that S3G is a binary version of G-code with a standard packet format.

- 1915 5. Added use case for printing with loaded materials
- 1916 6. Added use case for multi-material printing on a single material printer.
- 1917 7. Added use case for monitoring print progress visually with a web cam.
- 1918 8. Added exception for "skipping" (insufficient material flow/feed)
- 1919 9. Added exception for adhesion issues
- 1920 10. Added exception for build plate being full.
- 1921 11. Added exception for head movement issues.
- 1922 12. Added figure showing the typical coordinate system.
- 1923 13. Expanded Job Template and Printer Description details, added comments for
- 1924 discussion.
- 1925 14. Added new Unicode considerations and references.

1926 **18.16 January 23, 2015**

1927 Initial revision.

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Figure 1 - Generalized IPP Model (RFC 2911)	16
Figure 2 - 3D Build Volume	18

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document-password PWG 5100.13

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document-password-supported PWG 5100.13

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, "y-accuracy (integer(0:MAX))", and "z-accuracy (integer(0:MAX))" member attributes specify the general positioning and feature accuracy required in each axis. The "accuracy-units (type2 keyword)" member attribute specifies the units for the accuracy numbers. Keyword values include:

- 'mm': Accuracy numbers are in millimeters.
- 'um': Accuracy numbers are in micrometers.
- 'nm': Accuracy numbers are in nanometers.

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materials-col-actual (1setOf collection)

This Job Status attribute provides a receipt of the actual material(s) used for the Job.

print-objects-actual (1setOf collection)

This Job Status attribute provides a receipt of the objects that were printed.

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```

x-accuracy (1setOf (integer(0:MAX) | rangeOfInteger(0:MAX)))
[PWG5100.NN]
y-accuracy (1setOf (integer(0:MAX) | rangeOfInteger(0:MAX)))
[PWG5100.NN]
z-accuracy (1setOf (integer(0:MAX) | rangeOfInteger(0:MAX)))
[PWG5100.NN]

```