



The Printer Working Group

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Working Draft

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

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

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55 widely used with multiple independent and interoperable implementations. Printer
56 manufacturers and vendors of printer related software benefit from the interoperability
57 provided by voluntary conformance to these standards.

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258 **1. Introduction**

259 This specification defines an extension to the Internet Printing Protocol (IPP) that supports
260 printing of physical objects by Additive Manufacturing devices such as three-dimensional
261 (3D) printers.

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

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

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

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

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

278 **2. Terminology**

279 **2.1 Conformance Terminology**

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

285 **2.2 Printing Terminology**

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

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

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

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

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

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

299 **2.3 Protocol Role Terminology**

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

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

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

307 **2.4 3D Printing Terminology**

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

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

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

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

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

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

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

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

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

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

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

331 **2.5 Other Terminology**

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

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

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

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

339 **2.6 Acronyms and Organizations**

340 *3D PDF Consortium*: <http://www.3dpdfconsortium.org/>

341 *3MF Consortium*: 3D Manufacturing Format Consortium, <http://www.3mf.io/>

342 *CNC*: Computer Numerical Control

343 *DLP*: Digital Light Processing

344 *FDM*: Fused Deposition Modeling

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

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

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

348 *ODL*: Object Definition Language

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

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

351 *SDL*: Selective Deposition Lamination

352 *SL*: Stereo Lithography

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

354

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

356 Existing specifications define the following:

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

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

380 **3.1 Use Cases**

381 **3.1.1 Print a 3D Object**

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

385 **3.1.2 Print a 3D Object Using Loaded Materials**

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

389 3.1.3 Print a 3D Object with Multiple Materials

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

394 3.1.4 Print a Tool

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

399 3.1.5 View a 3D Object During Printing

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

402 3.2 Exceptions**403 3.2.1 Clogged Extruder**

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

407 3.2.2 Extruder Temperature Out of Range

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

412 3.2.3 Extruder Head Movement Issues

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

416 3.2.4 Filament Feed Jam

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

420 3.2.5 Filament Feed Skip

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

424 3.2.6 Material Empty

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

428 3.2.7 Material Adhesion Issues

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

433 3.2.8 Build Platform Temperature Out of Range

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

437 3.2.9 Build Platform Not Clear

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

442 3.3 Out of Scope

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

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

448

449 **3.4 Design Requirements**

450 The design requirements for this document are:

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

466 The design recommendations for this document are:

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

468

469 **4. 3D Print Service Model**

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

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

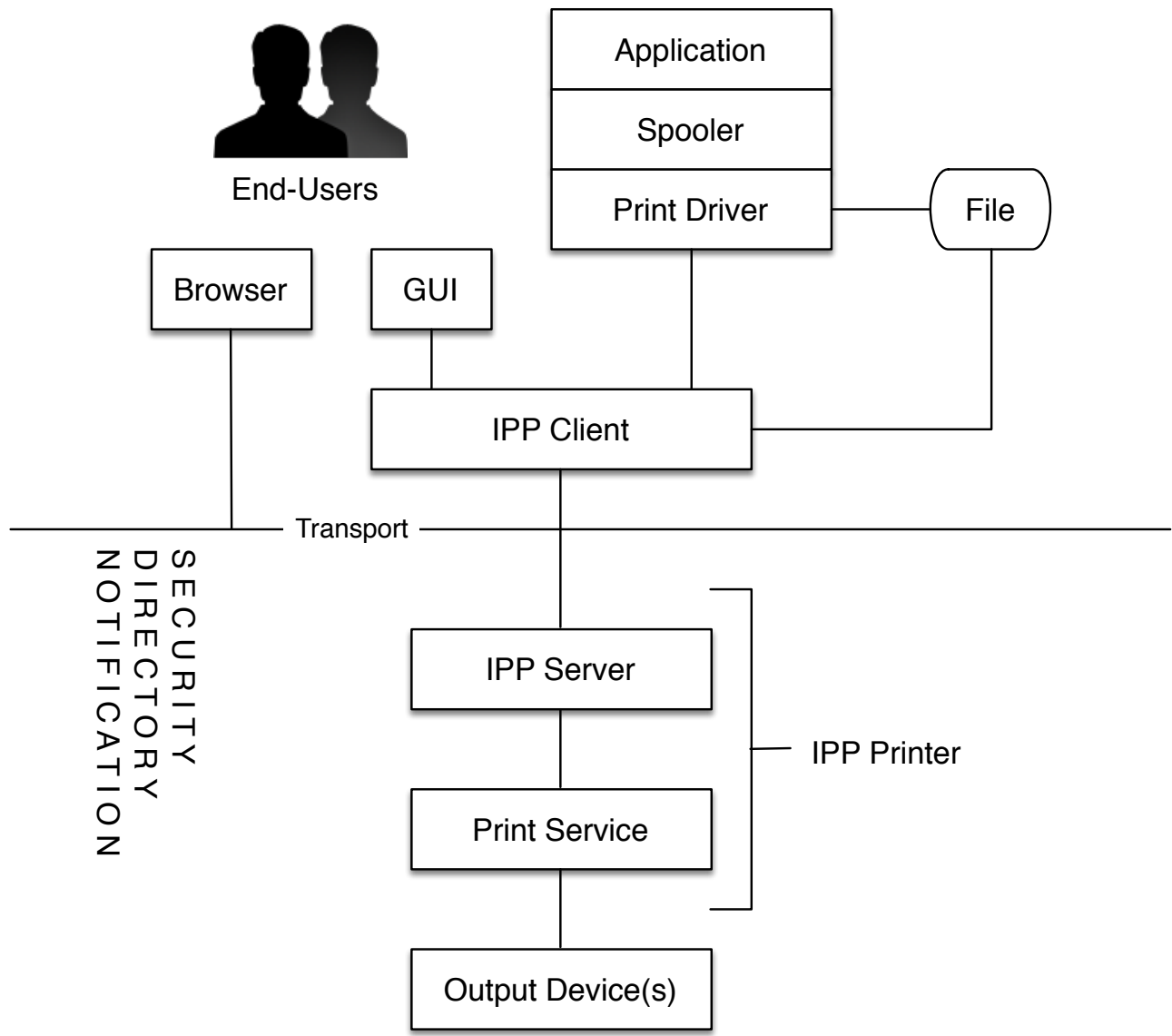
481 The IPP Printer object contains zero or more Job objects and is responsible for managing,
482 scheduling, and processing Jobs. It also provides the current state of the Output Device(s)
483 and communicates with them as needed.

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

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

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

495



496

497

498

Figure 1 - Generalized IPP Model (RFC 8011)

499 **4.1 3D Print Service**

500 3D printing uses a variation of the traditional Print service that maintains state and capability
 501 information specific to 3D printing. The 3D Print service supports all of the same operations
 502 of the Print service described in [RFC8011] except for the Print-Job and Print-URI operations
 503 which are compound requests that are not used in newer IPP services. Similarly, the 3D
 504 Print service uses a superset of the Print service attributes except where such attributes are
 505 not applicable, for example the "media" attributes for a 3D printer that does not use media
 506 sheets. Attributes specific to the 3D Print Service are defined in section 8.

507 **4.2 3D Printer Subunits**

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

510 **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 |

511 **4.2.1 Finishing Devices**

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

514 **4.2.2 Input Trays/Rolls**

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

516 **4.2.3 Marker Supplies**

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

519 4.2.4 Markers

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

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

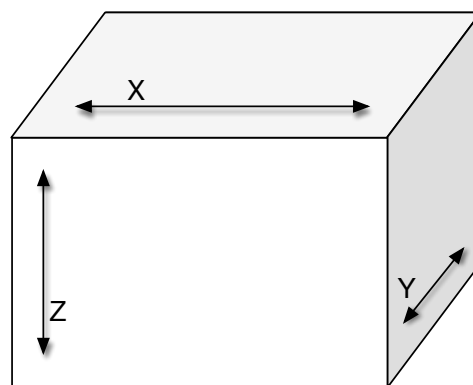
525 4.2.5 Media Paths

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

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

531 4.3 3D Printer Coordinate System

532 3D printers operate in three dimensions and thus have three axis of movement. For the
533 purposes of IPP, the build volume is defined as a rectangular prism (Figure 2) with the X
534 axis representing the width, the Y axis representing the depth, and the Z axis representing
535 the height. The origin is implementation-specific.



536

537

Figure 2 - 3D Build Volume

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

542 **4.4 Output Intent and Job Processing**

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

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

552 **4.5 Job Spooling**

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

556 **4.6 Multiple Document Jobs**

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

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

563 **4.7 Cloud-Based Printing**

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

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

571

572 5. Discovery Protocols

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

575 5.1 DNS Service Discovery (DNS-SD)

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

580 5.1.1 Service Instance Name

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

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

584 5.1.2 Service Type

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

586 5.1.3 TXT Record

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

590 **Table 2 - IPPS 3D Print Service TXT Record Keys**

| Key | Description | Default Value |
|----------|---|---------------|
| adminurl | The 'https' URL for the Printer's embedded web server. | None |
| note | The value of the "printer-location" Printer Description attribute. | "" |
| pdl | The values of the "document-formats-supported" Printer Description attribute. | "model/3mf" |
| rp | The resource path for this service instance without the leading "/". | "ipp/print3d" |
| ty | The value of the "printer-make-and-model" Printer Description attribute. | "" |
| UUID | The value of the "printer-uuid" Printer Status attribute without the leading 'urn:uuid:'. | None |

591 **5.2 LDAP Discovery**

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

595 **5.2.1 printerIPPS3D Class**

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

```
598     ( 1.3.18.0.2.24.46.2.1
599       NAME 'printerIPPS3D'
600       DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
601       AUXILIARY
602       SUP top
603       MAY ( printer-ipp-versions-supported $
604             printer-ipp-features-supported $
605             printer-multiple-document-jobs-supported )
606     )
607
```

608 **6. Protocol Binding**

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

612 **6.1 Transport and Resource Path**

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

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

620 **6.2 HTTP Features**

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

624 **6.2.1 Host**

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

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

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

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

634 **6.2.3 Cache-Control**

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

640 6.3 IPP Operations

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

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

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

645 6.4 IPP Operation Attributes

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

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

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

648 6.5 IPP Printer Description Attributes

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

650

Table 5 - IPP 3D REQUIRED Printer Description Attributes

| Attribute | Reference |
|---|------------------|
| accuracy-units-supported | Section 8.3.1 |
| charset-configured | RFC 8011 |
| charset-supported | RFC 8011 |
| color-supported | RFC 8011 |
| compression-supported | RFC 8011 |
| document-format-default | RFC 8011 |
| document-format-supported | RFC 8011 |
| generated-natural-language-supported | RFC 8011 |
| identify-actions-default | PWG 5100.13 |
| identify-actions-supported | PWG 5100.13 |
| ipp-features-supported | PWG 5100.13 |
| ipp-versions-supported | RFC 8011 |
| job-creation-attributes-supported | PWG 5100.11 |
| job-ids-supported | PWG 5100.11 |
| material-diameter-supported (note 2) | Section 8.3.3 |
| material-purpose-supported | Section 8.3.5 |
| material-rate-supported | Section 8.3.6 |
| material-rate-units-supported | Section 8.3.7 |
| material-shell-thickness-supported | Section 8.3.8 |
| material-temperature-supported (note 3) | Section 8.3.8 |
| material-type-supported | Section 8.3.10 |
| materials-col-default | Section 8.3.12 |
| materials-col-ready | Section 8.3.13 |
| materials-col-supported | Section 8.3.14 |
| max-materials-col-supported | Section 8.3.15 |
| multiple-document-jobs-supported | RFC 8011 |
| multiple-object-handling-default | Section 8.3.16 |
| multiple-object-handling-supported | Section 8.3.17 |
| multiple-operation-timeout | RFC 8011 |
| multiple-operation-timeout-action | PWG 5100.13 |
| natural-language-configured | RFC 8011 |
| operations-supported | RFC 8011 |
| platform-temperature-default (note 4) | Section 8.3.20 |
| platform-temperature-supported (note 4) | Section 8.3.21 |
| print-accuracy-default | Section 8.3.22 |
| print-accuracy-supported | Section 8.3.23 |
| print-base-default | Section 8.3.24 |
| print-base-supported | Section 8.3.25 |
| print-objects-supported | Section 8.3.26 |
| print-quality-default | RFC 8011 |
| print-quality-supported | RFC 8011 |
| print-supports-default | Section 8.3.27 |
| print-supports-supported | Section 8.3.28 |

| | |
|----------------------------------|----------------|
| printer-geo-location | PWG 5100.13 |
| printer-get-attributes-supported | PWG 5100.13 |
| printer-icons (note 1) | PWG 5100.13 |
| printer-info | RFC 8011 |
| printer-location | RFC 8011 |
| printer-make-and-model | RFC 8011 |
| printer-more-info | RFC 8011 |
| printer-name | RFC 8011 |
| printer-organization | PWG 5100.13 |
| printer-organizational-unit | PWG 5100.13 |
| printer-volume-supported | Section 8.3.31 |
| printer-xri-supported (note 1) | RFC 3380 |
| which-jobs-supported | PWG 5100.11 |

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

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

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

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

658 **6.6 IPP Printer Status Attributes**

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

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

| Attribute | Reference |
|---------------------------------------|------------------|
| printer-camera-image-uri (notes 1, 2) | Section 8.4.1 |
| printer-config-change-date-time | PWG 5100.13 |
| printer-config-change-time | PWG 5100.13 |
| printer-is-accepting-jobs | RFC 8011 |
| printer-state | RFC 8011 |
| printer-state-change-date-time | RFC 3995 |
| printer-state-change-time | RFC 3995 |
| printer-state-message | RFC 8011 |
| printer-state-reasons | RFC 8011 |
| printer-up-time | RFC 8011 |
| printer-uri-supported (note 1) | RFC 8011 |
| printer-uuid | PWG 5100.13 |
| queued-job-count | RFC 8011 |
| uri-authentication-supported | RFC 8011 |
| uri-security-supported | RFC 8011 |
| xri-authentication-supported | RFC 3380 |
| xri-security-supported | RFC 3380 |
| xri-uri-scheme-supported | RFC 3380 |

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

663 Note 2: REQUIRED for Printers that have one or more cameras.
 664

665 6.7 IPP Job Template Attributes

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

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

| Attribute | Reference |
|-----------------------------------|---------------|
| materials-col | Section 8.1.1 |
| multiple-document-handling | RFC 8011 |
| multiple-object-handling (note 1) | Section 8.1.2 |
| platform-temperature (note 2) | Section 8.1.3 |
| print-accuracy | Section 8.1.4 |
| print-base | Section 8.1.5 |
| print-objects (note 1) | Section 8.1.6 |
| print-quality | RFC 8011 |
| print-supports | Section 8.1.7 |

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

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

670 6.8 IPP Job Description Attributes

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

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

| Attribute | Source |
|-----------|----------|
| job-name | RFC 8011 |

673 6.9 IPP Job Status Attributes

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

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

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

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

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

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

678 6.9.1 job-id (integer)

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

684 6.9.2 job-uri (uri)

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

691 7. Document Formats

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

697 **8. New Attributes**698 **8.1 Job Template Attributes**

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

701 **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) |
| platform-temperature (integer no-value) | platform-temperature-default (integer no-value) | platform-temperature-supported (1setOf (integer rangeOfInteger) no-value) |
| print-accuracy (collection) | print-accuracy-default (collection) | accuracy-units-supported (1setOf type2 keyword) print-accuracy-supported (collection) |
| print-base (type2 keyword) | print-base-default (type2 keyword) | print-base-supported (1setOf type2 keyword) |
| print-objects (1setOf collection) | N/A | print-objects-supported (boolean) |
| print-supports (type2 keyword) | print-supports-default (type2 keyword) | print-supports-supported (1setOf type2 keyword) |
| printer-volume-temperature (integer no-value) | printer-volume-temperature-default (integer no-value) | printer-volume-temperature-supported (1setOf (integer rangeOfInteger) no-value) |

702 **8.1.1 materials-col (1setOf collection)**

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

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

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

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

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

717 **8.1.1.1 material-amount (integer(0:MAX) | unknown)**

718 This RECOMMENDED member attribute provides the estimated amount of material that is
 719 available ("materials-col-database" and "materials-col-ready" values), the estimated amount
 720 of material that is required ("materials-col" values), or the actual amount of material that has
 721 been used ("materials-col-actual" values).

722 **8.1.1.2 material-amount-units (type2 keyword)**

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

725 'g': Value is mass in grams.

726 'kg': Value is mass in kilograms.

727 'l': Value is volume in liters.

728 'm': Value is length in meters.

729 'ml': Value is volume in milliliters.

730 'mm': Value is length in millimeters.

731 **8.1.1.3 material-color (type2 keyword)**

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

734 **8.1.1.4 material-diameter (integer(0:MAX))**

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

738 **8.1.1.5 material-diameter-tolerance (integer(0:MAX))**

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

741 **8.1.1.6 material-fill-density (integer(0:100))**

742 This REQUIRED member attribute specifies the desired density of filled interior regions in
743 percent.

744 **8.1.1.7 material-key (keyword)**

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

747 **8.1.1.8 material-name (name(MAX))**

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

749 **8.1.1.9 material-nozzle-diameter (integer(0:MAX))**

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

753 **8.1.1.10 material-purpose (1setOf type2 keyword)**

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

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

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

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

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

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

762 **8.1.1.11 material-rate (integer(1:MAX))**

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

765 **8.1.1.12 material-rate-units (type2 keyword)**

766 This member attribute provides the units for the "material-rate" member attribute. Values
767 include:

768 'mg_sec ': Value is milligrams per second.

769 'ml_sec ': Value is milliliters per second.

770 'mm_sec ': Value is millimeters per second.

771 **8.1.1.13 material-retraction (boolean)**

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

774 **8.1.1.14 material-shell-thickness (integer(0:MAX))**

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

777 **8.1.1.15 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))**

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

781 **8.1.1.16 material-type (type2 keyword | name(MAX))**

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

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

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

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

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

790 'chocolate': Chocolate.

791 'gold': Gold (metal).

792 'nylon': Nylon.

793 'pet': Polyethylene terephthalate (PET).

794 'photopolymer': Photopolymer (liquid) resin.

795 'pla': Polylactic Acid (PLA).

796 'pla-conductive': Conductive PLA.

797 'pla-dissolvable': Dissolvable PLA.

798 'pla-flexible': Flexible PLA.

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

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

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

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

803 'polycarbonate': Polycarbonate.

804 'silver': Silver (metal).

805 'titanium': Titanium (metal).

806 'wax': Wax.

807 Editor's note: Discuss naming convention for materials defined by other standards bodies,
808 e.g. "iso1234_name" or "asme5678_other-name".

809 8.1.2 multiple-object-handling (type2 keyword)

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

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

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

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

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

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

819 8.1.3 platform-temperature (integer(-273:MAX))

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

823 8.1.4 print-accuracy (collection)

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

826 When enforcing attribute fidelity ("ipp-attribute-fidelity" with a value of 'true'), Printers only
827 reject "print-accuracy" values that are smaller than the "print-accuracy-supported" (section
828 8.3.23) value.

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

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

830 8.1.4.1 accuracy-units (type2 keyword)

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

833 'mm': Accuracy numbers are in millimeters.

834 'um': Accuracy numbers are in micrometers.

835 'nm': Accuracy numbers are in nanometers.

836 **8.1.4.2 x-accuracy (integer(0:MAX))**

837 This REQUIRED member attribute specifies the X axis accuracy in the units specified by the
838 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than
839 1 unit.

840 **8.1.4.3 y-accuracy (integer(0:MAX))**

841 This REQUIRED member attribute specifies the Y axis accuracy in the units specified by the
842 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than
843 1 unit.

844 **8.1.4.4 z-accuracy (integer(0:MAX))**

845 This REQUIRED member attribute specifies the Z axis accuracy in the units specified by the
846 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than
847 1 unit.

848 **8.1.5 print-base (type2 keyword)**

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

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

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

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

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

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

857 **8.1.6 print-objects (1setOf collection)**

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

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

863 **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 |

864

865 **8.1.6.1 document-number (integer(1:MAX))**

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

868 **8.1.6.2 object-offset (collection)**

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

873 **8.1.6.3 object-size (collection)**

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

877 **8.1.6.4 object-uuid (uri)**

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

880 **8.1.7 print-supports (type2 keyword)**

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

883 'none': Do not print supports.

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

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

886 8.1.8 printer-volume-humidity (integer(0:100) | no-value)

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

890 8.1.9 printer-volume-temperature (integer(-273:MAX) | no-value)

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

894

895 **8.2 Job Status Attributes**

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

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

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

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

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

902 **8.2.1 materials-col-actual (1setOf collection)**

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

905 **8.2.2 multiple-object-handling-actual (type2 keyword)**

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

909 **8.2.3 print-accuracy-actual (collection)**

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

911 **8.2.4 platform-temperature-actual (1setOf integer(-273:MAX))**

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

915 **8.2.5 print-accuracy-actual (1setOf collection)**

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

918 **8.2.6 print-base-actual (1setOf type2 keyword)**

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

921 **8.2.7 print-objects-actual (1setOf collection)**

922 This CONDITIONALLY REQUIRED Job Status attribute lists the objects that were
923 processed. Printers that support the 'application/pdf' document format MUST support this
924 attribute.

925 **8.2.8 print-supports-actual (1setOf type2 keyword)**

926 This REQUIRED Job Status attribute specifies whether supports were printed during the
927 processing of the Job.

928 **8.3 Printer Description Attributes**

929 **8.3.1 accuracy-units-supported (1setOf type2 keyword)**

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

932 **8.3.2 material-amount-units-supported (1setOf type2 keyword)**

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

936 **8.3.3 material-diameter-supported (1setOf (integer | rangeOfInteger))**

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

940 **8.3.4 material-nozzle-diameter-supported (1setOf (integer | rangeOfInteger))**

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

944 **8.3.5 material-purpose-supported (1setOf type2 keyword)**

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

947 8.3.6 material-rate-supported (1setOf (integer | rangeOfInteger))

948 This Printer Description attribute lists the supported "material-rate" values for the Printer.
949 This attribute MUST be supported if the "material-rate" member attribute (Section 8.1.1.11)
950 is supported.

951 8.3.7 material-rate-units-supported (1setOf type2 keyword)

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

**955 8.3.8 material-shell-thickness-supported (1setOf (integer(1:MAX) |
956 rangeOfInteger(1:MAX)))**

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

**959 8.3.9 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-
960 273:MAX)))**

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

964 8.3.10 material-type-supported (1setOf type2 keyword)

965 This REQUIRED Printer Description attribute lists the supported "material-type" values for
966 the Printer.

967 8.3.11 materials-col-database (1setOf collection)

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

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

```
974     materials-col-database =  
975     { material-name="Generic PLA Filament" material-key="generic-pla"  
976     material-diameter=285 material-temperature=215-235 }  
977
```

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

```
980     materials-col-database =  
981     { material-name="Generic PLA Filament" material-key="generic-pla"  
982     material-diameter=285 material-temperature=215-235 },  
983     { material-name="Example Corp Flexible Midnight Blue PLA" material-  
984     key="com.example.flexible-midnight-blue" material-  
985     color="com.example.midnight-blue_000027" material-diameter=285 material-  
986     temperature=210-225 }
```

987 **8.3.12 materials-col-default (1setOf collection)**

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

990 **8.3.13 materials-col-ready (1setOf collection)**

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

993 **8.3.14 materials-col-supported (1setOf type2 keyword)**

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

998 **8.3.15 max-materials-col-supported (integer(1:MAX))**

999 This REQUIRED Printer Description attribute specifies the maximum number of values that
1000 can be provided with the "materials-col" Job Template attribute (section 8.1.1).

1001 **8.3.16 multiple-object-handling-default (type2 keyword)**

1002 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default
1003 "multiple-object-handling" value. Printers that support the 'application/pdf' Document format
1004 MUST support this attribute.

1005 **8.3.17 multiple-object-handling-supported (1setOf type2 keyword)**

1006 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported
1007 "multiple-object-handling" values. Printers that support the 'application/pdf' Document format
1008 MUST support this attribute.
1009

1010 8.3.18 pdf-features-supported (1setOf type2 keyword)

1011 This CONDITIONALLY REQUIRED Printer Description attribute lists the PDF features that
1012 are supported by the Printer. Printers that support the 'application/pdf' Document format
1013 MUST support this attribute.

1014 Values include:

1015 'prc': The Printer supports 3D objects in the Product Representation Compact
1016 (PRC) format [ISO14739-1].

1017 'u3d': The Printer supports 3D objects in the Universal 3D (U3D) format [ECMA363].

1018 8.3.19 platform-shape (type2 keyword)

1019 This RECOMMENDED Printer Description attribute describes the overall shape of the build
1020 platform. Values include:

1021 'ellipse': The build platform is elliptical, forming a cylindrical build volume.

1022 'rectangle': The build platform is rectangular, forming a cubic build volume.

1023 8.3.20 platform-temperature-default (integer(-273:MAX))

1024 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default
1025 "platform-temperature" value. Printers that control the temperature of the Build Platform
1026 MUST support this attribute.

**1027 8.3.21 platform-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-
1028 273:MAX)))**

1029 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported
1030 "platform-temperature" values and/or ranges. Printers that control the temperature of the
1031 Build Platform MUST support this attribute.

1032 8.3.22 print-accuracy-default (collection)

1033 This REQUIRED Printer Description attribute specifies the default "print-accuracy" value.

1034 8.3.23 print-accuracy-supported (collection)

1035 This REQUIRED Printer Description attribute specifies the best "print-accuracy" value that
1036 is supported by the Printer.

1037 8.3.24 print-base-default (type2 keyword)

1038 This REQUIRED Printer Description attribute specifies the default "print-base" value.

1039 **8.3.25 print-base-supported (1setOf type2 keyword)**

1040 This REQUIRED Printer Description attribute lists the supported "print-base" values.

1041 **8.3.26 print-objects-supported (1setOf type2 keyword)**

1042 This CONDITIONALLY REQUIRED Printer Description attribute specifies which "print-
1043 objects" member attributes are supported. Printers that support the 'application/pdf'
1044 Document format MUST support this attribute.

1045 **8.3.27 print-supports-default (type2 keyword)**

1046 This REQUIRED Printer Description attribute specifies the default "print-supports" value.

1047 **8.3.28 print-supports-supported (1setOf type2 keyword)**

1048 This REQUIRED Printer Description attribute lists the supported "print-supports" values.

1049 **8.3.29 printer-volume-humidity-default (integer(0:100) | no-value)**

1050 This CONDITIONALLY REQUIRED attribute specifies the default relative humidity of the build
1051 chamber as a percentage. Printers that support humidity control MUST support this attribute.

1052 **8.3.30 printer-volume-humidity-supported (boolean)**

1053 This CONDITIONALLY REQUIRED attribute specifies whether the "printer-volume-humidity"
1054 Job Template attribute (section 8.1.8) is supported. Printers that support humidity control
1055 MUST support this attribute.

1056 **8.3.31 printer-volume-supported (collection)**

1057 This REQUIRED Printer Description attribute specifies the maximum build volume supported
1058 by the Printer. Table 15 lists the REQUIRED member attributes.

1059 **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))

1060 **8.3.31.1 x-dimension (integer(1:MAX))**

1061 This member attributes specifies the width of the build volume in hundredths of millimeters
1062 (1/2540th of an inch).

1063 8.3.31.2 y-dimension (integer(1:MAX))

1064 This member attributes specifies the depth of the build volume in hundredths of millimeters
1065 (1/2540th of an inch).

1066 8.3.31.3 z-dimension (integer(1:MAX))

1067 This member attributes specifies the height of the build volume in hundredths of millimeters
1068 (1/2540th of an inch).

1069 8.3.32 printer-volume-temperature-default (integer(-273:MAX) | no-value)

1070 This CONDITIONALLY REQUIRED attribute contains the default temperature of the build
1071 chamber in degrees Celsius, if configured. Printers that provide a temperature-controlled
1072 build chamber MUST support this attribute.

**1073 8.3.33 printer-volume-temperature-supported (1setOf (integer(-273:MAX) |
1074 rangeOfInteger(-273:MAX)))**

1075 This CONDITIONALLY REQUIRED attribute lists the supported temperatures (or ranges of
1076 temperatures) of the build chamber in degrees Celsius. Printers that provide a temperature-
1077 controlled build chamber MUST support this attribute.

1078 8.4 Printer Status Attributes**1079 8.4.1 printer-camera-image-uri (1setOf uri)**

1080 This Printer Status attribute lists the URIs for one or more resident camera snapshots. Each
1081 URI corresponds to a separate resident camera. The images referenced by each URI can
1082 change at any time so it is up to the Client to periodically poll for changes and for the Printer
1083 to atomically update the images so that Clients can safely do so. The referenced images
1084 MUST be PNG [RFC2083] or JPEG [JFIF] format.

1085 8.4.2 printer-volume-humidity-current (integer(0:100) | unknown)

1086 This CONDITIONALLY REQUIRED attribute reports the current relative humidity of the build
1087 chamber as a percentage. Printers that support humidity control MUST support this attribute.

1088 8.4.3 printer-volume-temperature-current (integer(-273:MAX) | unknown)

1089 This CONDITIONALLY REQUIRED attribute reports the current temperature of the build
1090 chamber in degrees Celsius, if known. Printers that provide a temperature-controlled build
1091 chamber MUST support this attribute.

1092 **9. New Values for Existing Attributes**

1093 **9.1 ipp-features-supported (1setOf type2 keyword)**

1094 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-
1095 supported" Printer Description attribute.

1096 **9.2 printer-state-reasons (1setOf type2 keyword)**

1097 This specification registers the following new values for the "printer-state-reasons" Printer
1098 Status attribute:

1099 'camera-failure': A camera is no longer working.

1100 'chamber-cooling': A chamber is being cooled.

1101 'chamber-failure': A chamber has failed and requires maintenance or replacement.

1102 'chamber-heating': A chamber is being heated.

1103 'chamber-temperature-high': The temperature of a chamber is high.

1104 'chamber-temperature-low': The temperature of a chamber is low.

1105 'extruder-cooling': An extruder is being cooled.

1106 'extruder-failure': An extruder has failed and requires maintenance or replacement.

1107 'extruder-heating': An extruder is being heated.

1108 'extruder-jam': An extruder is jammed or clogged.

1109 'extruder-temperature-high': The temperature of an extruder is too high.

1110 'extruder-temperature-low': The temperature of an extruder is too low.

1111 'fan-failure': A fan has failed.

1112 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.

1113 'lamp-failure': A lamp has failed.

1114 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.

1115 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.

1116 'laser-failure': A laser has failed.

- 1117 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.
- 1118 'material-empty': One or more build materials have been exhausted.
- 1119 'material-low': One or more build materials may need replenishment soon.
- 1120 'material-needed': One or more build materials need to be loaded for a processing
1121 Job.
- 1122 'motor-failure': A motor has failed.
- 1123 'platform-cooling': A Build Platform is being cooled.
- 1124 'platform-failure': A Build Platform has failed and requires maintenance or
1125 replacement.
- 1126 'platform-heating': A Build Platform is being heated.
- 1127 'platform-temperature-high': The temperature of a Build Platform is too high.
- 1128 'platform-temperature-low': The temperature of a Build Platform is too low.
1129

1130 **10. Conformance Requirements**

1131 **10.1 Printer Conformance Requirements**

1132 In order for a Printer to claim conformance to this specification, a Printer MUST support:

- 1133 1. The required discovery protocols in section 5;
- 1134 2. The required transports and resource paths in section 6.1;
- 1135 3. The required HTTP features in section 6.2;
- 1136 4. The required IPP operations in section 6.3;
- 1137 5. The required IPP attributes in sections 6.4 through 6.9;
- 1138 6. The required document formats in section 7;
- 1139 7. The additional values defined in section 9;
- 1140 8. The internationalization considerations in section 11; and
- 1141 9. The security considerations in section 12.

1142 **10.2 Client Conformance Requirements**

1143 In order for a Client to claim conformance to this specification, a Client MUST support:

- 1144 1. The required discovery protocols in section 5;
- 1145 2. The required transports and resource paths in section 6.1;
- 1146 3. The required HTTP features in section 6.2;
- 1147 4. The required IPP operations in section 6.3;
- 1148 5. The required IPP attributes in sections 6.4 through 6.9;
- 1149 6. The required document formats in section 7;
- 1150 7. The additional values defined in section 9;
- 1151 8. The internationalization considerations in section 11; and
- 1152 9. The security considerations in section 12.

1153

1154 **11. Internationalization Considerations**

1155 For interoperability and basic support for multiple languages, conforming implementations
1156 MUST support:

- 1157 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)
1158 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 1159 2. The Unicode Format for Network Interchange [RFC5198] which requires
1160 transmission of well-formed UTF-8 strings and recommends transmission of
1161 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1162 Unicode NFC is defined as the result of performing Canonical Decomposition (into base
1163 characters and combining marks) followed by Canonical Composition (into canonical
1164 composed characters wherever Unicode has assigned them).

1165 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and
1166 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in IPP
1167 Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8 URIs
1168 now 'hidden').

1169 Implementations of this specification SHOULD conform to the following standards on
1170 processing of human-readable Unicode text strings, see:

1171 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical

1172 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping

1173 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]

1174 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences

1175 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization

1176 Unicode Character Encoding Model [UTR17] – multi-layer character model

1177 Unicode in XML and other Markup Languages [UTR20] – XML usage

1178 Unicode Character Property Model [UTR23] – character properties

1179 Unicode Conformance Model [UTR33] – Unicode conformance basis+

1180 Unicode Collation Algorithm [UTS10] – sorting

1181 Unicode Locale Data Markup Language [UTS35] – locale databases

1182 **12. Security Considerations**

1183 In addition to the security considerations described in the IPP/1.1: Model and Semantics
1184 [RFC8011], the following sub-sections describe issues that are unique to 3D printing.

1185 Implementations of this specification SHOULD conform to the following standards on
1186 processing of human-readable Unicode text strings, see:

1187 Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1188 Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

1189 **12.1 Confidentiality**

1190 Clients and Printers MUST provide confidentiality of data in transit using either an interface
1191 providing physical security such as USB or using TLS encryption [RFC5246] over
1192 unsecured/network connections,

1193 **12.2 Access Control**

1194 Because of the potential for abuse and misuse, Printers SHOULD provide access control
1195 mechanisms including lists of allowed Clients, authentication, and authorization to site
1196 defined policies.

1197 **12.3 Physical Safety**

1198 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such
1199 as protective gates, covers, or interlocks.

1200 **12.4 Material Safety**

1201 Printers MUST restrict usage and combination of materials to those that can be safely
1202 printed. Access controls (section 12.2) MAY be used to allow authorized End Users to
1203 experiment with untested materials or combinations, but only when such materials or
1204 combinations can reasonably be expected to not pose a safety risk.

1205 **12.5 Temperature Control**

1206 Printers MUST validate values provided by Clients and limit material, extruder, Build
1207 Platform, and print chamber temperatures within designed limits to prevent unsafe operating
1208 conditions, damage to the hardware, hazardous emissions, explosions, and/or fires.

1209

1210 13. IANA and PWG Considerations

1211 13.1 Attribute Registrations

1212 The attributes defined in this specification will be published by IANA according to the
1213 procedures in IPP/1.1 Model and Semantics [RFC8011] section 7.2 in the following file:

1214 <http://www.iana.org/assignments/ipp-registrations>

1215 The registry entries will contain the following information:

| 1216 Document Status attributes: | Reference |
|--|--------------|
| 1217 ----- | ----- |
| 1218 materials-col-actual (1setOf collection) | [PWG5100.21] |
| 1219 < member attributes are the same as materials-col > | [PWG5100.21] |
| 1220 multiple-object-handling-actual (type2 keyword) | [PWG5100.21] |
| 1221 platform-temperature-actual (1setOf integer(-273:MAX)) | [PWG5100.21] |
| 1222 print-accuracy-actual (collection) | [PWG5100.21] |
| 1223 < member attributes are the same as print-accuracy > | [PWG5100.21] |
| 1224 print-base-actual (1setOf type2 keyword) | [PWG5100.21] |
| 1225 print-objects-actual (1setOf collection) | [PWG5100.21] |
| 1226 < member attributes are the same as print-objects > | [PWG5100.21] |
| 1227 print-supports-actual (1setOf type2 keyword) | [PWG5100.21] |
| 1228 | |
| 1229 Document Template attributes: | Reference |
| 1230 ----- | ----- |
| 1231 materials-col (1setOf collection) | [PWG5100.21] |
| 1232 material-amount (integer(0:MAX)) | [PWG5100.21] |
| 1233 material-amount-units (type2 keyword) | [PWG5100.21] |
| 1234 material-color (type2 keyword) | [PWG5100.21] |
| 1235 material-diameter (integer(0:MAX)) | [PWG5100.21] |
| 1236 material-diameter-tolerance (integer(0:MAX)) | [PWG5100.21] |
| 1237 material-fill-density (integer(0:100)) | [PWG5100.21] |
| 1238 material-key (keyword) | [PWG5100.21] |
| 1239 material-name (name(MAX)) | [PWG5100.21] |
| 1240 material-nozzle-diameter (integer(0:MAX)) | [PWG5100.21] |
| 1241 material-purpose (1setOf type2 keyword) | [PWG5100.21] |
| 1242 material-rate (integer(1:MAX)) | [PWG5100.21] |
| 1243 material-rate-units (type2 keyword) | [PWG5100.21] |
| 1244 material-retraction (boolean) | [PWG5100.21] |
| 1245 material-shell-thickness (integer(0:MAX)) | [PWG5100.21] |
| 1246 material-temperature (integer(-273:MAX) rangeOfInteger(-273:MAX)) | [PWG5100.21] |
| 1247 | |
| 1248 material-type (type2 keyword name(MAX)) | [PWG5100.21] |
| 1249 multiple-object-handling (type2 keyword) | [PWG5100.21] |
| 1250 platform-temperature (integer(-273:MAX)) | [PWG5100.21] |
| 1251 print-accuracy (collection) | [PWG5100.21] |
| 1252 accuracy-units (type2 keyword) | [PWG5100.21] |
| 1253 x-accuracy (integer(0:MAX)) | [PWG5100.21] |
| 1254 y-accuracy (integer(0:MAX)) | [PWG5100.21] |
| 1255 z-accuracy (integer(0:MAX)) | [PWG5100.21] |
| 1256 print-base (type2 keyword) | [PWG5100.21] |
| 1257 print-objects (1setOf collection) | [PWG5100.21] |

| | | |
|------|---|--------------|
| 1258 | document-number (integer(1:MAX)) | [PWG5100.21] |
| 1259 | object-offset (collection) | [PWG5100.21] |
| 1260 | x-offset (integer(0:MAX)) | [PWG5100.21] |
| 1261 | y-offset (integer(0:MAX)) | [PWG5100.21] |
| 1262 | z-offset (integer(0:MAX)) | [PWG5100.21] |
| 1263 | object-size (collection) | [PWG5100.21] |
| 1264 | x-dimension (integer(1:MAX)) | [PWG5100.21] |
| 1265 | y-dimension (integer(1:MAX)) | [PWG5100.21] |
| 1266 | z-dimension (integer(1:MAX)) | [PWG5100.21] |
| 1267 | object-uuid (uri) | [PWG5100.21] |
| 1268 | print-supports (type2 keyword) | [PWG5100.21] |
| 1269 | printer-volume-humidity (integer(0:100) no-value) | [PWG5100.21] |
| 1270 | printer-volume-temperature (integer(-273:MAX) no-value) | [PWG5100.21] |
| 1271 | | [PWG5100.21] |
| 1272 | | |
| 1273 | Job Status attributes: | Reference |
| 1274 | ----- | ----- |
| 1275 | materials-col-actual (1setOf collection) | [PWG5100.21] |
| 1276 | < member attributes are the same as materials-col > | [PWG5100.21] |
| 1277 | multiple-object-handling-actual (type2 keyword) | [PWG5100.21] |
| 1278 | platform-temperature-actual (1setOf integer(-273:MAX)) | [PWG5100.21] |
| 1279 | print-accuracy-actual (collection) | [PWG5100.21] |
| 1280 | < member attributes are the same as print-accuracy > | [PWG5100.21] |
| 1281 | print-base-actual (1setOf type2 keyword) | [PWG5100.21] |
| 1282 | print-objects-actual (1setOf collection) | [PWG5100.21] |
| 1283 | < member attributes are the same as print-objects > | [PWG5100.21] |
| 1284 | print-supports-actual (1setOf type2 keyword) | [PWG5100.21] |
| 1285 | | |
| 1286 | Job Template attributes: | Reference |
| 1287 | ----- | ----- |
| 1288 | materials-col (1setOf collection) | [PWG5100.21] |
| 1289 | material-amount (integer(0:MAX)) | [PWG5100.21] |
| 1290 | material-amount-units (type2 keyword) | [PWG5100.21] |
| 1291 | material-color (type2 keyword) | [PWG5100.21] |
| 1292 | material-diameter (integer(0:MAX)) | [PWG5100.21] |
| 1293 | material-diameter-tolerance (integer(0:MAX)) | [PWG5100.21] |
| 1294 | material-fill-density (integer(0:100)) | [PWG5100.21] |
| 1295 | material-key (keyword) | [PWG5100.21] |
| 1296 | material-name (name(MAX)) | [PWG5100.21] |
| 1297 | material-nozzle-diameter (integer(0:MAX)) | [PWG5100.21] |
| 1298 | material-purpose (1setOf type2 keyword) | [PWG5100.21] |
| 1299 | material-rate (integer(1:MAX)) | [PWG5100.21] |
| 1300 | material-rate-units (type2 keyword) | [PWG5100.21] |
| 1301 | material-retraction (boolean) | [PWG5100.21] |
| 1302 | material-shell-thickness (integer(0:MAX)) | [PWG5100.21] |
| 1303 | material-temperature (integer(-273:MAX) rangeOfInteger(-273:MAX)) | [PWG5100.21] |
| 1304 | | [PWG5100.21] |
| 1305 | material-type (type2 keyword name(MAX)) | [PWG5100.21] |
| 1306 | multiple-object-handling (type2 keyword) | [PWG5100.21] |
| 1307 | platform-temperature (integer(-273:MAX)) | [PWG5100.21] |
| 1308 | print-accuracy (collection) | [PWG5100.21] |
| 1309 | accuracy-units (type2 keyword) | [PWG5100.21] |
| 1310 | x-accuracy (integer(0:MAX)) | [PWG5100.21] |
| 1311 | y-accuracy (integer(0:MAX)) | [PWG5100.21] |
| 1312 | z-accuracy (integer(0:MAX)) | [PWG5100.21] |
| 1313 | print-base (type2 keyword) | [PWG5100.21] |

| | | |
|------|---|--------------|
| 1314 | print-objects (1setOf collection) | [PWG5100.21] |
| 1315 | document-number (integer(1:MAX)) | [PWG5100.21] |
| 1316 | object-offset (collection) | [PWG5100.21] |
| 1317 | x-offset (integer(0:MAX)) | [PWG5100.21] |
| 1318 | y-offset (integer(0:MAX)) | [PWG5100.21] |
| 1319 | z-offset (integer(0:MAX)) | [PWG5100.21] |
| 1320 | object-size (collection) | [PWG5100.21] |
| 1321 | x-dimension (integer(1:MAX)) | [PWG5100.21] |
| 1322 | y-dimension (integer(1:MAX)) | [PWG5100.21] |
| 1323 | z-dimension (integer(1:MAX)) | [PWG5100.21] |
| 1324 | object-uuid (uri) | [PWG5100.21] |
| 1325 | print-supports (type2 keyword) | [PWG5100.21] |
| 1326 | printer-volume-humidity (integer(0:100) no-value) | [PWG5100.21] |
| 1327 | printer-volume-temperature (integer(-273:MAX) no-value) | [PWG5100.21] |
| 1328 | | [PWG5100.21] |
| 1329 | | |
| 1330 | Printer Description attributes: | Reference |
| 1331 | ----- | ----- |
| 1332 | accuracy-units-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1333 | material-amount-units-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1334 | material-diameter-supported (1setOf (integer(0:MAX) | |
| 1335 | rangeOfInteger(0:MAX))) | [PWG5100.21] |
| 1336 | material-nozzle-diameter-supported (1setOf (integer(0:MAX) | |
| 1337 | rangeOfInteger(0:MAX))) | [PWG5100.21] |
| 1338 | material-purpose-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1339 | material-rate-supported (1setOf (integer(1:MAX) rangeOfInteger(1:MAX))) | [PWG5100.21] |
| 1340 | | [PWG5100.21] |
| 1341 | material-rate-units-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1342 | material-shell-thickness-supported (1setOf (integer(0:MAX) | |
| 1343 | rangeOfInteger(0:MAX))) | [PWG5100.21] |
| 1344 | material-temperature-supported (1setOf (integer(-273:MAX) | |
| 1345 | rangeOfInteger(-273:MAX))) | [PWG5100.21] |
| 1346 | material-type-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1347 | materials-col-database (1setOf collection) | [PWG5100.21] |
| 1348 | < member attributes are the same as materials-col > | [PWG5100.21] |
| 1349 | materials-col-default (1setOf collection) | [PWG5100.21] |
| 1350 | < member attributes are the same as materials-col > | [PWG5100.21] |
| 1351 | materials-col-ready (1setOf collection) | [PWG5100.21] |
| 1352 | < member attributes are the same as materials-col > | [PWG5100.21] |
| 1353 | materials-col-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1354 | max-materials-col-supported (integer(1:MAX)) | [PWG5100.21] |
| 1355 | multiple-object-handling-default (type2 keyword) | [PWG5100.21] |
| 1356 | multiple-object-handling-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1357 | pdf-features-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1358 | platform-shape (type2 keyword) | [PWG5100.21] |
| 1359 | platform-temperature-default (integer(-273:MAX)) | [PWG5100.21] |
| 1360 | platform-temperature-supported (1setOf (integer(-273:MAX) | |
| 1361 | rangeOfInteger(-273:MAX))) | [PWG5100.21] |
| 1362 | print-accuracy-supported (collection) | [PWG5100.21] |
| 1363 | < member attributes are the same as print-accuracy > | [PWG5100.21] |
| 1364 | print-base-default (type2 keyword) | [PWG5100.21] |
| 1365 | print-base-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1366 | print-objects-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1367 | print-supports-default (type2 keyword) | [PWG5100.21] |
| 1368 | print-supports-supported (1setOf type2 keyword) | [PWG5100.21] |

| | | |
|------|---|--------------|
| 1369 | printer-volume-humidity-default (integer(0:100) no-value) | |
| 1370 | | [PWG5100.21] |
| 1371 | printer-volume-humidity-supported (boolean) | [PWG5100.21] |
| 1372 | printer-volume-supported (collection) | [PWG5100.21] |
| 1373 | x-dimension (integer(1:MAX)) | [PWG5100.21] |
| 1374 | y-dimension (integer(1:MAX)) | [PWG5100.21] |
| 1375 | z-dimension (integer(1:MAX)) | [PWG5100.21] |
| 1376 | printer-volume-temperature-default (integer(-273:MAX) no-value) | |
| 1377 | | [PWG5100.21] |
| 1378 | printer-volume-temperature-supported (1setOf (integer(-273:MAX) | |
| 1379 | rangeOfInteger(-273:MAX)) | [PWG5100.21] |
| 1380 | | |
| 1381 | Printer Status attributes: | Reference |
| 1382 | ----- | ----- |
| 1383 | printer-camera-image-uri (1setOf uri) | [PWG5100.21] |
| 1384 | printer-volume-humidity-current (integer(0:100) unknown) | |
| 1385 | | [PWG5100.21] |
| 1386 | printer-volume-temperature-current (integer(-273:MAX) unknown) | |
| 1387 | | [PWG5100.21] |

1388 13.2 Attribute Value Registrations

1389 The attributes defined in this specification will be published by IANA according to the
1390 procedures in IPP/1.1 Model and Semantics [RFC8011] section 7.1 in the following file:

1391 <http://www.iana.org/assignments/ipp-registrations>

1392 The registry entries will contain the following information:

| | | |
|------|---|--------------|
| 1393 | Attributes (attribute syntax) | |
| 1394 | Keyword Attribute Value | Reference |
| 1395 | ----- | ----- |
| 1396 | accuracy-units (type2 keyword) | [PWG5100.21] |
| 1397 | mm | [PWG5100.21] |
| 1398 | nm | [PWG5100.21] |
| 1399 | um | [PWG5100.21] |
| 1400 | accuracy-units-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1401 | < any accuracy-units values > | [PWG5100.21] |
| 1402 | ipp-features-supported (1setOf type2 keyword) | [PWG5100.13] |
| 1403 | ipp-3d | [PWG5100.21] |
| 1404 | material-amount-units (type2 keyword) | [PWG5100.21] |
| 1405 | g | [PWG5100.21] |
| 1406 | kg | [PWG5100.21] |
| 1407 | l | [PWG5100.21] |
| 1408 | m | [PWG5100.21] |
| 1409 | ml | [PWG5100.21] |
| 1410 | mm | [PWG5100.21] |
| 1411 | material-color (type2 keyword) | [PWG5100.21] |
| 1412 | < any "media" color name > | [PWG5100.21] |
| 1413 | material-purpose (1setOf type2 keyword) | [PWG5100.21] |
| 1414 | all | [PWG5100.21] |
| 1415 | base | [PWG5100.21] |
| 1416 | in-fill | [PWG5100.21] |
| 1417 | shell | [PWG5100.21] |

| | | |
|------|---|--------------|
| 1418 | support | [PWG5100.21] |
| 1419 | material-rate-units (type2 keyword) | [PWG5100.21] |
| 1420 | mg_second | [PWG5100.21] |
| 1421 | ml_second | [PWG5100.21] |
| 1422 | mm_second | [PWG5100.21] |
| 1423 | material-type (type2 keyword) | [PWG5100.21] |
| 1424 | abs | [PWG5100.21] |
| 1425 | abs-carbon-fiber | [PWG5100.21] |
| 1426 | abs-carbon-nanotube | [PWG5100.21] |
| 1427 | chocolate | [PWG5100.21] |
| 1428 | gold | [PWG5100.21] |
| 1429 | nylon | [PWG5100.21] |
| 1430 | pet | [PWG5100.21] |
| 1431 | photopolymer | [PWG5100.21] |
| 1432 | pla | [PWG5100.21] |
| 1433 | pla-conductive | [PWG5100.21] |
| 1434 | pla-dissolvable | [PWG5100.21] |
| 1435 | pla-flexible | [PWG5100.21] |
| 1436 | pla-magnetic | [PWG5100.21] |
| 1437 | pla-steel | [PWG5100.21] |
| 1438 | pla-stone | [PWG5100.21] |
| 1439 | pla-wood | [PWG5100.21] |
| 1440 | polycarbonate | [PWG5100.21] |
| 1441 | silver | [PWG5100.21] |
| 1442 | titanium | [PWG5100.21] |
| 1443 | wax | [PWG5100.21] |
| 1444 | materials-col-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1445 | < any materials-col member attribute name > | [PWG5100.21] |
| 1446 | multiple-object-handling (type2 keyword) | [PWG5100.21] |
| 1447 | auto | [PWG5100.21] |
| 1448 | best-fit | [PWG5100.21] |
| 1449 | best-quality | [PWG5100.21] |
| 1450 | best-speed | [PWG5100.21] |
| 1451 | one-at-a-time | [PWG5100.21] |
| 1452 | multiple-object-handling-actual (1setOf type2 keyword) | [PWG5100.21] |
| 1453 | < any multiple-object-handling Job Template attribute value > | [PWG5100.21] |
| 1454 | | [PWG5100.21] |
| 1455 | multiple-object-handling-default (type2 keyword) | [PWG5100.21] |
| 1456 | < any multiple-object-handling Job Template attribute value > | [PWG5100.21] |
| 1457 | | [PWG5100.21] |
| 1458 | multiple-object-handling-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1459 | < any multiple-object-handling Job Template attribute value > | [PWG5100.21] |
| 1460 | | [PWG5100.21] |
| 1461 | pdf-features-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1462 | prc | [PWG5100.21] |
| 1463 | u3d | [PWG5100.21] |
| 1464 | platform-shape (type2 keyword) | [PWG5100.21] |
| 1465 | ellipse | [PWG5100.21] |
| 1466 | rectangle | [PWG5100.21] |
| 1467 | print-base (type2 keyword) | [PWG5100.21] |
| 1468 | brim | [PWG5100.21] |
| 1469 | none | [PWG5100.21] |
| 1470 | raft | [PWG5100.21] |
| 1471 | skirt | [PWG5100.21] |
| 1472 | standard | [PWG5100.21] |
| 1473 | print-base-actual (1setOf type2 keyword) | [PWG5100.21] |

| | | |
|------|---|--------------|
| 1474 | < any print-base Job Template attribute value > | [PWG5100.21] |
| 1475 | print-base-default (type2 keyword) | [PWG5100.21] |
| 1476 | < any print-base Job Template attribute value > | [PWG5100.21] |
| 1477 | print-base-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1478 | < any print-base Job Template attribute value > | [PWG5100.21] |
| 1479 | print-objects-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1480 | < any print-objects member attribute name > | [PWG5100.21] |
| 1481 | print-supports (type2 keyword) | [PWG5100.21] |
| 1482 | material | [PWG5100.21] |
| 1483 | none | [PWG5100.21] |
| 1484 | standard | [PWG5100.21] |
| 1485 | print-supports-actual (1setOf type2 keyword) | [PWG5100.21] |
| 1486 | < any print-supports Job Template attribute value > | [PWG5100.21] |
| 1487 | print-supports-default (type2 keyword) | [PWG5100.21] |
| 1488 | < any print-supports Job Template attribute value > | [PWG5100.21] |
| 1489 | print-supports-supported (1setOf type2 keyword) | [PWG5100.21] |
| 1490 | < any print-supports Job Template attribute value > | [PWG5100.21] |
| 1491 | printer-state-reasons (1setOf type2 keyword) | [RFC8011] |
| 1492 | camera-failure | [PWG5100.21] |
| 1493 | chamber-cooling | [PWG5100.21] |
| 1494 | chamber-failure | [PWG5100.21] |
| 1495 | chamber-heating | [PWG5100.21] |
| 1496 | chamber-temperature-high | [PWG5100.21] |
| 1497 | chamber-temperature-low | [PWG5100.21] |
| 1498 | extruder-cooling | [PWG5100.21] |
| 1499 | extruder-failure | [PWG5100.21] |
| 1500 | extruder-heating | [PWG5100.21] |
| 1501 | extruder-jam | [PWG5100.21] |
| 1502 | extruder-temperature-high | [PWG5100.21] |
| 1503 | extruder-temperature-low | [PWG5100.21] |
| 1504 | fan-failure | [PWG5100.21] |
| 1505 | lamp-at-eol | [PWG5100.21] |
| 1506 | lamp-failure | [PWG5100.21] |
| 1507 | lamp-near-eol | [PWG5100.21] |
| 1508 | laser-at-eol | [PWG5100.21] |
| 1509 | laser-failure | [PWG5100.21] |
| 1510 | laser-near-eol | [PWG5100.21] |
| 1511 | material-empty | [PWG5100.21] |
| 1512 | material-low | [PWG5100.21] |
| 1513 | material-needed | [PWG5100.21] |
| 1514 | motor-failure | [PWG5100.21] |
| 1515 | platform-cooling | [PWG5100.21] |
| 1516 | platform-failure | [PWG5100.21] |
| 1517 | platform-heating | [PWG5100.21] |
| 1518 | platform-temperature-high | [PWG5100.21] |
| 1519 | platform-temperature-low | [PWG5100.21] |

1520 13.3 Service Type Registration

1521 The DNS-SD service type defined in this specification will be published by IANA according
1522 to the procedures in Internet Assigned Numbers Authority (IANA) Procedures for the
1523 Management of the Service Name and Transport Protocol Port Number Registry [BCP165].

1524 The registration template is as follows:

1525 Service Name: ipp3d
1526
1527 Transport Protocol(s): tcp
1528
1529 Assignee/Contact: Michael Sweet, msweet@apple.com
1530
1531 Description: 3D Print services (3D printers) using the Internet Printing
1532 Protocol over HTTPS.
1533
1534 Reference: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf)
1535 [5100.21.pdf](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf)
1536
1537 Port Number:
1538
1539 Service Code:
1540
1541 Known Unauthorized Uses:
1542
1543 Assignment Notes: Change controller is The Printer Working Group, c/o The
1544 IEEE Industry Standards and Technology Organization, 445 Hoes Lane,
1545 Piscataway, NJ 08854, USA

1546 14. References

1547 14.1 Normative References

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1709 Michael Scrutton, Adobe Systems
1710 Emmet Lalish, Microsoft Corporation
1711

1712 **16. Object Definition Languages (ODLs)**

1713 This section provides information on several commonly used ODLs with either existing
1714 (registered) or suggested MIME media types.

1715 **16.1 3D Manufacturing Format (3MF)**

1716 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that
1717 provides geometry, material, and texture information necessary to support a wide variety of
1718 3D printers. Materials can be named and composed within the geometry, facilitating multiple
1719 material support in coordination with a Job Ticket.

1720 The registered MIME media type for the original Microsoft published specification is
1721 "application/vnd.ms-3mfdocument". The MIME media type for the 3MF Consortium's
1722 published specification is "model/3mf".

1723 **16.2 Additive Manufacturing Format (AMF)**

1724 AMF [ISO52915] is a relatively new format that was designed as a replacement for the
1725 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-
1726 available specification, but has several advantages over STL including:

- 1727 1. Shared vertices which eliminates holes and other breaks in the surface
1728 geometry of objects,
- 1729 2. Specification of multiple materials in a single file,
- 1730 3. Curved surfaces can be specified, and
- 1731 4. Coordinates use explicit units for proper output dimensions.

1732 The suggested (but not registered) MIME media type is 'model/amf'.

1733 **16.3 Portable Document Format (PDF)**

1734 PDF [ISO32000] is widely supported for 2D printing and has two 3D formats that are used
1735 to embed 3D objects - PRC [ISO14739-1] and U3D [ECMA363]. The registered MIME media
1736 type for PDF is "application/pdf".

1737 [For discussion: define a "model/pdf" MIME media type for PDFs containing 3D content?]

1738 **16.4 Standard Tessellation Language (STL)**

1739 STL [STLFORMAT] is widely supported by existing client software. The registered MIME
1740 media type is 'application/sla'.

1741

1742 **17. Design Choices**

1743 This section documents some of the design choices that were made during the development
1744 of this specification.

1745 **17.1 Units for Length Values**

1746 The default unit for most length values is hundredths of millimeters (1/2540th of an inch),
1747 matching the units for 2D printing and providing a range of 0.01mm to 21.47km. This was
1748 determined to be sufficient for the class of printers this specification targets.

1749 **17.2 Units for Thickness Values**

1750 The default unit for most thickness values is nanometers, which provides a range of
1751 0.000001mm to 2.147m. This was determined to be sufficient for the class of printers this
1752 specification targets.

1753 **17.3 Use of Celsius for Temperatures**

1754 The various integer attributes for temperature use degrees Celsius. This was done because
1755 most existing printers and materials are specified using degrees Celsius. There is no
1756 advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to perform
1757 additional unit conversions could cause safety issues. All temperature attributes use a range
1758 of -273 (absolute zero) to MAX (2147483647 - significantly hotter than our sun) to allow
1759 flexibility.

1760 **17.4 Explicit Units for Other Values**

1761 Some attributes have a companion "xxx-units" attribute that specifies an explicit unit for the
1762 given measurement(s). The initial list of unit values for each attribute has been limited to
1763 those necessary for current printers and technologies at the time of writing of this
1764 specification in order to minimize interoperability issues.

1765 **17.5 Intent vs. Process**

1766 The IPP Model [RFC8011], and more generally the PWG Semantic Model [PWG5108.1],
1767 have long focused on Job Tickets specifying "what" is wanted for the printed output vs. "how"
1768 that output is produced. This focus has served IPP well and allowed it to be used with wildly
1769 different printing technologies.

1770 During the development of this specification, attributes that define a specific process or
1771 technological parameter have been introduced and later replaced by intent-based
1772 alternatives that allow an implementation to select suitable process-based parameters at

1773 print time, preserving the intrinsic value of such parameters without burdening the Client or
1774 End User with such things.

1775 At the same time, some process parameters are needed for things like material specification.
1776 For example, a particular brand of PLA may require a higher melting temperature - this
1777 information might only be known to the End User, so the "materials-col" collection contains
1778 an member attribute to convey this process-specific parameter. The Printer advertises
1779 whether temperature is a valid material property in the "materials-col-supported" Printer
1780 Description attribute.

1781 Finally, IPP does not prohibit the definition or use of process-based Job Template attributes
1782 for specific implementations. Such extension attributes can be listed in the "job-creation-
1783 attributes-supported" Printer Description attribute to notify Clients of their existence.

1784 **17.6 Choosing a Required Document Format**

1785 One of the design consideration of this specification is to choose an open, freely available
1786 file format for use as required document format. Having a required document format makes
1787 interoperability significantly easier, and using an open and freely available format allows
1788 developers of "consumer" printers to support IPP 3D. Several formats were considered,
1789 including STL, AMF, PDF, and 3MF.

1790 While STL is a widely-implemented, open, and freely available file format, it lacks support
1791 for multiple materials and colors/textures, and has technical issues that cause "holes" in
1792 generated models.

1793 While AMF supports multiple materials and does not have the "holes" issue, it is not freely
1794 available nor widely-implemented.

1795 PDF is the most capable 3D format but is not freely available and has the interoperability
1796 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-
1797 features-supported" Printer Description attribute (section 8.3.18) allows Clients to determine
1798 whether a 3D PDF file can be printed by the Printer.

1799 3MF is open and freely available, supports multiple materials and color/textures, does not
1800 have the "holes" issue of STL, and has a freely available open source implementation that
1801 supports both creation and consumption of 3MF files.
1802

1803 **18. Overview of Changes**

1804 **18.1 IPP 3D Printing Extensions v1.1**

1805 The following changes were made since v1.0 of this document:

- 1806 5. Made 3MF CONDITIONALLY REQUIRED for Printers that do Slicing,
1807 RECOMMEND support for a standard layered format otherwise.
- 1808 6. Added the CONDITIONALLY REQUIRED "material-nozzle-diameter" and
1809 "material-retraction" member attributes for the "materials-col" Job Template
1810 attribute.
- 1811 7. Added the RECOMMENDED "platform-shape" Printer Description attribute
- 1812 8. Added the CONDITIONALLY REQUIRED "printer-volume-humidity" and "printer-
1813 volume-temperature" Job Template attributes.
- 1814 9. Defined a naming convention for standard "material-type" values.
1815

1816 **19. Change History**

1817 **19.1 April 26, 2018**

1818 Initial revision.