



The Printer Working Group

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Working Draft**

IPP 3D Printing Extensions (3D)

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

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50 systems supporting them work together better. All references to the PWG in this
51 document implicitly mean “The Printer Working Group, a Program of the IEEE ISTO.” In
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
58 substantial operational experience, and enjoys significant public support.

59 For additional information regarding the Printer Working Group visit:

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67

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.
79

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262 **1. Introduction**

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

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

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

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

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

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

282 **2. Terminology**

283 **2.1 Conformance Terminology**

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

289 **2.2 Printing Terminology**

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

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

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

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

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

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

304 **2.3 Protocol Role Terminology**

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

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

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

312 **2.4 3D Printing Terminology**

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

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

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

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

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

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

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

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

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

331 **2.5 Acronyms and Organizations**

332 *CNC*: Computer Numerical Control

333 *DLP*: Digital Light Processing

334 *FDM*: Fused Deposition Modeling

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

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

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

338 *ODL*: Object Definition Language

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

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

341 *SDL*: Selective Deposition Lamination

342 *SL*: Stereo Lithography

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

344

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

346 Existing specifications define the following:

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

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

361 **3.1 Use Cases**

362 **3.1.1 Print a 3D Object**

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

366 **3.1.2 Print a 3D Object Using Loaded Materials**

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

370 **3.1.3 Print a 3D Object with Multiple Materials**

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

375 **3.1.4 Print a Tool**

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

379 The Printer then validates that it can support the required accuracy before accepting the
380 Job.

381 **3.1.5 View a 3D Object During Printing**

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

384 **3.2 Exceptions**

385 **3.2.1 Clogged Extruder**

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

389 **3.2.2 Extruder Temperature Out of Range**

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

394 **3.2.3 Extruder Head Movement Issues**

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

398 **3.2.4 Filament Feed Jam**

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

402 **3.2.5 Filament Feed Skip**

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

406 **3.2.6 Material Empty**

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

410 3.2.7 Material Adhesion Issues

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

415 3.2.8 Print Bed Temperature Out of Range

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

419 3.2.9 Print Bed Not Clear

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

424 3.3 Out of Scope

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

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

430

431 **3.4 Design Requirements**

432 The design requirements for this document are:

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

448 The design recommendations for this document are:

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

450

451 **4. 3D Print Service Model**

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

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

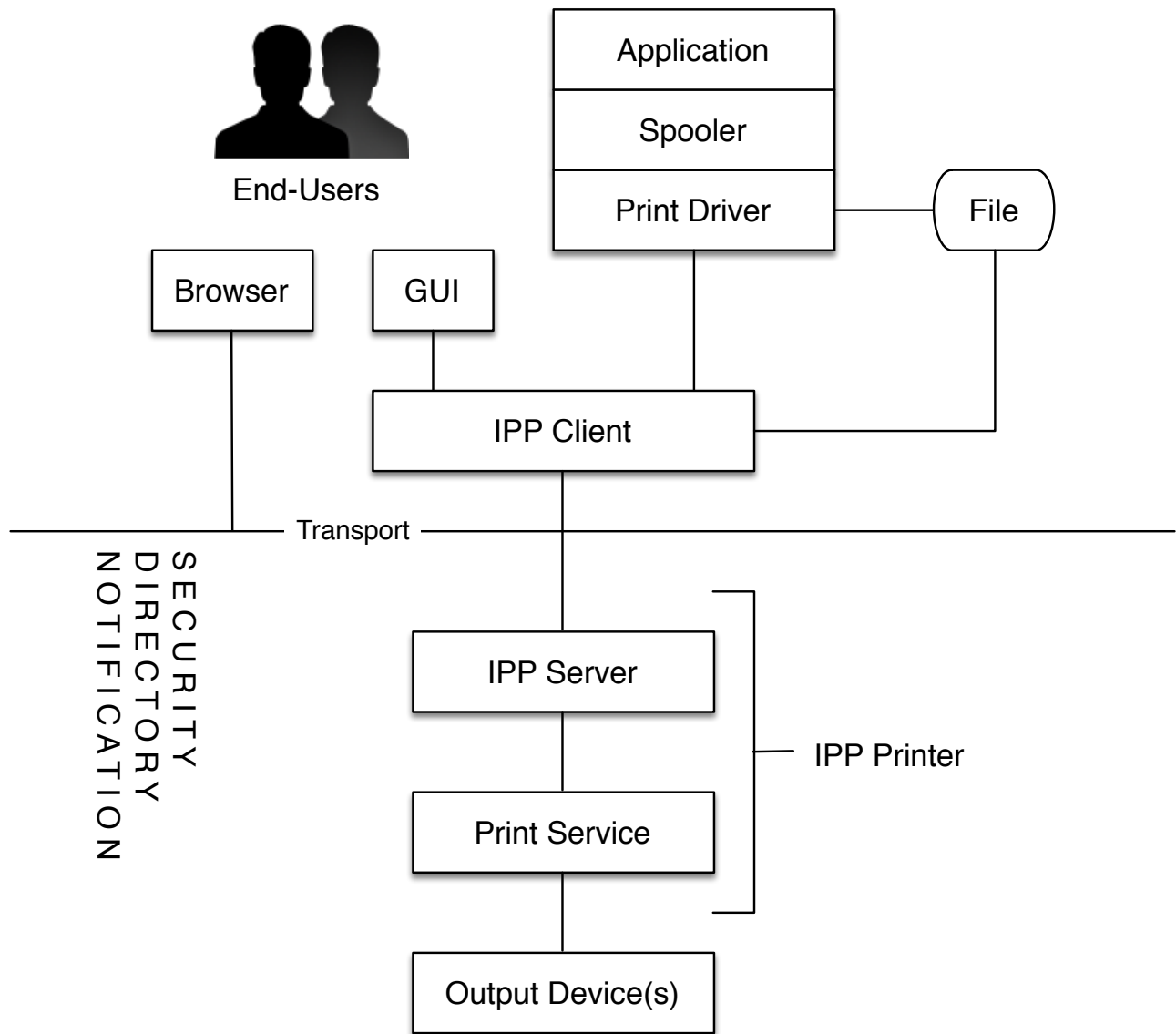
464 The IPP Printer object contains zero or more Job objects and is responsible for managing,
465 scheduling, and processing Jobs. It also provides the current state of the Output Device(s)
466 and communicates with them as needed.

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

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

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

478



479

480

481

Figure 1 - Generalized IPP Model (RFC 2911)

482 **4.1 3D Print Service**

483 3D printing uses a variation of the traditional Print service that maintains state and
 484 capability information specific to 3D printing. The 3D Print service supports all of the same
 485 operations of the Print service described in [RFC2911] except for the Print-Job and Print-
 486 URI operations which are compound requests that are not used in newer IPP services.
 487 Similarly, the 3D Print service uses a superset of the Print service attributes except where
 488 such attributes are not applicable, for example the "media" attributes for a 3D printer that
 489 does not use media sheets. Attributes specific to the 3D Print Service are defined in
 490 section 8.

491 **4.2 3D Printer Subunits**

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

494 **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

495 **4.2.1 Finishing Devices**

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

498 **4.2.2 Input Trays/Rolls**

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

500 **4.2.3 Marker Supplies**

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

503 4.2.4 Markers

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

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

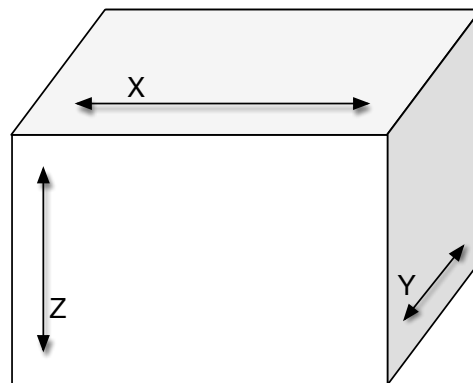
509 4.2.5 Media Paths

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

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

516 4.3 3D Printer Coordinate System

517 3D printers operate in three dimensions and thus have three axis of movement. For the
518 purposes of IPP, the build volume is defined as a rectangular prism (Figure 2) with the X
519 axis representing the width, the Y axis representing the depth, and the Z axis representing
520 the height. The origin is implementation-specific.



521

522

Figure 2 - 3D Build Volume

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

527 **4.4 Output Intent and Job Processing**

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

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

538 **4.5 Job Spooling**

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

542 **4.6 Multiple Document Jobs**

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

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

549 **4.7 Cloud-Based Printing**

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

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

557

558 **5. Discovery Protocols**

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

561 **5.1 DNS Service Discovery (DNS-SD)**

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

566 **5.1.1 Service Instance Name**

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

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

570 **5.1.2 Service Type**

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

572 **5.1.3 TXT Record**

573

574 Table 2 lists the TXT record key/value pairs for IPPS 3D Print services. The TXT record
575 associated with the service MUST include the "adminurl" and "UUID" keys and MUST
576 include the "note" and "rp" keys when they are not the default values.
577

578

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

579 **5.2 LDAP Discovery**

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

583 **5.2.1 printerIPPS3D Class**

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

```

586 ( 1.3.18.0.2.24.46.??? <ASSIGN OID HERE>
587   NAME 'printerIPPS3D'
588   DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
589   AUXILIARY
590   SUP top
591   MAY ( printer-ipp-versions-supported $
592         printer-ipp-features-supported $
593         printer-multiple-document-jobs-supported )
594 )
595
```


596 **6. Protocol Binding**

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

600 **6.1 Transport and Resource Path**

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

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

608 **6.2 HTTP Features**

609 In additional to the IPP over HTTP conformance requirements defined in section 7.3 of IPP
610 2.0, 2.1, and 2.2 [PWG5100.12], Printers MUST support the following additional HTTP
611 headers and status codes defined in Hypertext Transfer Protocol -- HTTP/1.1 [RFC7230].

612 **6.2.1 Host**

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

615 **6.2.2 If-Modified-Since, Last-Modified, and 304 Not Modified**

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

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

622 **6.2.3 Cache-Control**

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

629 6.3 IPP Operations

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

634 **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

635 6.4 IPP Operation Attributes

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

637 **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

638 **6.5 IPP Printer Description Attributes**

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

640 **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
color-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
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

- 641 Note 1: URIs SHOULD use Host value from HTTP header (section 6.2.1) and MUST NOT
642 use link-local addresses (section 8.4 of [PWG5100.14]).
- 643 Note 2: REQUIRED for Printers that use filament-based materials.
- 644 Note 3: REQUIRED for Printers that control the material temperature during printing.
- 645 Note 4: REQUIRED for Printers that have a temperature-controlled build platform.
646

647 **6.6 IPP Printer Status Attributes**

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

649 **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

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

652 Note 2: REQUIRED for Printers that have one or more cameras.
 653

654 **6.7 IPP Job Template Attributes**

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

656 **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

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

658 Note 2: REQUIRED for Printers that have a temperature-controlled build platform.

659 **6.8 IPP Job Description Attributes**

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

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

Attribute	Source
job-name	RFC 2911

662 **6.9 IPP Job Status Attributes**

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

664 **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

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 Error! Reference source not found.
print-objects-actual (note 1)	Section Error! Reference source not found.
time-at-completed	RFC 2911
time-at-creation	RFC 2911
time-at-processing	RFC 2911

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

666 **6.9.1 job-id (integer)**

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

672 **6.9.2 job-uri (uri)**

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

679 **7. Document Formats**

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

683 **8. New Attributes**684 **8.1 Job Template Attributes**

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

687 **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)

688 **8.1.1 materials-col (1setOf collection)**

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

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

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

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

Member Attribute	Printer: Supported Values
material-amount	N/A
material-amount-units	material-amount-units-supported
material-color	N/A
material-diameter	material-diameter-supported
material-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

703 **8.1.1.1 material-amount (integer(0:MAX) | unknown)**

704 This RECOMMENDED member attribute provides the estimated amount of material that is
 705 available ("materials-col-database" and "materials-col-ready" values), the estimated
 706 amount of material that is required ("materials-col" values), or the actual amount of
 707 material that has been used ("materials-col-actual" values).

708 **8.1.1.2 material-amount-units (type2 keyword)**

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

711 'g': Value is mass in grams.

712 'kg': Value is mass in kilograms.

713 'l': Value is volume in liters.

714 'm': Value is length in meters.

715 'ml': Value is volume in milliliters.

716 'mm': Value is length in millimeters.

717 **8.1.1.3 material-color (type2 keyword)**

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

720 **8.1.1.4 material-diameter (integer(0:MAX))**

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

724 **8.1.1.5 material-fill-density (integer(0:100))**

725 This REQUIRED member attribute specifies the desired density of filled interior regions in
726 percent.

727 **8.1.1.6 material-key (keyword)**

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

730 **8.1.1.7 material-name (name(MAX))**

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

732 **8.1.1.8 material-purpose (1setOf type2 keyword)**

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

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

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

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

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

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

740 **8.1.1.9 material-rate (integer(1:MAX))**

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

743 8.1.1.10 material-rate-units (type2 keyword)

744 This member attribute provides the units for the "material-rate" member attribute. Values
745 include:

746 'mg_sec ': Value is milligrams per second.

747 'ml_sec ': Value is milliliters per second.

748 'mm_sec ': Value is millimeters per second.

749 8.1.1.11 material-shell-thickness (integer(0:MAX))

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

752 8.1.1.12 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))

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

756 8.1.1.13 material-type (type2 keyword | name(MAX))

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

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

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

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

765 'chocolate': Chocolate.

766 'gold': Gold (metal).

767 'nylon': Nylon.

768 'pet': Polyethylene terephthalate (PET).

769 'photopolymer': Photopolymer (liquid) resin.

770 'pla': Polylactic Acid (PLA).

- 771 'pla-conductive': Conductive PLA.
- 772 'pla-dissolvable': Dissolvable PLA.
- 773 'pla-flexible': Flexible PLA.
- 774 'pla-magnetic': PLA with embedded iron particles.
- 775 'pla-steel': PLA with embedded steel particles.
- 776 'pla-stone': PLA with embedded stone chips.
- 777 'pla-wood': PLA with embedded wood fibers.
- 778 'polycarbonate': Polycarbonate.
- 779 'silver': Silver (metal).
- 780 'titanium': Titanium (metal).
- 781 'wax': Wax.

782 **8.1.2 multiple-object-handling (type2 keyword)**

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

- 787 'auto': Automatically determine the best way to print multiple objects in a Job.
- 788 'best-fit': Fit as many objects as possible within the build volume.
- 789 'best-quality': Optimize the number of objects for print quality.
- 790 'best-speed': Optimize the number of objects for print speed.
- 791 'one-at-a-time': Print one object at a time.
- 792

793 **8.1.3 print-accuracy (collection)**

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

796 When enforcing attribute fidelity ("ipp-attribute-fidelity" with a value of 'true'), Printers only
797 reject "print-accuracy" values that are smaller than the "print-accuracy-supported" (section
798 8.3.18) value.

799 **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

800 **8.1.3.1 accuracy-units (type2 keyword)**

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

803 'mm': Accuracy numbers are in millimeters.

804 'um': Accuracy numbers are in micrometers.

805 'nm': Accuracy numbers are in nanometers.

806 **8.1.3.2 x-accuracy (integer(0:MAX))**

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

810 **8.1.3.3 y-accuracy (integer(0:MAX))**

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

814 **8.1.3.4 z-accuracy (integer(0:MAX))**

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

818 **8.1.4 print-objects (1setOf collection)**

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

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

824 **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

825

826 **8.1.4.1 document-number (integer(1:MAX))**

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

829 **8.1.4.2 object-offset (collection)**

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

834 **8.1.4.3 object-size (collection)**

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

839 **8.1.4.4 object-uuid (uri)**

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

842 8.1.5 print-rafts (type2 keyword)

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

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

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

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

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

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

851 8.1.6 print-supports (type2 keyword)

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

854 'none': Do not print supports.

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

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

857 8.1.7 printer-bed-temperature (integer(-273:MAX))

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

861

862 **8.2 Job Status Attributes**

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

865 **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)

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

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

868 **8.3 Printer Description Attributes**

869 **8.3.1 accuracy-units-supported (1setOf type2 keyword)**

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

872 **8.3.2 material-amount-units-supported (1setOf type2 keyword)**

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

876 **8.3.3 material-diameter-supported (1setOf (integer | rangeOfInteger))**

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

880 **8.3.4 material-purpose-supported (1setOf type2 keyword)**

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

883 8.3.5 material-rate-supported (1setOf (integer | rangeOfInteger))

884 This Printer Description attribute lists the supported "material-rate" values for the Printer.
885 This attribute MUST be supported if the "material-rate" member attribute (Section 8.1.1.9)
886 is supported.

887 8.3.6 material-rate-units-supported (1setOf type2 keyword)

888 This Printer Description attribute lists the supported "material-rate-units" values for the
889 Printer. This attribute MUST be supported if the "material-rate-units" member attribute
890 (Section 8.1.1.10) is supported.

**891 8.3.7 material-shell-thickness-supported (1setOf (integer(1:MAX) |
892 rangeOfInteger(1:MAX)))**

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

**895 8.3.8 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-
896 273:MAX)))**

897 This CONDITIONALLY REQUIRED Printer Description attribute specifies the supported
898 "material-temperature" values (or ranges of values) in degrees Celsius. This attribute
899 MUST be supported if the "material-temperature" member attribute (Section 8.1.1.12) is
900 supported.

901 8.3.9 material-type-supported (1setOf type2 keyword)

902 This REQUIRED Printer Description attribute lists the supported "material-type" values for
903 the Printer.

904 8.3.10 materials-col-database (1setOf collection)

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

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

```
912     materials-col-database =  
913         { material-name="Generic PLA Filament" material-key="generic-pla"  
914           material-diameter=285 material-temperature=215-235 }  
915
```

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

```
918     materials-col-database =  
919     { material-name="Generic PLA Filament" material-key="generic-pla"  
920     material-diameter=285 material-temperature=215-235 },  
921     { material-name="Example Corp Flexible Midnight Blue PLA" material-  
922     key="com.example.flexible-midnight-blue" material-  
923     color="com.example.midnight-blue_000027" material-diameter=285 material-  
924     temperature=210-225 }
```

925 **8.3.11 materials-col-default (1setOf collection)**

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

928 **8.3.12 materials-col-ready (1setOf collection)**

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

931 **8.3.13 materials-col-supported (1setOf type2 keyword)**

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

936 **8.3.14 multiple-object-handling-default (type2 keyword)**

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

940 **8.3.15 multiple-object-handling-supported (1setOf type2 keyword)**

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

944

945 **8.3.16 pdf-features-supported (1setOf type2 keyword)**

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

949 Values include:

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

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

953 **8.3.17 print-accuracy-default (collection)**

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

955 **8.3.18 print-accuracy-supported (collection)**

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

958 **8.3.19 print-objects-supported (1setOf type2 keyword)**

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

962 **8.3.20 print-rafts-default (type2 keyword)**

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

964 **8.3.21 print-rafts-supported (1setOf type2 keyword)**

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

966 **8.3.22 print-supports-default (type2 keyword)**

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

968 **8.3.23 print-supports-supported (1setOf type2 keyword)**

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

970 **8.3.24 printer-bed-temperature-default (integer(-273:MAX))**

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

974 **8.3.25 printer-bed-temperature-supported (1setOf (integer(-273:MAX) |
975 rangeOfInteger(-273:MAX)))**

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

979 **8.3.26 printer-camera-image-uri (1setOf uri)**

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

984 **8.3.27 printer-volume-supported (collection)**

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

987 **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))

988 **8.3.27.1 x-dimension (integer(1:MAX))**

989 This member attributes specifies the width of the build volume in hundredths of millimeters
990 (1/2540th of an inch).

991 **8.3.27.2 y-dimension (integer(1:MAX))**

992 This member attributes specifies the depth of the build volume in hundredths of millimeters
993 (1/2540th of an inch).

994 **8.3.27.3 z-dimension (integer(1:MAX))**

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

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

998 **9.1 ipp-features-supported (1setOf type2 keyword)**

999 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-
1000 supported" Printer Description attribute.

1001 **9.2 printer-state-reasons (1setOf type2 keyword)**

1002 This specification registers the following new values for the "printer-state-reasons" Printer
1003 Status attribute:

1004 'camera-failure': A camera is no longer working.

1005 'chamber-cooling': A chamber is being cooled.

1006 'chamber-heating': A chamber is being heated.

1007 'chamber-temperature-high': The temperature of a chamber is high.

1008 'chamber-temperature-low': The temperature of a chamber is low.

1009 'extruder-cooling': An extruder is being cooled.

1010 'extruder-failure': An extruder has failed and requires maintenance or replacement.

1011 'extruder-heating': An extruder is being heated.

1012 'extruder-jam': An extruder is jammed or clogged.

1013 'extruder-temperature-high': The temperature of an extruder is too high.

1014 'extruder-temperature-low': The temperature of an extruder is too low.

1015 'fan-failure': A fan has failed.

1016 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.

1017 'lamp-failure': A lamp has failed.

1018 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.

1019 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.

1020 'laser-failure': A laser has failed.

1021 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.

- 1022 'material-empty': One or more build materials have been exhausted.
- 1023 'material-low': One or more build materials may need replenishment soon.
- 1024 'material-needed': One or more build materials need to be loaded for a processing Job.
- 1025 'motor-failure': A motor has failed.
- 1026

1027 **10. Conformance Requirements**

1028 **10.1 Printer Conformance Requirements**

1029 In order for a Printer to claim conformance to this specification, a Printer MUST support:

- 1030 1. The required discovery protocols in section 5;
- 1031 2. The required transports and resource paths in section 6.1;
- 1032 3. The required HTTP features in section 6.2;
- 1033 4. The required IPP operations in section 6.3;
- 1034 5. The required IPP attributes in sections 6.4 through 6.9;
- 1035 6. The required document formats in section 7;
- 1036 7. The additional values defined in section 9;
- 1037 8. The internationalization considerations in section 11; and
- 1038 9. The security considerations in section 12.

1039 **10.2 Client Conformance Requirements**

1040 In order for a Client to claim conformance to this specification, a Client MUST support:

- 1041 1. The required discovery protocols in section 5;
- 1042 2. The required transports and resource paths in section 6.1;
- 1043 3. The required HTTP features in section 6.2;
- 1044 4. The required IPP operations in section 6.3;
- 1045 5. The required IPP attributes in sections 6.4 through 6.9;
- 1046 6. The required document formats in section 7;
- 1047 7. The additional values defined in section 9;
- 1048 8. The internationalization considerations in section 11; and
- 1049 9. The security considerations in section 12.

1050

1051 **11. Internationalization Considerations**

1052 For interoperability and basic support for multiple languages, conforming implementations
1053 MUST support:

- 1054 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)
1055 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 1056 2. The Unicode Format for Network Interchange [RFC5198] which requires
1057 transmission of well-formed UTF-8 strings and recommends transmission of
1058 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1059 Unicode NFC is defined as the result of performing Canonical Decomposition (into base
1060 characters and combining marks) followed by Canonical Composition (into canonical
1061 composed characters wherever Unicode has assigned them).

1062 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and
1063 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in
1064 IPP Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8
1065 URIs now 'hidden').

1066 Implementations of this specification SHOULD conform to the following standards on
1067 processing of human-readable Unicode text strings, see:

1068 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical

1069 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping

1070 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]

1071 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences

1072 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization

1073 Unicode Character Encoding Model [UTR17] – multi-layer character model

1074 Unicode in XML and other Markup Languages [UTR20] – XML usage

1075 Unicode Character Property Model [UTR23] – character properties

1076 Unicode Conformance Model [UTR33] – Unicode conformance basis+

1077 Unicode Collation Algorithm [UTS10] – sorting

1078 Unicode Locale Data Markup Language [UTS35] – locale databases

1079 **12. Security Considerations**

1080 In addition to the security considerations described in the IPP/1.1: Model and Semantics
1081 [RFC2911], the following sub-sections describe issues that are unique to 3D printing.

1082 Implementations of this specification SHOULD conform to the following standards on
1083 processing of human-readable Unicode text strings, see:

1084 Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1085 Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

1086 **12.1 Confidentiality**

1087 Clients and Printers MUST provide confidentiality of data in transit using either an interface
1088 providing physical security such as USB or using TLS encryption [RFC5246] over
1089 unsecured/network connections,

1090 **12.2 Access Control**

1091 Because of the potential for abuse and misuse, Printers SHOULD provide access control
1092 mechanisms including lists of allowed Clients, authentication, and authorization to site
1093 defined policies.

1094 **12.3 Physical Safety**

1095 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such
1096 as protective gates, covers, or interlocks.

1097 **12.4 Material Safety**

1098 Printers MUST restrict usage and combination of materials to those that can be safely
1099 printed. Access controls (section 12.2) MAY be used to allow authorized End Users to
1100 experiment with untested materials or combinations, but only when such materials or
1101 combinations can reasonably be expected to not pose a safety risk.

1102 **12.5 Temperature Control**

1103 Printers MUST validate values provided by Clients and limit material, extruder, build
1104 platform, and print chamber temperatures within designed limits to prevent unsafe
1105 operating conditions, damage to the hardware, hazardous emissions, explosions, and/or
1106 fires.

1107

1108 13. IANA and PWG Considerations

1109 13.1 Attribute Registrations

1110 The attributes defined in this specification will be published by IANA according to the
1111 procedures in IPP/1.1 Model and Semantics [RFC2911] section 6.2 in the following file:

1112 <http://www.iana.org/assignments/ipp-registrations>

1113 The registry entries will contain the following information:

1114 Job Status attributes:	Reference
-----	-----
1115 materials-col-actual (1setOf collection)	[PWG5100.NN]
1116 < member attributes are the same as materials-col >	[PWG5100.NN]
1117 multiple-object-handling-actual (type2 keyword)	[PWG5100.NN]
1118 print-accuracy-actual (collection)	[PWG5100.NN]
1119 < member attributes are the same as print-accuracy >	[PWG5100.NN]
1120 print-objects-actual (1setOf collection)	[PWG5100.NN]
1121 < member attributes are the same as print-objects >	[PWG5100.NN]
1122 print-rafts-actual (1setOf type2 keyword)	[PWG5100.NN]
1123 print-supports-actual (1setOf type2 keyword)	[PWG5100.NN]
1124 printer-bed-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.NN]
1125	
1126	
1127 Job Template attributes:	Reference
-----	-----
1128 materials-col (1setOf collection)	[PWG5100.NN]
1129 material-amount (integer(0:MAX))	[PWG5100.NN]
1130 material-amount-units (type2 keyword)	[PWG5100.NN]
1131 material-color (type2 keyword)	[PWG5100.NN]
1132 material-diameter (integer(1:MAX))	[PWG5100.NN]
1133 material-fill-density (integer(0:100))	[PWG5100.NN]
1134 material-key (keyword)	[PWG5100.NN]
1135 material-name (name(MAX))	[PWG5100.NN]
1136 material-purpose (1setOf type2 keyword)	[PWG5100.NN]
1137 material-rate (integer(1:MAX))	[PWG5100.NN]
1138 material-rate-units (type2 keyword)	[PWG5100.NN]
1139 material-shell-thickness (integer(0:MAX))	[PWG5100.NN]
1140 material-temperature (integer(-273:MAX) rangeOfInteger(-273:MAX))	[PWG5100.NN]
1141	
1142	
1143 material-type (type2 keyword name(MAX))	[PWG5100.NN]
1144 multiple-object-handling (type2 keyword)	[PWG5100.NN]
1145 print-accuracy (collection)	[PWG5100.NN]
1146 accuracy-units (type2 keyword)	[PWG5100.NN]
1147 x-accuracy (integer(0:MAX))	[PWG5100.NN]
1148 y-accuracy (integer(0:MAX))	[PWG5100.NN]
1149 z-accuracy (integer(0:MAX))	[PWG5100.NN]
1150 print-objects (1setOf collection)	[PWG5100.NN]
1151 document-number (integer(1:MAX))	[PWG5100.NN]
1152 object-offset (collection)	[PWG5100.NN]
1153 x-offset (integer(0:MAX))	[PWG5100.NN]
1154 y-offset (integer(0:MAX))	[PWG5100.NN]
1155 z-offset (integer(0:MAX))	[PWG5100.NN]

1156	object-size (collection)	[PWG5100.NN]
1157	x-dimension (integer(1:MAX))	[PWG5100.NN]
1158	y-dimension (integer(1:MAX))	[PWG5100.NN]
1159	z-dimension (integer(1:MAX))	[PWG5100.NN]
1160	object-uuid (uri)	[PWG5100.NN]
1161	print-rafts (type2 keyword)	[PWG5100.NN]
1162	print-supports (type2 keyword)	[PWG5100.NN]
1163	printer-bed-temperature (integer(-273:MAX))	[PWG5100.NN]
1164		
1165	Printer Description attributes:	Reference
1166	-----	-----
1167	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.NN]
1168	material-amount-units-supported (1setOf type2 keyword)	[PWG5100.NN]
1169	material-diameter-supported (1setOf (integer(0:MAX)	
1170	rangeOfInteger(0:MAX)))	[PWG5100.NN]
1171	material-purpose-supported (1setOf type2 keyword)	[PWG5100.NN]
1172	material-rate-supported (1setOf (integer(1:MAX) rangeOfInteger(1:MAX)))	
1173		[PWG5100.NN]
1174	material-rate-units-supported (1setOf type2 keyword)	[PWG5100.NN]
1175	material-shell-thickness-supported (1setOf (integer(0:MAX)	
1176	rangeOfInteger(0:MAX)))	[PWG5100.NN]
1177	material-temperature-supported (1setOf (integer(-273:MAX)	
1178	rangeOfInteger(-273:MAX)))	[PWG5100.NN]
1179	material-type-supported (1setOf type2 keyword)	[PWG5100.NN]
1180	materials-col-database (1setOf collection)	[PWG5100.NN]
1181	< member attributes are the same as materials-col >	[PWG5100.NN]
1182	materials-col-default (1setOf collection)	[PWG5100.NN]
1183	< member attributes are the same as materials-col >	[PWG5100.NN]
1184	materials-col-ready (1setOf collection)	[PWG5100.NN]
1185	< member attributes are the same as materials-col >	[PWG5100.NN]
1186	materials-col-supported (1setOf type2 keyword)	[PWG5100.NN]
1187	multiple-object-handling-default (type2 keyword)	[PWG5100.NN]
1188	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.NN]
1189	pdf-features-supported (1setOf type2 keyword)	[PWG5100.NN]
1190	print-accuracy-supported (collection)	[PWG5100.NN]
1191	< member attributes are the same as print-accuracy >	[PWG5100.NN]
1192	print-objects-supported (1setOf type2 keyword)	[PWG5100.NN]
1193	print-rafts-default (type2 keyword)	[PWG5100.NN]
1194	print-rafts-supported (1setOf type2 keyword)	[PWG5100.NN]
1195	print-supports-default (type2 keyword)	[PWG5100.NN]
1196	print-supports-supported (1setOf type2 keyword)	[PWG5100.NN]
1197	printer-bed-temperature-default (integer(-273:MAX))	[PWG5100.NN]
1198	printer-bed-temperature-supported (1setOf (integer(-273:MAX)	
1199	rangeOfInteger(-273:MAX)))	[PWG5100.NN]
1200	printer-camera-image-uri (1setOf uri)	[PWG5100.NN]
1201	printer-volume-supported (collection)	[PWG5100.NN]
1202	x-dimension (integer(1:MAX))	[PWG5100.NN]
1203	y-dimension (integer(1:MAX))	[PWG5100.NN]
1204	z-dimension (integer(1:MAX))	[PWG5100.NN]

1205 13.2 Attribute Value Registrations

1206 The attributes defined in this specification will be published by IANA according to the
1207 procedures in IPP/1.1 Model and Semantics [RFC2911] section 6.1 in the following file:

1208	http://www.iana.org/assignments/ipp-registrations	
1209	The registry entries will contain the following information:	
1210	Attributes (attribute syntax)	
1211	Keyword Attribute Value	Reference
1212	-----	-----
1213	accuracy-units (type2 keyword)	[PWG5100.NN]
1214	mm	[PWG5100.NN]
1215	nm	[PWG5100.NN]
1216	um	[PWG5100.NN]
1217	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.NN]
1218	< any accuracy-units values >	[PWG5100.NN]
1219	ipp-features-supported (1setOf type2 keyword)	[PWG5100.13]
1220	ipp-3d	[PWG5100.NN]
1221	material-amount-units (type2 keyword)	[PWG5100.NN]
1222	g	[PWG5100.NN]
1223	kg	[PWG5100.NN]
1224	l	[PWG5100.NN]
1225	m	[PWG5100.NN]
1226	ml	[PWG5100.NN]
1227	mm	[PWG5100.NN]
1228	material-color (type2 keyword)	[PWG5100.NN]
1229	< any "media" color name >	[PWG5100.NN]
1230	material-purpose (1setOf type2 keyword)	[PWG5100.NN]
1231	all	[PWG5100.NN]
1232	in-fill	[PWG5100.NN]
1233	raft	[PWG5100.NN]
1234	shell	[PWG5100.NN]
1235	support	[PWG5100.NN]
1236	material-rate-units (type2 keyword)	[PWG5100.NN]
1237	mg_second	[PWG5100.NN]
1238	ml_second	[PWG5100.NN]
1239	mm_second	[PWG5100.NN]
1240	material-type (type2 keyword)	[PWG5100.NN]
1241	abs	[PWG5100.NN]
1242	abs-carbon-fiber	[PWG5100.NN]
1243	abs-carbon-nanotube	[PWG5100.NN]
1244	chocolate	[PWG5100.NN]
1245	gold	[PWG5100.NN]
1246	nylon	[PWG5100.NN]
1247	pet	[PWG5100.NN]
1248	photopolymer	[PWG5100.NN]
1249	pla	[PWG5100.NN]
1250	pla-conductive	[PWG5100.NN]
1251	pla-dissolvable	[PWG5100.NN]
1252	pla-flexible	[PWG5100.NN]
1253	pla-magnetic	[PWG5100.NN]
1254	pla-steel	[PWG5100.NN]
1255	pla-stone	[PWG5100.NN]
1256	pla-wood	[PWG5100.NN]
1257	polycarbonate	[PWG5100.NN]
1258	silver	[PWG5100.NN]
1259	titanium	[PWG5100.NN]
1260	wax	[PWG5100.NN]

1261	materials-col-supported (1setOf type2 keyword)	[PWG5100.NN]
1262	< any materials-col member attribute name >	[PWG5100.NN]
1263	multiple-object-handling (type2 keyword)	[PWG5100.NN]
1264	auto	[PWG5100.NN]
1265	best-fit	[PWG5100.NN]
1266	best-quality	[PWG5100.NN]
1267	best-speed	[PWG5100.NN]
1268	one-at-a-time	[PWG5100.NN]
1269	pdf-features-supported (1setOf type2 keyword)	[PWG5100.NN]
1270	prc	[PWG5100.NN]
1271	u3d	[PWG5100.NN]
1272	print-objects-supported (1setOf type2 keyword)	[PWG5100.NN]
1273	< any print-objects member attribute name >	[PWG5100.NN]
1274	print-rafts (type2 keyword)	[PWG5100.NN]
1275	brim	[PWG5100.NN]
1276	none	[PWG5100.NN]
1277	raft	[PWG5100.NN]
1278	skirt	[PWG5100.NN]
1279	standard	[PWG5100.NN]
1280	print-supports (type2 keyword)	[PWG5100.NN]
1281	material	[PWG5100.NN]
1282	none	[PWG5100.NN]
1283	standard	[PWG5100.NN]
1284	printer-state-reasons (1setOf type2 keyword)	[RFC2911]
1285	camera-failure	[PWG5100.NN]
1286	chamber-cooling	[PWG5100.NN]
1287	chamber-heating	[PWG5100.NN]
1288	chamber-temperature-high	[PWG5100.NN]
1289	chamber-temperature-low	[PWG5100.NN]
1290	extruder-cooling	[PWG5100.NN]
1291	extruder-failure	[PWG5100.NN]
1292	extruder-heating	[PWG5100.NN]
1293	extruder-jam	[PWG5100.NN]
1294	extruder-temperature-high	[PWG5100.NN]
1295	extruder-temperature-low	[PWG5100.NN]
1296	fan-failure	[PWG5100.NN]
1297	lamp-at-eol	[PWG5100.NN]
1298	lamp-failure	[PWG5100.NN]
1299	lamp-near-eol	[PWG5100.NN]
1300	laser-at-eol	[PWG5100.NN]
1301	laser-failure	[PWG5100.NN]
1302	laser-near-eol	[PWG5100.NN]
1303	material-empty	[PWG5100.NN]
1304	material-low	[PWG5100.NN]
1305	material-needed	[PWG5100.NN]
1306	motor-failure	[PWG5100.NN]

1307 13.3 Service Type Registration

1308 The DNS-SD service type defined in this specification will be published by IANA according
1309 to the procedures in Internet Assigned Numbers Authority (IANA) Procedures for the
1310 Management of the Service Name and Transport Protocol Port Number Registry
1311 [BCP165].

1312 The registration template is as follows:

1313 Service Name: ipp3d
1314
1315 Transport Protocol(s): tcp
1316
1317 Assignee/Contact: Michael Sweet, msweet@apple.com
1318
1319 Description: 3D Print services (3D printers) using the Internet Printing
1320 Protocol over HTTPS.
1321
1322 Reference: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-5100.NN.pdf)
1323 [5100.NN.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-5100.NN.pdf)
1324
1325 Port Number:
1326
1327 Service Code:
1328
1329 Known Unauthorized Uses:
1330
1331 Assignment Notes: Change controller is The Printer Working Group, c/o The
1332 IEEE Industry Standards and Technology Organization, 445 Hoes Lane,
1333 Piscataway, NJ 08854, USA

1334 13.4 MIME Media Type Registration

1335 The MIME media type defined in this specification will be published by IANA according to
1336 the procedures in Media Type Specifications and Registration Procedures [BCP13].

1337 The registration template is as follows:

1338 Type name: media
1339
1340 Subtype name: 3mf
1341
1342 Required parameters: N/A
1343
1344 Optional parameters: N/A
1345
1346 Encoding considerations: binary
1347
1348 Security considerations: 3MF files can be very large, particularly after
1349 decompression, which could fill a filesystem and cause a denial of service
1350 or system failure. This media type does not employ any sort of active or
1351 executable content. Neither privacy nor integrity protection is provided
1352 by the media type itself; if these protections are needed they must be
1353 implemented externally. Authentication, access control, and
1354 privacy/integrity are normally handled by the Internet Printing Protocol,
1355 Hyper-Text Transport Protocol, and Transport Layer Security.
1356
1357 Interoperability considerations:
1358
1359 Published specification: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-5100.NN.pdf)
1360 [YYYYMMDD-5100.NN.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-YYYYMMDD-5100.NN.pdf)

1361
1362 Applications that use this media type: 3D modeling and slicing software
1363
1364 Fragment identifier considerations:
1365
1366 Additional information:
1367
1368 Deprecated alias names for this type: N/A
1369
1370 Magic number(s): N/A
1371
1372 File extension(s): 3mf
1373
1374 Macintosh file type code(s): N/A
1375
1376 Person & email address to contact for further information: Michael Sweet,
1377 msweet@apple.com
1378
1379 Intended usage: COMMON
1380
1381 Restrictions on usage: N/A
1382
1383 Author/Change controller: The Printer Working Group, c/o The IEEE Industry
1384 Standards and Technology Organization, 445 Hoes Lane, Piscataway, NJ
1385 08854, USA
1386
1387 Provisional registration? (standards tree only): No

1388 **13.5 Semantic Model Registrations**

1389 The IPP attributes, values, and operations defined in this specification and listed in the
1390 preceding sections will be added to the PWG Semantic Model XML schema using the
1391 method defined in section 21 of [PWG5108.07].
1392

1393 14. References

1394 14.1 Normative References

- 1395 [3MF] "3D Manufacturing Format Core Specification & Reference Guide
1396 v1.0", [http://www.3mf.io/wp-](http://www.3mf.io/wp-content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf)
1397 [content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf](http://www.3mf.io/wp-content/uploads/2015/04/3MFcoreSpec_1.0.1.pdf)
- 1398 [BONJOUR] Apple Inc., "Bonjour Printing Specification Version 1.2", July 2013,
1399 <http://developer.apple.com/bonjour/>
- 1400 [ISO10646] "Information technology -- Universal Coded Character Set (UCS)",
1401 ISO/IEC 10646:2011
- 1402 [ISO32000] "Document management — Portable document format — Part 1: PDF
1403 1.7", ISO 32000-2008
- 1404 [ISO52915] "Standard Specification for Additive Manufacturing File Format (AMF)
1405 Version 1.1", ISO/ASTM 52915, 2013
- 1406 [PWG5100.5] D. Carney, T. Hastings, P. Zehler, "IPP: Document Object", PWG
1407 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)
1408 [ippdocobject10-20031031-5100.5.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippdocobject10-20031031-5100.5.pdf)
- 1409 [PWG5100.11] T. Hastings, D. Fullman, "IPP Job and Printer Extensions - Set 2
1410 (JPS2)", PWG 5100.11-2010, October 2010,
1411 [http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-20101030-5100.11.pdf)
1412 [20101030-5100.11.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext10-20101030-5100.11.pdf)
- 1413 [PWG5100.12] M. Sweet, I. McDonald, "IPP Version 2.0, 2.1, and 2.2", PWG
1414 5100.12-2015, October 2015,
1415 <http://ftp.pwg.org/pub/pwg/standards/std-ipp20-20151030-5100.12.pdf>
- 1416 [PWG5100.13] M. Sweet, I. McDonald, "IPP Job and Printer Extensions - Set 3
1417 (JPS3)", PWG 5100.13-2012, July 2012,
1418 [http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext3v10-](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext3v10-20120727-5100.13.pdf)
1419 [20120727-5100.13.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippjobprinterext3v10-20120727-5100.13.pdf)
- 1420 [PWG5100.14] M. Sweet, I. McDonald, A. Mitchell, J. Hutchings, "IPP Everywhere",
1421 PWG 5100.14-2013, January 2013,
1422 [http://ftp.pwg.org/pub/pwg/candidates/cs-ippeve10-20130128-](http://ftp.pwg.org/pub/pwg/candidates/cs-ippeve10-20130128-5100.14.pdf)
1423 [5100.14.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ippeve10-20130128-5100.14.pdf)
- 1424 [PWG5100.18] M. Sweet, I. McDonald, "IPP Shared Infrastructure Extensions
1425 (INFRA)", PWG 5100.18-2015, June 2015,

- 1426 <http://ftp.pwg.org/pub/pwg/candidates/cs-ippinfra10-20150619-5100.18.pdf>
1427
- 1428 [PWG5108.01] W. Wagner, P. Zehler, "MFD Model and Common Semantics", PWG
1429 5108.01-2011, April 2011, <http://ftp.pwg.org/pub/pwg/candidates/cs-sm20-mfdmodel10-20110415-5108.1.pdf>
1430
- 1431 [PWG5108.07] P. Zehler, "PWG Print Job Ticket and Associated Capabilities Version
1432 1.0 (PJT)", PWG 5108.07-2012, August 2012,
1433 <http://ftp.pwg.org/pub/pwg/candidates/cs-sm20-pjt10-20120801-5108.07.pdf>
1434
- 1435 [RFC2911] T. Hastings, R. Herriot, R. deBry, S. Isaacson, P. Powell, "Internet
1436 Printing Protocol/1.1: Model and Semantics", RFC 2911, September
1437 2000, <http://tools.ietf.org/html/rfc2911>
- 1438 [RFC3805] R. Bergman, H. Lewis, I. McDonald, "Printer MIB v2", RFC 3805, June
1439 2004, <http://tools.ietf.org/html/rfc3805>
- 1440 [RFC3806] R. Bergman, H. Lewis, I. McDonald, "Printer Finishing MIB", RFC
1441 3806, June 2004, <http://tools.ietf.org/html/rfc3806>
- 1442 [RFC5198] J. Klensin, M. Padlipsky, "Unicode Format for Network Interchange",
1443 RFC 5198, March 2008, <http://tools.ietf.org/html/rfc5198>
- 1444 [RFC5246] T.Dierks, E. Rescorla, "Transport Layer Security 1.2", RFC 5246,
1445 August 2008, <http://tools.ietf.org/html/rfc5246>
- 1446 [RFC6762] S. Cheshire, M. Krochmal, "Multicast DNS", RFC 6762, February
1447 2013, <http://tools.ietf.org/html/rfc6762>
- 1448 [RFC6763] S. Cheshire, M. Krochmal, "DNS-Based Service Discovery", RFC
1449 6763, February 2013, <http://tools.ietf.org/html/rfc6763>
- 1450 [STD63] F. Yergeau, "UTF-8, a transformation format of ISO 10646", RFC
1451 3629/STD 63, November 2003, <http://tools.ietf.org/html/rfc3629>
- 1452 [UAX9] Unicode Consortium, "Unicode Bidirectional Algorithm", UAX#9, June
1453 2014,
1454 <http://www.unicode.org/reports/tr9/tr9-31.html>
- 1455 [UAX14] Unicode Consortium, "Unicode Line Breaking Algorithm", UAX#14,
1456 June 2014,
1457 <http://www.unicode.org/reports/tr14/tr14-33.html>
- 1458 [UAX15] Unicode Consortium, "Normalization Forms", UAX#15, June 2014,
1459 <http://www.unicode.org/reports/tr15/tr15-41.html>

- 1460 [UAX29] Unicode Consortium, “Unicode Text Segmentation”, UAX#29, June
1461 2014,
1462 <http://www.unicode.org/reports/tr29/tr29-25.html>
- 1463 [UAX31] Unicode Consortium, “Unicode Identifier and Pattern Syntax”,
1464 UAX#31, June 2014,
1465 <http://www.unicode.org/reports/tr31/tr31-21.html>
- 1466 [UNICODE] Unicode Consortium, "Unicode Standard", Version 9.0.0, June 2016,
1467 <http://www.unicode.org/versions/Unicode9.0.0/>
- 1468 [UTS10] Unicode Consortium, “Unicode Collation Algorithm”, UTS#10, June
1469 2014,
1470 <http://www.unicode.org/reports/tr10/tr10-30.html>
- 1471 [UTS35] Unicode Consortium, “Unicode Locale Data Markup Language”,
1472 UTS#35, September 2014,
1473 <http://www.unicode.org/reports/tr35/tr35-37/tr35.html>
- 1474 [UTS39] Unicode Consortium, “Unicode Security Mechanisms”, UTS#39,
1475 September 2014,
1476 <http://www.unicode.org/reports/tr39/tr39-9.html>

1477 **14.2 Informative References**

- 1478 [BCP13] N. Freed, J. Klensin, T. Hansen, "Media Type Specifications and
1479 Registration Procedures", BCP 13, RFC 6838,
1480 <http://tools.ietf.org/html/rfc6838>
- 1481 [BCP165] M. Cotton, L. Eggert, J. Touch, M. Westerlund, S. Cheshire, "Internet
1482 Assigned Numbers Authority (IANA) Procedures for the Management
1483 of the Service Name and Transport Protocol Port Number Registry",
1484 BCP 165, RFC 6335, <http://tools.ietf.org/html/rfc6335>
- 1485 [IPPSAMPLE] "ISTO-PWG IPP Sample Code Repository",
1486 <https://github.com/istopwg/ippsample>
- 1487 [STLFORMAT] 3D Systems, Inc., "SLC File Specification", 1994
- 1488 [UNISECFAQ] Unicode Consortium “Unicode Security FAQ”, November 2013,
1489 <http://www.unicode.org/faq/security.html>
- 1490 [UTR17] Unicode Consortium “Unicode Character Encoding Model”, UTR#17,
1491 November 2008,
1492 <http://www.unicode.org/reports/tr17/tr17-7.html>

- 1493 [UTR20] Unicode Consortium “Unicode in XML and other Markup Languages”,
1494 UTR#20, January 2013,
1495 <http://www.unicode.org/reports/tr20/tr20-9.html>
- 1496 [UTR23] Unicode Consortium “Unicode Character Property Model”, UTR#23,
1497 November 2008,
1498 <http://www.unicode.org/reports/tr23/tr23-9.html>
- 1499 [UTR33] Unicode Consortium “Unicode Conformance Model”, UTR#33,
1500 November 2008,
1501 <http://www.unicode.org/reports/tr33/tr33-5.html>

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1513 Michael Scrutton, Adobe Systems
1514 Emmet Lalish, Microsoft Corporation
1515

1516 **16. Object Definition Languages (ODLs)**

1517 This section provides information on several commonly used ODLs with either existing
1518 (registered) or suggested MIME media types.

1519 **16.1 3D Manufacturing Format (3MF)**

1520 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that
1521 provides geometry, material, and texture information necessary to support a wide variety of
1522 3D printers. Materials can be named and composed within the geometry, facilitating
1523 multiple material support in coordination with a Job Ticket.

1524 The registered MIME media type for the original Microsoft published specification is
1525 "application/vnd.ms-3mfdocument". The suggested (but not registered) MIME media type
1526 for the 3MF Consortium's published specification is "model/3mf".

1527 **16.2 Additive Manufacturing Format (AMF)**

1528 AMF [ISO52915] is a relatively new format that was designed as a replacement for the
1529 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-
1530 available specification, but has several advantages over STL including:

- 1531 1. Shared vertices which eliminates holes and other breaks in the surface
1532 geometry of objects,
- 1533 2. Specification of multiple materials in a single file,
- 1534 3. Curved surfaces can be specified, and
- 1535 4. Coordinates use explicit units for proper output dimensions.

1536 The suggested (but not registered) MIME media type is 'model/amf'.

1537 **16.3 Portable Document Format (PDF)**

1538 PDF [ISO32000] is widely supported for 2D printing and has two 3D formats that are used
1539 to embed 3D objects - PRC [ISO14739-1] and U3D [ECMA363]. The registered MIME
1540 media type for PDF is "application/pdf".

1541 [For discussion: define a "model/pdf" MIME media type for PDFs containing 3D content?]

1542 **16.4 Standard Tessellation Language (STL)**

1543 STL [STLFORMAT] is widely supported by existing client software. The registered MIME
1544 media type is 'application/sla'.

1545

1546 **17. Design Choices**

1547 This section documents some of the design choices that were made during the
1548 development of this specification.

1549 **17.1 Units for Length Values**

1550 The default unit for most length values is hundredths of millimeters (1/2540th of an inch),
1551 matching the units for 2D printing and providing a range of 0.01mm to 21.47km. This was
1552 determined to be sufficient for the class of printers this specification targets.

1553 **17.2 Units for Thickness Values**

1554 The default unit for most thickness values is nanometers, which provides a range of
1555 0.000001mm to 2.147m. This was determined to be sufficient for the class of printers this
1556 specification targets.

1557 **17.3 Use of Celsius for Temperatures**

1558 The various integer attributes for temperature use degrees Celsius. This was done
1559 because most existing printers and materials are specified using degrees Celsius. There is
1560 no advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to
1561 perform additional unit conversions could cause safety issues. All temperature attributes
1562 use a range of -273 (absolute zero) to MAX (2147483647 - significantly hotter than our
1563 sun) to allow flexibility.

1564 **17.4 Explicit Units for Other Values**

1565 Some attributes have a companion "xxx-units" attribute that specifies an explicit unit for the
1566 given measurement(s). The initial list of unit values for each attribute has been limited to
1567 those necessary for current printers and technologies at the time of writing of this
1568 specification in order to minimize interoperability issues.

1569 **17.5 Intent vs. Process**

1570 The IPP Model [RFC2911], and more generally the PWG Semantic Model [PWG5108.1],
1571 have long focused on Job Tickets specifying "what" is wanted for the printed output vs.
1572 "how" that output is produced. This focus has served IPP well and allowed it to be used
1573 with wildly different printing technologies.

1574 During the development of this specification, attributes that define a specific process or
1575 technological parameter have been introduced and later replaced by intent-based
1576 alternatives that allow an implementation to select suitable process-based parameters at

1577 print time, preserving the intrinsic value of such parameters without burdening the Client or
1578 End User with such things.

1579 At the same time, some process parameters are needed for things like material
1580 specification. For example, a particular brand of PLA may require a higher melting
1581 temperature - this information might only be known to the End User, so the "materials-col"
1582 collection contains an member attribute to convey this process-specific parameter. The
1583 Printer advertises whether temperature is a valid material property in the "materials-col-
1584 supported" Printer Description attribute.

1585 Finally, IPP does not prohibit the definition or use of process-based Job Template
1586 attributes for specific implementations. Such extension attributes can be listed in the "job-
1587 creation-attributes-supported" Printer Description attribute to notify Clients of their
1588 existence.

1589 **17.6 Choosing a Required Document Format**

1590 One of the design consideration of this specification is to choose an open, freely available
1591 file format for use as required document format. Having a required document format
1592 makes interoperability significantly easier, and using an open and freely available format
1593 allows developers of "consumer" printers to support IPP 3D. Several formats were
1594 considered, including STL, AMF, PDF, and 3MF.

1595 While STL is a widely-implemented, open, and freely available file format, it lacks support
1596 for multiple materials and colors/textures, and has technical issues that cause "holes" in
1597 generated models.

1598 While AMF supports multiple materials and does not have the "holes" issue, it is not freely
1599 available nor widely-implemented.

1600 PDF is the most capable 3D format but is not freely available and has the interoperability
1601 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-
1602 features-supported" Printer Description attribute (section 8.3.16) allows Clients to
1603 determine whether a 3D PDF file can be printed by the Printer.

1604 3MF is open and freely available, supports multiple materials and color/textures, does not
1605 have the "holes" issue of STL, and has a freely available open source implementation that
1606 supports both creation and consumption of 3MF files.
1607

1608 **18. Change History**

1609 **18.1 November 14, 2016**

- 1610 1. Status: Stable
- 1611 2. Added "color-supported" as a required Printer Description attribute.

1612 **18.2 August 24, 2016**

- 1613 1. Section 5.1.2: "over DNS-SD"
- 1614 2. Section 6.4: Dropped document-password from required operation attributes
- 1615 3. Section 6.5: Dropped document-password-supported from required Printer
- 1616 Description attributes, fixed section reference for material-shell-thickness, fixed
- 1617 note 1 reference for link-local addresses.
- 1618 4. Section 6.7: Fixed section references.
- 1619 5. Section 8.1: Updated print-accuracy -supported attributes.
- 1620 6. Section 8.1.3: Broke up print-accuracy member attributes into subsections.
- 1621 7. Section 8.1.4: Added table listing member attributes.
- 1622 8. Sections 8.1.4.x: Added syntax to each of the sub-member attributes.
- 1623 9. Section 8.2: Reworked as table listing the member attributes.
- 1624 10. Section 8.3.18: Reworded as the best supported "print-accuracy" value.
- 1625 11. Section 8.3.27: Broke up member attributes into subsections.
- 1626 12. Section 17.3: Mentioned the range for temperature values.

1627 **18.3 August 16, 2016**

- 1628 1. Section 1: Added informative reference to IPP sample code.
- 1629 2. Section 6.2: Fixed reference to HTTP/1.1 spec.
- 1630 3. Section 6.2.2: "camera image" instead of "ICC profile".
- 1631 4. Table 5: Added missing print-accuracy-default attribute, fix link-local rule to point
- 1632 to PWG5100.14.
- 1633 5. Table 6: Add missing reference for printer-camera-image-uri attribute, drop note
- 1634 3.
- 1635 6. Section 8.1.1.4: Use nanometers for material-diameter, just like material-shell-
- 1636 thickness.
- 1637 7. Section 8.1.1.10: Added '_sec' to material-rate-units values.
- 1638 8. Section 8.1.3: Added accuracy-units member attribute.
- 1639 9. Section 8.3.x: Added missing print-accuracy-default attribute.
- 1640 10. Section 8.3.x: Added accuracy-units-supported attribute.
- 1641 11. Section 8.3.6: Fix reference to "material-shell-thickness" member attribute.
- 1642 12. Section 8.3.11: Required.
- 1643 13. Section 8.3.13: List required values.
- 1644 14. Section 10.x: Fix spelling of "attribute" and section reference for document
- 1645 formats.

- 1646 15. Section 13: Updated registration information.
1647 16. Section 14.1: Updated Unicode reference to v9.0.0.
1648 17. Section 14.2: Added informative reference to IPP sample code.
1649 18. Section 17: Update and talk about length, thickness, and explicit unit attribute
1650 values.

1651 **18.4 July 14, 2016**

- 1652 1. Updated with conformance requirements.
1653 2. Added a new Protocol Binding section that outlines the core IPP and HTTP
1654 requirements.
1655 3. Section 8.1.x: Made materials-col, print-rafts, and print-supports REQUIRED,
1656 print-objects and multiple-object-handling CONDITIONALLY REQUIRED for
1657 PDF printers, added printer-bed-temperature and made it CONDITIONALLY
1658 REQUIRED for printers with a temperature-controlled build platform.
1659 4. Table 3: The supported values for print-accuracy are in print-accuracy-
1660 supported, not x/y/z-accuracy-supported.
1661 5. Section 8.1.4: Changed print-accuracy to use hundredths of millimeters for the
1662 units, with 0 being <0.01mm.
1663 6. Section 8.2: The -actual attributes are all Job Status (read-only)
1664 7. Section 8.3.16: Changed to use hundredths of millimeters for units.
1665 8. Section 8.3.x: Add printer-bed-temperature-default and -supported.

1666 **18.5 April 30, 2016**

- 1667 1. Status: Prototype
1668 2. Section 3.1.x: Added a new use case for tool printing where precision is needed.
1669 3. Section 3.3 and 3.4: Updated list of design requirements and out-of-scope items
1670 based on April 2016 F2F discussions.
1671 4. New Section 5 for transport and resource path requirements.
1672 5. Section 6.1: No longer reference Bonjour Printing spec, but instead define
1673 everything here. Service type is now "_ippes-3d._tcp".
1674 6. Section 6.2: Fill in LDAP information.
1675 7. Section 8.1: Drop print-quality-details, add print-accuracy, make print-objects a
1676 1setOf collection
1677 8. Section 8.1.1: Add material-fill-density and material-shell-thickness member
1678 attributes
1679 9. Section 8.1.3: Change to 1setOf collection and define member attributes for
1680 dimensions, offset, UUID, and document number.
1681 10. Section 8.2: Add print-objects-actual
1682 11. Section 8.3: Add material-thickness-supported, print-accuracy-supported, and
1683 drop print-quality-details-xxx
1684 12. Section 8.3.17: print-objects-supported is now a 1setOf type2 keyword
1685 13. Section 8.3.23: Dimensions are in hundredths of millimeters
1686 14. Section 10: Filled in conformance requirements

- 1687 15. Section 12.1: Talk about confidentiality
1688 16. Section 13: Filled in IANA considerations
1689 17. Section 17: Talk about use of PWG units (hundredths of millimeters) and
1690 nanometers.

1691 **18.6 April 20, 2016**

- 1692 1. Section 4.2: Add note that not all subunits are exposed, input tray/roll, trimmers
1693 are All.
1694 2. Section 4.3: Update Figure 2
1695 3. Section 4.6: Fix section reference
1696 4. Section 5: Drop SLP
1697 5. Section 5.1: Update to use _ipp3d._tcp, define TXT record
1698 6. Section 5.2: Drop SLP
1699 7. Section 7.1.4: Clarify keyword value definitions.

1700 **18.7 March 3, 2016**

- 1701 1. Added background on choice of 3MF vs. PDF.
1702 2. Added PDF to list of ODLs.
1703 3. Added pdf-features-supported attribute.

1704 **18.8 February 17, 2016**

- 1705 1. Global: "Document" instead of "document".
1706 2. Added discovery protocols and document formats sections, with requirements.
1707 3. Section 1: Reworded, added discovery and standard ODL discussion.
1708 4. Section 1.1: Dropped
1709 5. Section 4.2: Reworked subunits to be abstract views necessary for maintenance
1710 and status monitoring, entirely matching up with the Printer and Finisher MIBs
1711 6. Section 4.3: Replace Figure 2 with a depiction of the build volume, explain IPP
1712 coordinate system for build volume
1713 7. Section 4.4: Reword and drop mention of temperatures as intent.
1714 8. Section 5.1.x: Drop all of the process attributes (thickness, fill percent, speed,
1715 temperatures), add new print-quality-details attribute
1716 9. Section 5.1.1: Reference materials-col-supported, materials-col.material-name is
1717 enough in job ticket to use existing -database or -ready.
1718 10. Section 5.1.2: Added multiple-object-handling attribute
1719 11. Section 5.1.1.10: Clarified this is the printing temperature.
1720 12. Section 5.1.1.11: Dropped "filament", "powder", etc., talk about localization of
1721 values, and make "keyword | name".
1722 13. Section 5.3.x: Drop all of the process attributes, add new multiple-object-
1723 handling-xxx and print-quality-details-xxx attributes
1724 14. Section 5.4.x: Dropped

- 1725 15. Section 11.x: Updated references, moved STL to informative section, added
1726 PDF 1.7 (ISO 32000)
1727 16. Section 14.3: Added section on process vs intent

1728 **18.9 February 1, 2016**

- 1729 1. Updated front matter for working draft
1730 2. Fixed one remaining use of "white paper"

1731 **18.10 January 28, 2016**

- 1732 1. Updated to working draft template.
1733 2. Fixed document URLs.
1734 3. Global: "white paper" changed to "specification" as needed.
1735 4. Abstract: "this specification", extension to IPP Everywhere as well.
1736 5. Section 4: "3D Print Service Model", remove old intro text
1737 6. Dropped tables 1-3, instead just say "same as 2D print service" and mention that
1738 certain Job Template attributes such as "media" are not applicable to most 3D
1739 printers.
1740 7. Table 4: Added section references, reordered so that all RFC 3805 subunits are
1741 listed first.
1742 8. Section 4.x: Reword in places now that this is a specification.
1743 9. Section 5: Added subunit collection attributes
1744 10. Section 6: Add registration (instead of just suggestion)
1745 11. Added Section 14 on design choices

1746 **18.11 November 16, 2015**

- 1747 1. Section 1: Fix typos
1748 2. Section 3: Updated rationale to talk about 3MF instead of AMF and STL
1749 3. Section 4: Added new subsection on the 3D Print Service and the operations
1750 and attributes that are used.
1751 4. Section 4.3: Added Chambers to list of subunits since we are providing access
1752 to the temperature.
1753 5. Section 5.1.1: Added table listing all member attributes.
1754 6. Section 5.1.1.x: Added sections on material-amount, material-amount-units,
1755 material-diameter, material-rate, material-rate-units
1756 7. Section 5.1.1.x: Renamed "material-use" to "material-purpose" to avoid
1757 confusion with "material-amount-xxx".
1758 8. Section 5.3: Add new materials-col member attribute -supported attributes
1759 9. Section 7.1: Note existing MS 3DMF MIME media type
1760 10. Global: printer-bed-xxx -> printer-platform-xxx
1761 11. Global: Add range for all temperature attributes (-273:MAX)

1762 18.12 October 29, 2015

- 1763 1. Greatly expanded the discussion of how current solutions work and the IPP
- 1764 model
- 1765 2. Added discussion points for amount of material used
- 1766 3. Added materials-col-actual Job Description attribute
- 1767 4. Added 3MF description and reference
- 1768 5. Fixed link to IPP Everywhere in references

1769 18.13 August 12, 2015

- 1770 1. Dropped “0.1” from the title
- 1771 2. Various typographical changes
- 1772 3. Section 2.2: Added ODL acronym
- 1773 4. Table 1: Added reference column
- 1774 5. Figure 1: Updated figure to show Z increasing downward (direction of build
- 1775 platform movement)
- 1776 6. Section 4.x: Added sub-section on output intent.
- 1777 7. Section 5.1: Added table listing Job Template and corresponding -default and -
- 1778 supported attributes.
- 1779 8. Section 5.1.1.4: Added more types of filament, solid wax, and clarification on the
- 1780 names used for material type keywords.
- 1781 9. Section 5.1.1.5: Made material-use 1setOf, added 'all' value.
- 1782 10. Updated printer-bed-temperature-supported and printer-chamber-temperature-
- 1783 supported to allow 'no-value' values.
- 1784 11. Section 9.x: Added subsections on specific 3D printing security considerations.

1785 18.14 July 29, 2015

- 1786 1. Dropped all references to X3G and G-code.
- 1787 2. Reworked materials-col to specify materials but not temperatures and other
- 1788 physical properties
- 1789 3. Added “material-use” member attribute to assign materials to specific uses.
- 1790 4. Supports and rafts pick materials based on “material-use” values and not
- 1791 indices.
- 1792 5. Added reference to IPP INFRA
- 1793 6. Added printer-camera-image-uri Printer Description attribute.

1794 18.15 April 13, 2015

- 1795 1. Updated front matter to incorporate new IEEE-ISTO boilerplate for a contributed
- 1796 white paper.

1797 18.16 April 5, 2015

- 1798 1. Updated front matter to remove IEEE-ISTO boilerplate.
- 1799 2. Fixed various typos
- 1800 3. Clarified that SLC files are commonly known as STL files.
- 1801 4. Clarified that S3G is a binary version of G-code with a standard packet format.
- 1802 5. Added use case for printing with loaded materials
- 1803 6. Added use case for multi-material printing on a single material printer.
- 1804 7. Added use case for monitoring print progress visually with a web cam.
- 1805 8. Added exception for "skipping" (insufficient material flow/feed)
- 1806 9. Added exception for adhesion issues
- 1807 10. Added exception for build plate being full.
- 1808 11. Added exception for head movement issues.
- 1809 12. Added figure showing the typical coordinate system.
- 1810 13. Expanded Job Template and Printer Description details, added comments for
- 1811 discussion.
- 1812 14. Added new Unicode considerations and references.

1813 18.17 January 23, 2015

1814 Initial revision.