



The Printer Working Group

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Working Draft

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

Status: Prototype

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

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63 Contact information:

64 The Printer Working Group
65 c/o The IEEE Industry Standards and Technology Organization
66 445 Hoes Lane
67 Piscataway, NJ 08854
68 USA

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262 **1. Introduction**

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

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

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

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

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

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

282 **2. Terminology**

283 **2.1 Conformance Terminology**

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

289 **2.2 Printing Terminology**

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

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

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

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

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

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

303 **2.3 Protocol Role Terminology**

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

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

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

311 **2.4 3D Printing Terminology**

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

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

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

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

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

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

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

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

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

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

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

335 **2.5 Other Terminology**

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

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

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

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

343 **2.6 Acronyms and Organizations**

344 *3D PDF Consortium*: <http://www.3dpdfconsortium.org/>

345 *3MF Consortium*: 3D Manufacturing Format Consortium, <http://www.3mf.io/>

346 *CNC*: Computer Numerical Control

347 *DLP*: Digital Light Processing

348 *FDM*: Fused Deposition Modeling

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

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

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

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

360 Existing specifications define the following:

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

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

384 **3.1 Use Cases**

385 **3.1.1 Print a 3D Object**

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, specifies material and print settings, and submits the object for
388 printing.

389 **3.1.2 Print a 3D Object Using Loaded Materials**

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

393 **3.1.3 Print a 3D Object with Multiple Materials**

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

398 **3.1.4 Print a Tool**

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

403 **3.1.5 View a 3D Object During Printing**

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

406 **3.2 Exceptions**

407 **3.2.1 Clogged Extruder**

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

411 **3.2.2 Extruder Temperature Out of Range**

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

416 **3.2.3 Extruder Head Movement Issues**

417 While printing a 3D object, the extruder head movement becomes irregular. 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 **3.2.4 Filament Feed Jam**

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

424 3.2.5 Filament Feed Skip

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

428 3.2.6 Material Empty

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

432 3.2.7 Material Adhesion Issues

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

437 3.2.8 Build Platform Temperature Out of Range

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

441 3.2.9 Build Platform Not Clear

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

446 3.3 Out of Scope

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

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

452

453 **3.4 Design Requirements**

454 The design requirements for this document are:

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

470 The design recommendations for this document are:

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

473 **4. 3D Print Service Model**

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

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

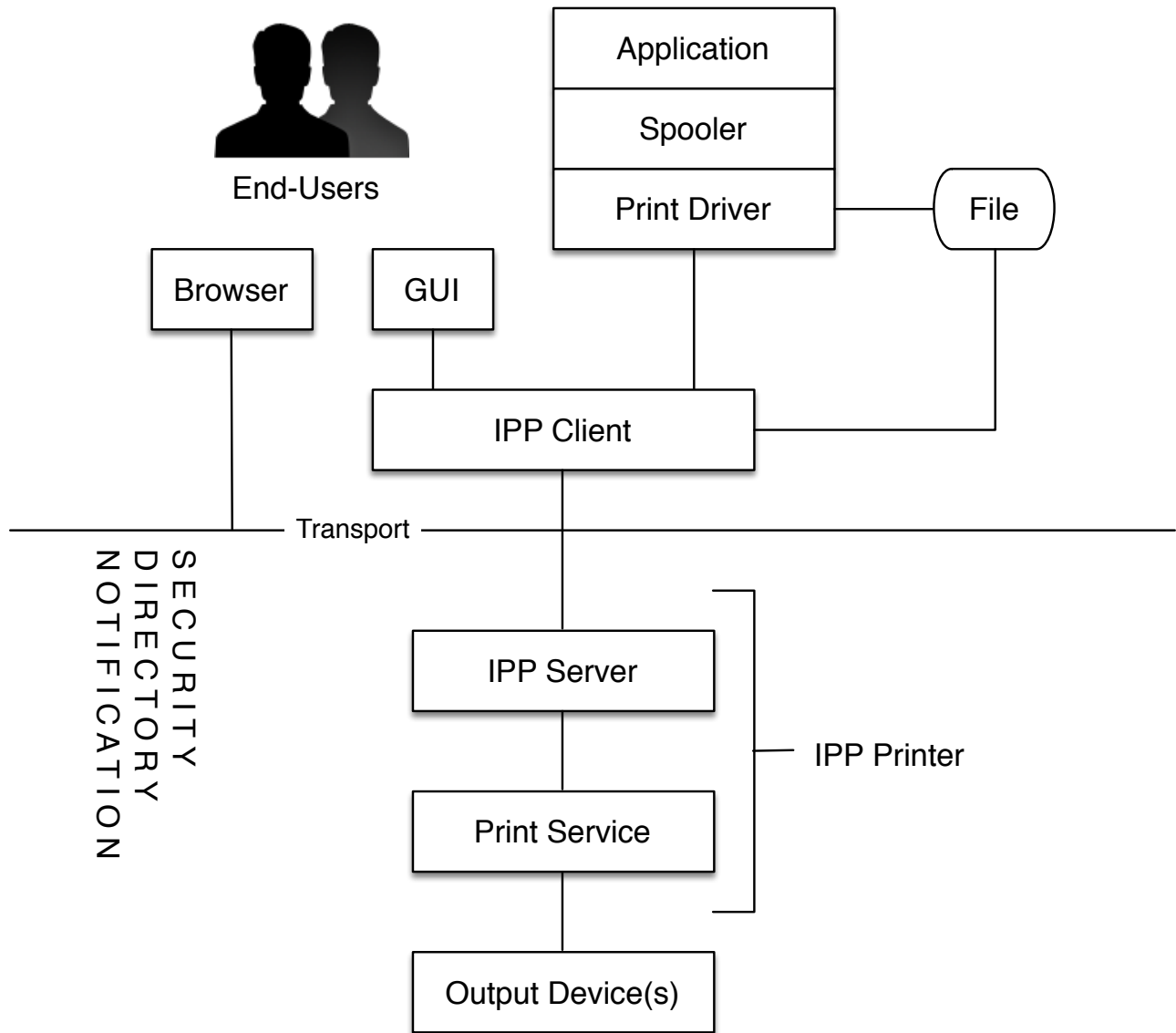
484 The IPP Printer object contains zero or more Job objects and is responsible for managing,
485 scheduling, and processing Jobs. It also provides the current state of the Output Device(s)
486 and communicates with them as needed.

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

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

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

498



499

500

501

Figure 1 - Generalized IPP Model (RFC 8011)

502 4.1 3D Print Service

503 3D printing uses a variation of the traditional Print service that maintains state and capability
 504 information specific to 3D printing. The 3D Print service supports all of the same operations
 505 of the Print service described in [STD92] except for the Print-Job and Print-URI operations
 506 which are compound requests that are not used in newer IPP services. Similarly, the 3D
 507 Print service uses a superset of the Print service attributes except where such attributes are
 508 not applicable, for example the "media" attributes for a 3D printer that does not use media
 509 sheets. Attributes specific to the 3D Print Service are defined in section 8.

510 4.2 3D Printer Subunits

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

513

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

514 4.2.1 Finishing Devices

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

517 4.2.2 Input Trays/Rolls

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

519 4.2.3 Marker Supplies

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

522 4.2.4 Markers

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

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

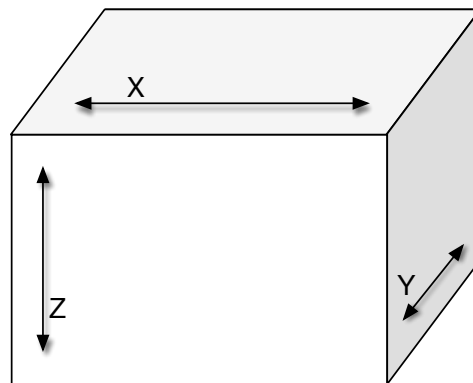
528 4.2.5 Media Paths

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

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

534 4.3 3D Printer Coordinate System

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



539

540

Figure 2 - 3D Build Volume

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

545 **4.4 Output Intent and Job Processing**

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

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

555 **4.5 Job Spooling**

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

559 **4.6 Multiple Document Jobs**

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

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

566 **4.7 Cloud-Based Printing**

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

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

574

575 **5. Discovery Protocols**

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

578 **5.1 DNS Service Discovery (DNS-SD)**

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

583 **5.1.1 Service Instance Name**

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

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

587 **5.1.2 Service Type**

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

589 **5.1.3 TXT Record**

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

593 **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

594 **5.2 LDAP Discovery**

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

598 **5.2.1 printerIPPS3D Class**

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

```
601         ( 1.3.18.0.2.24.46.2.1
602           NAME 'printerIPPS3D'
603           DESC 'Internet Printing Protocol (IPP) 3D Print Service information.'
604           AUXILIARY
605           SUP top
606           MAY ( printer-ipp-versions-supported $
607                printer-ipp-features-supported $
608                printer-multiple-document-jobs-supported )
609         )
610
```

611 **6. Protocol Binding**

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

615 **6.1 Transport and Resource Path**

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

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

623 **6.2 HTTP Features**

624 In addition to the IPP over HTTP conformance requirements defined in section 7.3 of IPP
625 2.0, 2.1, and 2.2 [PWG5100.12], Printers MUST support the following additional HTTP
626 headers and status codes defined in Hypertext Transfer Protocol -- HTTP/1.1 [RFC7230].

627 **6.2.1 Host**

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

630 **6.2.2 If-Modified-Since, Last-Modified, and 304 Not Modified**

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

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

637 **6.2.3 Cache-Control**

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

643 **6.3 IPP Operations**

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

647 **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

648 **6.4 IPP Operation Attributes**

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

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

Attribute	Reference
compression	RFC 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

651 **6.5 IPP Printer Description Attributes**

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

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

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

print-objects-supported	Section 8.3.30
print-quality-default	RFC 8011
print-quality-supported	RFC 8011
print-supports-default	Section 8.3.31
print-supports-supported	Section 8.3.32
printer-geo-location	PWG 5100.13
printer-get-attributes-supported	PWG 5100.13
printer-icons (note 1)	PWG 5100.13
printer-info	RFC 8011
printer-location	RFC 8011
printer-make-and-model	RFC 8011
printer-more-info	RFC 8011
printer-name	RFC 8011
printer-organization	PWG 5100.13
printer-organizational-unit	PWG 5100.13
printer-volume-supported	Section 8.3.33
printer-xri-supported (note 1)	RFC 3380
which-jobs-supported	PWG 5100.11

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

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

657 Note 3: REQUIRED for Printers that control the material temperature during
658 printing.

659 Note 4: REQUIRED for Printers that have a temperature-controlled Build Platform.
660

661 **6.6 IPP Printer Status Attributes**

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

663 **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

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

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

667

668 6.7 IPP Job Template Attributes

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

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

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

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

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

673 6.8 IPP Job Description Attributes

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

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

Attribute	Source
job-name	RFC 8011

676 6.9 IPP Job Status Attributes

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

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

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

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

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

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

681 **6.9.1 job-id (integer)**

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

687 **6.9.2 job-uri (uri)**

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

694 **7. Document Formats**

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

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

700 **8. New Attributes**701 **8.1 Job Template Attributes**

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

704 **Table 10 - IPP 3D Job Template Attributes**

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

705 **8.1.1 chamber-humidity (integer(0:100) | no-value)**

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

708 **8.1.2 chamber-temperature (integer(-273:MAX) | no-value)**

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

712 **8.1.3 materials-col (1setOf collection)**

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

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

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

726 **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

727 8.1.3.1 material-amount (integer(0:MAX) | unknown)

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

732 8.1.3.2 material-amount-units (type2 keyword)

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

735 'g': Value is mass in grams.

736 'kg': Value is mass in kilograms.

737 'l': Value is volume in liters.

738 'm': Value is length in meters.

739 'ml': Value is volume in milliliters.

740 'mm': Value is length in millimeters.

741 8.1.3.3 material-color (type2 keyword)

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

744 8.1.3.4 material-diameter (integer(0:MAX))

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

748 8.1.3.5 material-diameter-tolerance (integer(0:MAX))

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

751 8.1.3.6 material-fill-density (integer(0:100))

752 This REQUIRED member attribute specifies the desired density of filled interior regions in
753 percent.

754 **8.1.3.7 material-key (keyword)**

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

757 **8.1.3.8 material-name (name(MAX))**

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

759 **8.1.3.9 material-nozzle-diameter (integer(0:MAX))**

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

763 **8.1.3.10 material-purpose (1setOf type2 keyword)**

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

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

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

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

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

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

772 **8.1.3.11 material-rate (integer(1:MAX))**

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

775 **8.1.3.12 material-rate-units (type2 keyword)**

776 This member attribute provides the units for the "material-rate" member attribute. Values
777 include:

778 'mg_sec ': Value is milligrams per second.

779 'ml_sec ': Value is milliliters per second.

780 'mm_sec ': Value is millimeters per second.

781 8.1.3.13 material-retraction (boolean)

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

784 8.1.3.14 material-shell-thickness (integer(0:MAX))

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

787 8.1.3.15 material-temperature (integer(-273:MAX) | rangeOfInteger(-273:MAX))

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

791 8.1.3.16 material-type (type2 keyword | name(MAX))

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

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

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

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

800 'chocolate': Chocolate.

801 'gold': Gold (metal).

802 'nylon': Nylon.

803 'pet': Polyethylene terephthalate (PET).

804 'photopolymer': Photopolymer (liquid) resin.

805 'pla': Polylactic Acid (PLA).

806 'pla-conductive': Conductive PLA.

807 'pla-dissolvable': Dissolvable PLA.

808 'pla-flexible': Flexible PLA.

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

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

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

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

813 'polycarbonate': Polycarbonate.

814 'silver': Silver (metal).

815 'titanium': Titanium (metal).

816 'wax': Wax.

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

825 **8.1.4 multiple-object-handling (type2 keyword)**

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

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

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

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

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

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

835 **8.1.5 platform-temperature (integer(-273:MAX))**

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

839 **8.1.6 print-accuracy (collection)**

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

842 When enforcing attribute fidelity ("ipp-attribute-fidelity" with a value of 'true'), Printers only
843 reject "print-accuracy" values that are smaller than the "print-accuracy-supported" (section
844 8.3.27) value.

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

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

846 **8.1.6.1 accuracy-units (type2 keyword)**

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

849 'mm': Accuracy numbers are in millimeters.

850 'um': Accuracy numbers are in micrometers.

851 'nm': Accuracy numbers are in nanometers.

852 **8.1.6.2 x-accuracy (integer(0:MAX))**

853 This REQUIRED member attribute specifies the X axis accuracy in the units specified by the
854 "accuracy-units" member attribute. The value 0 specifies an accuracy better (smaller) than
855 1 unit.

856 **8.1.6.3 y-accuracy (integer(0:MAX))**

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

860 **8.1.6.4 z-accuracy (integer(0:MAX))**

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

864 **8.1.7 print-base (type2 keyword)**

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

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

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

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

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

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

873 **8.1.8 print-objects (1setOf collection)**

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

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

879 **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

880

881 **8.1.8.1 document-number (integer(1:MAX))**

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

884 **8.1.8.2 object-offset (collection)**

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

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

889 **8.1.8.3 object-size (collection)**

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

893 **8.1.8.4 object-uuid (uri)**

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

896 **8.1.9 print-supports (type2 keyword)**

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

899 'none': Do not print supports.

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

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

902

903 8.2 Job Status Attributes

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

906 **Table 14 - IPP 3D "-actual" Job Status Attributes**

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

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

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

910 8.2.1 chamber-humidity-actual (1setOf integer(0:100))

911 This Job Status attribute contains the chamber humidity values that were used throughout
912 the processing of the Job. Printers that support humidity control SHOULD support this
913 attribute.

914 8.2.2 chamber-temperature-actual (1setOf integer(-273:MAX))

915 This Job Status attribute contains the chamber temperature(s) that were used throughout
916 the processing of the Job. Printers that support a temperature-controlled build chamber
917 SHOULD support this attribute.

918 8.2.3 materials-col-actual (1setOf collection)

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

921 8.2.4 multiple-object-handling-actual (type2 keyword)

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

925 **8.2.5 print-accuracy-actual (collection)**

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

927 **8.2.6 platform-temperature-actual (1setOf integer(-273:MAX))**

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

931 **8.2.7 print-accuracy-actual (1setOf collection)**

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

934 **8.2.8 print-base-actual (1setOf type2 keyword)**

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

937 **8.2.9 print-objects-actual (1setOf collection)**

938 This CONDITIONALLY REQUIRED Job Status attribute lists the objects that were
939 processed. Printers that support the 'application/pdf' document format MUST support this
940 attribute.

941 **8.2.10 print-supports-actual (1setOf type2 keyword)**

942 This REQUIRED Job Status attribute specifies whether supports were printed during the
943 processing of the Job.

944 **8.3 Printer Description Attributes**

945 **8.3.1 accuracy-units-supported (1setOf type2 keyword)**

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

948 **8.3.2 chamber-humidity-default (integer(0:100) | no-value)**

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

952 8.3.3 chamber-humidity-supported (boolean)

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

956 8.3.4 chamber-temperature-default (integer(-273:MAX) | no-value)

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

**960 8.3.5 chamber-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-
961 273:MAX)))**

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

965 8.3.6 material-amount-units-supported (1setOf type2 keyword)

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

969 8.3.7 material-diameter-supported (1setOf (integer | rangeOfInteger))

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

973 8.3.8 material-nozzle-diameter-supported (1setOf (integer | rangeOfInteger))

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

977 8.3.9 material-purpose-supported (1setOf type2 keyword)

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

980 8.3.10 material-rate-supported (1setOf (integer | rangeOfInteger))

981 This Printer Description attribute lists the supported "material-rate" values for the Printer.
982 This attribute MUST be supported if the "material-rate" member attribute (Section 8.1.3.11)
983 is supported.

984 8.3.11 material-rate-units-supported (1setOf type2 keyword)

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

**988 8.3.12 material-shell-thickness-supported (1setOf (integer(1:MAX) |
989 rangeOfInteger(1:MAX)))**

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

**992 8.3.13 material-temperature-supported (1setOf (integer(-273:MAX) | rangeOfInteger(-
993 273:MAX)))**

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

997 8.3.14 material-type-supported (1setOf type2 keyword)

998 This REQUIRED Printer Description attribute lists the supported "material-type" values for
999 the Printer.

1000 8.3.15 materials-col-database (1setOf collection)

1001 This RECOMMENDED Printer Description attribute lists the pre-configured materials for the
1002 Printer. Each value contains the corresponding "materials-col" member attributes and will
1003 typically reflect vendor and site ("third party") materials that are supported by the Printer.

1004 In order to optimize the total size of this attribute, Printers MAY omit member attributes that
1005 allow the full range of supported values in a particular collection. For example, a Printer that
1006 supports generic PLA filament can report a single collection value:

```
1007     materials-col-database =  
1008     { material-name="Generic PLA Filament" material-key="generic-pla"  
1009     material-diameter=285 material-temperature=215-235 }
```

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

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

1019 **8.3.16 materials-col-default (1setOf collection)**

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

1022 **8.3.17 materials-col-ready (1setOf collection)**

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

1025 **8.3.18 materials-col-supported (1setOf type2 keyword)**

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

1030 **8.3.19 max-materials-col-supported (integer(1:MAX))**

1031 This REQUIRED Printer Description attribute specifies the maximum number of values that
1032 can be provided with the "materials-col" Job Template attribute (section 8.1.1).

1033 **8.3.20 multiple-object-handling-default (type2 keyword)**

1034 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default
1035 "multiple-object-handling" value. Printers that support the 'application/pdf' Document format
1036 MUST support this attribute.

1037 **8.3.21 multiple-object-handling-supported (1setOf type2 keyword)**

1038 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported
1039 "multiple-object-handling" values. Printers that support the 'application/pdf' Document format
1040 MUST support this attribute.

1041 **8.3.22 pdf-features-supported (1setOf type2 keyword)**

1042 This CONDITIONALLY REQUIRED Printer Description attribute lists the PDF features that
1043 are supported by the Printer. Printers that support the 'application/pdf' Document format
1044 MUST support this attribute.

1045 Values include:

1046 'prc': The Printer supports 3D objects in the Product Representation Compact
1047 (PRC) format [ISO14739-1].

1048 'u3d': The Printer supports 3D objects in the Universal 3D (U3D) format
1049 [ECMA363].

1050 **8.3.23 platform-shape (type2 keyword)**

1051 This RECOMMENDED Printer Description attribute describes the overall shape of the build
1052 platform. Values include:

1053 'ellipse': The build platform is elliptical, forming a cylindrical build volume.

1054 'rectangle': The build platform is rectangular, forming a cubic build volume.

1055 **8.3.24 platform-temperature-default (integer(-273:MAX))**

1056 This CONDITIONALLY REQUIRED Printer Description attribute specifies the default
1057 "platform-temperature" value. Printers that control the temperature of the Build Platform
1058 MUST support this attribute.

1059 **8.3.25 platform-temperature-supported (1setOf (integer(-273:MAX) |
1060 rangeOfInteger(-273:MAX)))**

1061 This CONDITIONALLY REQUIRED Printer Description attribute lists the supported
1062 "platform-temperature" values and/or ranges. Printers that control the temperature of the
1063 Build Platform MUST support this attribute.

1064 **8.3.26 print-accuracy-default (collection)**

1065 This REQUIRED Printer Description attribute specifies the default "print-accuracy" value.

1066 **8.3.27 print-accuracy-supported (collection)**

1067 This REQUIRED Printer Description attribute specifies the best "print-accuracy" value that
1068 is supported by the Printer.

1069 **8.3.28 print-base-default (type2 keyword)**

1070 This REQUIRED Printer Description attribute specifies the default "print-base" value.

1071 **8.3.29 print-base-supported (1setOf type2 keyword)**

1072 This REQUIRED Printer Description attribute lists the supported "print-base" values.

1073 **8.3.30 print-objects-supported (1setOf type2 keyword)**

1074 This CONDITIONALLY REQUIRED Printer Description attribute specifies which "print-
1075 objects" member attributes are supported. Printers that support the 'application/pdf'
1076 Document format MUST support this attribute.

1077 **8.3.31 print-supports-default (type2 keyword)**

1078 This REQUIRED Printer Description attribute specifies the default "print-supports" value.

1079 **8.3.32 print-supports-supported (1setOf type2 keyword)**

1080 This REQUIRED Printer Description attribute lists the supported "print-supports" values.

1081 **8.3.33 printer-volume-supported (collection)**

1082 This REQUIRED Printer Description attribute specifies the maximum build volume supported
1083 by the Printer. Table 15 lists the REQUIRED member attributes.

1084 **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))

1085 **8.3.33.1 x-dimension (integer(1:MAX))**

1086 This member attributes specifies the width of the build volume in hundredths of millimeters
1087 (1/2540th of an inch).

1088 **8.3.33.2 y-dimension (integer(1:MAX))**

1089 This member attributes specifies the depth of the build volume in hundredths of millimeters
1090 (1/2540th of an inch).

1091 **8.3.33.3 z-dimension (integer(1:MAX))**

1092 This member attributes specifies the height of the build volume in hundredths of millimeters
1093 (1/2540th of an inch).

1094 **8.4 Printer Status Attributes**

1095 **8.4.1 chamber-humidity-current (integer(0:100) | unknown)**

1096 This Printer Status attribute reports the current relative humidity of the build chamber as a
1097 percentage. Printers that support the "chamber-humidity" Job Template attribute (section
1098 8.1.1) MUST support this attribute.

1099 **8.4.2 chamber-temperature-current (integer(-273:MAX) | unknown)**

1100 This Printer Status attribute reports the current temperature of the build chamber in degrees
1101 Celsius, if known. Printers that support the "chamber-temperature" Job Template attribute
1102 (section 8.1.2) MUST support this attribute.

1103 **8.4.3 printer-camera-image-uri (1setOf uri)**

1104 This Printer Status attribute lists the URIs for one or more resident camera snapshots. Each
1105 URI corresponds to a separate resident camera. The images referenced by each URI can
1106 change at any time so it is up to the Client to periodically poll for changes and for the Printer
1107 to atomically update the images so that Clients can safely do so. The referenced images
1108 MUST be PNG [RFC2083] or JPEG [JFIF] format.

1109 **9. New Values for Existing Attributes**

1110 **9.1 ipp-features-supported (1setOf type2 keyword)**

1111 This specification registers the new REQUIRED value 'ipp-3d' for the "ipp-features-
1112 supported" Printer Description attribute.

1113 **9.2 printer-state-reasons (1setOf type2 keyword)**

1114 This specification registers the following new values for the "printer-state-reasons" Printer
1115 Status attribute:

1116 'camera-failure': A camera is no longer working.

1117 'chamber-cooling': A chamber is being cooled.

1118 'chamber-failure': A chamber has failed and requires maintenance or replacement.

1119 'chamber-heating': A chamber is being heated.

1120 'chamber-temperature-high': The temperature of a chamber is high.

1121 'chamber-temperature-low': The temperature of a chamber is low.

1122 'extruder-cooling': An extruder is being cooled.

1123 'extruder-failure': An extruder has failed and requires maintenance or replacement.

1124 'extruder-heating': An extruder is being heated.

1125 'extruder-jam': An extruder is jammed or clogged.

1126 'extruder-temperature-high': The temperature of an extruder is too high.

1127 'extruder-temperature-low': The temperature of an extruder is too low.

1128 'fan-failure': A fan has failed.

- 1129 'lamp-at-eol': A lamp has reached its end-of-life and will need to be replaced soon.
- 1130 'lamp-failure': A lamp has failed.
- 1131 'lamp-near-eol': A lamp is near its end-of-life and may need to be replaced soon.
- 1132 'laser-at-eol': A laser has reached its end-of-life and will need to be replaced soon.
- 1133 'laser-failure': A laser has failed.
- 1134 'laser-near-eol': A laser is near its end-of-life and may need to be replaced soon.
- 1135 'material-empty': One or more build materials have been exhausted.
- 1136 'material-low': One or more build materials may need replenishment soon.
- 1137 'material-needed': One or more build materials need to be loaded for a processing
1138 Job.
- 1139 'motor-failure': A motor has failed.
- 1140 'platform-cooling': A Build Platform is being cooled.
- 1141 'platform-failure': A Build Platform has failed and requires maintenance or
1142 replacement.
- 1143 'platform-heating': A Build Platform is being heated.
- 1144 'platform-temperature-high': The temperature of a Build Platform is too high.
- 1145 'platform-temperature-low': The temperature of a Build Platform is too low.
1146

1147 **10. Conformance Requirements**

1148 **10.1 Printer Conformance Requirements**

1149 In order for a Printer to claim conformance to this specification, a Printer MUST support:

- 1150 1. The required discovery protocols in section 5;
- 1151 2. The required transports and resource paths in section 6.1;
- 1152 3. The required HTTP features in section 6.2;
- 1153 4. The required IPP operations in section 6.3;
- 1154 5. The required IPP attributes in sections 6.4 through 6.9;
- 1155 6. The required document formats in section 7;
- 1156 7. The additional values defined in section 9;
- 1157 8. The internationalization considerations in section 11; and
- 1158 9. The security considerations in section 12.

1159 **10.2 Client Conformance Requirements**

1160 In order for a Client to claim conformance to this specification, a Client MUST support:

- 1161 1. The required discovery protocols in section 5;
- 1162 2. The required transports and resource paths in section 6.1;
- 1163 3. The required HTTP features in section 6.2;
- 1164 4. The required IPP operations in section 6.3;
- 1165 5. The required IPP attributes in sections 6.4 through 6.9;
- 1166 6. The required document formats in section 7;
- 1167 7. The additional values defined in section 9;
- 1168 8. The internationalization considerations in section 11; and
- 1169 9. The security considerations in section 12.

1170

1171 **11. Internationalization Considerations**

1172 For interoperability and basic support for multiple languages, conforming implementations
1173 MUST support:

- 1174 1. The Universal Character Set (UCS) Transformation Format -- 8 bit (UTF-8)
1175 [STD63] encoding of Unicode [UNICODE] [ISO10646]; and
- 1176 2. The Unicode Format for Network Interchange [RFC5198] which requires
1177 transmission of well-formed UTF-8 strings and recommends transmission of
1178 normalized UTF-8 strings in Normalization Form C (NFC) [UAX15].

1179 Unicode NFC is defined as the result of performing Canonical Decomposition (into base
1180 characters and combining marks) followed by Canonical Composition (into canonical
1181 composed characters wherever Unicode has assigned them).

1182 WARNING – Performing normalization on UTF-8 strings received from IPP Clients and
1183 subsequently storing the results (e.g., in IPP Job objects) could cause false negatives in IPP
1184 Client searches and failed access (e.g., to IPP Printers with percent-encoded UTF-8 URIs
1185 now 'hidden').

1186 Implementations of this specification SHOULD conform to the following standards on
1187 processing of human-readable Unicode text strings, see:

1188 Unicode Bidirectional Algorithm [UAX9] – left-to-right, right-to-left, and vertical

1189 Unicode Line Breaking Algorithm [UAX14] – character classes and wrapping

1190 Unicode Normalization Forms [UAX15] – especially NFC for [RFC5198]

1191 Unicode Text Segmentation [UAX29] – grapheme clusters, words, sentences

1192 Unicode Identifier and Pattern Syntax [UAX31] – identifier use and normalization

1193 Unicode Character Encoding Model [UTR17] – multi-layer character model

1194 Unicode in XML and other Markup Languages [UTR20] – XML usage

1195 Unicode Character Property Model [UTR23] – character properties

1196 Unicode Conformance Model [UTR33] – Unicode conformance basis+

1197 Unicode Collation Algorithm [UTS10] – sorting

1198 Unicode Locale Data Markup Language [UTS35] – locale databases

1199 **12. Security Considerations**

1200 In addition to the security considerations described in the IPP/1.1: Model and Semantics
1201 [STD92], the following sub-sections describe issues that are unique to 3D printing.

1202 Implementations of this specification SHOULD conform to the following standards on
1203 processing of human-readable Unicode text strings, see:

1204 Unicode Security Mechanisms [UTS39] – detecting and avoiding security attacks

1205 Unicode Security FAQ [UNISECFAQ] – common Unicode security issues

1206 **12.1 Confidentiality**

1207 Clients and Printers MUST provide confidentiality of data in transit using either an interface
1208 providing physical security such as USB or using TLS encryption [RFC5246] over
1209 unsecured/network connections,

1210 **12.2 Access Control**

1211 Because of the potential for abuse and misuse, Printers SHOULD provide access control
1212 mechanisms including lists of allowed Clients, authentication, and authorization to site
1213 defined policies.

1214 **12.3 Physical Safety**

1215 Printers MUST NOT allow Clients to disable physical safety features of the hardware, such
1216 as protective gates, covers, or interlocks.

1217 **12.4 Material Safety**

1218 Printers MUST restrict usage and combination of materials to those that can be safely
1219 printed. Access controls (section 12.2) MAY be used to allow authorized End Users to
1220 experiment with untested materials or combinations, but only when such materials or
1221 combinations can reasonably be expected to not pose a safety risk.

1222 **12.5 Temperature Control**

1223 Printers MUST validate values provided by Clients and limit material, extruder, Build
1224 Platform, and print chamber temperatures within designed limits to prevent unsafe operating
1225 conditions, damage to the hardware, hazardous emissions, explosions, and/or fires.

1226

1227 **13. IANA and PWG Considerations**1228 **13.1 Attribute Registrations**

1229 The attributes defined in this specification will be published by IANA according to the
 1230 procedures in IPP/1.1 Model and Semantics [STD92] section 7.2 in the following file:

1231 <http://www.iana.org/assignments/ipp-registrations>

1232 The registry entries will contain the following information:

1233 Document Status attributes:	Reference
1234 -----	-----
1235 chamber-humidity-actual (1setOf integer(0:100))	[PWG5100.21]
1236 chamber-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1237 materials-col-actual (1setOf collection)	[PWG5100.21]
1238 < member attributes are the same as materials-col >	[PWG5100.21]
1239 multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1240 platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1241 print-accuracy-actual (collection)	[PWG5100.21]
1242 < member attributes are the same as print-accuracy >	[PWG5100.21]
1243 print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1244 print-objects-actual (1setOf collection)	[PWG5100.21]
1245 < member attributes are the same as print-objects >	[PWG5100.21]
1246 print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1247	
1248 Document Template attributes:	Reference
1249 -----	-----
1250 chamber-humidity (integer(0:100))	[PWG5100.21]
1251 chamber-temperature (integer(-273:MAX))	[PWG5100.21]
1252 materials-col (1setOf collection)	[PWG5100.21]
1253 material-amount (integer(0:MAX))	[PWG5100.21]
1254 material-amount-units (type2 keyword)	[PWG5100.21]
1255 material-color (type2 keyword)	[PWG5100.21]
1256 material-diameter (integer(0:MAX))	[PWG5100.21]
1257 material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1258 material-fill-density (integer(0:100))	[PWG5100.21]
1259 material-key (keyword)	[PWG5100.21]
1260 material-name (name(MAX))	[PWG5100.21]
1261 material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
1262 material-purpose (1setOf type2 keyword)	[PWG5100.21]
1263 material-rate (integer(1:MAX))	[PWG5100.21]
1264 material-rate-units (type2 keyword)	[PWG5100.21]
1265 material-retraction (boolean)	[PWG5100.21]
1266 material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1267 material-temperature (integer(-273:MAX) rangeOfInteger(-273:MAX))	[PWG5100.21]
1268	
1269 material-type (type2 keyword name(MAX))	[PWG5100.21]
1270 multiple-object-handling (type2 keyword)	[PWG5100.21]
1271 platform-temperature (integer(-273:MAX))	[PWG5100.21]
1272 print-accuracy (collection)	[PWG5100.21]
1273 accuracy-units (type2 keyword)	[PWG5100.21]
1274 x-accuracy (integer(0:MAX))	[PWG5100.21]

1275	y-accuracy (integer(0:MAX))	[PWG5100.21]
1276	z-accuracy (integer(0:MAX))	[PWG5100.21]
1277	print-base (type2 keyword)	[PWG5100.21]
1278	print-objects (1setOf collection)	[PWG5100.21]
1279	document-number (integer(1:MAX))	[PWG5100.21]
1280	object-offset (collection)	[PWG5100.21]
1281	x-offset (integer(0:MAX))	[PWG5100.21]
1282	y-offset (integer(0:MAX))	[PWG5100.21]
1283	z-offset (integer(0:MAX))	[PWG5100.21]
1284	object-size (collection)	[PWG5100.21]
1285	x-dimension (integer(1:MAX))	[PWG5100.21]
1286	y-dimension (integer(1:MAX))	[PWG5100.21]
1287	z-dimension (integer(1:MAX))	[PWG5100.21]
1288	object-uuid (uri)	[PWG5100.21]
1289	print-supports (type2 keyword)	[PWG5100.21]
1290		
1291	Job Status attributes:	Reference
1292	-----	-----
1293	chamber-humidity-actual (1setOf integer(0:100))	[PWG5100.21]
1294	chamber-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1295	materials-col-actual (1setOf collection)	[PWG5100.21]
1296	< member attributes are the same as materials-col >	[PWG5100.21]
1297	multiple-object-handling-actual (type2 keyword)	[PWG5100.21]
1298	platform-temperature-actual (1setOf integer(-273:MAX))	[PWG5100.21]
1299	print-accuracy-actual (collection)	[PWG5100.21]
1300	< member attributes are the same as print-accuracy >	[PWG5100.21]
1301	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1302	print-objects-actual (1setOf collection)	[PWG5100.21]
1303	< member attributes are the same as print-objects >	[PWG5100.21]
1304	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1305		
1306	Job Template attributes:	Reference
1307	-----	-----
1308	chamber-humidity (integer(0:100))	[PWG5100.21]
1309	chamber-temperature (integer(-273:MAX))	[PWG5100.21]
1310	materials-col (1setOf collection)	[PWG5100.21]
1311	material-amount (integer(0:MAX))	[PWG5100.21]
1312	material-amount-units (type2 keyword)	[PWG5100.21]
1313	material-color (type2 keyword)	[PWG5100.21]
1314	material-diameter (integer(0:MAX))	[PWG5100.21]
1315	material-diameter-tolerance (integer(0:MAX))	[PWG5100.21]
1316	material-fill-density (integer(0:100))	[PWG5100.21]
1317	material-key (keyword)	[PWG5100.21]
1318	material-name (name(MAX))	[PWG5100.21]
1319	material-nozzle-diameter (integer(0:MAX))	[PWG5100.21]
1320	material-purpose (1setOf type2 keyword)	[PWG5100.21]
1321	material-rate (integer(1:MAX))	[PWG5100.21]
1322	material-rate-units (type2 keyword)	[PWG5100.21]
1323	material-retraction (boolean)	[PWG5100.21]
1324	material-shell-thickness (integer(0:MAX))	[PWG5100.21]
1325	material-temperature (integer(-273:MAX) rangeOfInteger(-273:MAX))	[PWG5100.21]
1326		
1327	material-type (type2 keyword name(MAX))	[PWG5100.21]
1328	multiple-object-handling (type2 keyword)	[PWG5100.21]
1329	platform-temperature (integer(-273:MAX))	[PWG5100.21]
1330	print-accuracy (collection)	[PWG5100.21]

1331	accuracy-units (type2 keyword)	[PWG5100.21]
1332	x-accuracy (integer(0:MAX))	[PWG5100.21]
1333	y-accuracy (integer(0:MAX))	[PWG5100.21]
1334	z-accuracy (integer(0:MAX))	[PWG5100.21]
1335	print-base (type2 keyword)	[PWG5100.21]
1336	print-objects (1setOf collection)	[PWG5100.21]
1337	document-number (integer(1:MAX))	[PWG5100.21]
1338	object-offset (collection)	[PWG5100.21]
1339	x-offset (integer(0:MAX))	[PWG5100.21]
1340	y-offset (integer(0:MAX))	[PWG5100.21]
1341	z-offset (integer(0:MAX))	[PWG5100.21]
1342	object-size (collection)	[PWG5100.21]
1343	x-dimension (integer(1:MAX))	[PWG5100.21]
1344	y-dimension (integer(1:MAX))	[PWG5100.21]
1345	z-dimension (integer(1:MAX))	[PWG5100.21]
1346	object-uuid (uri)	[PWG5100.21]
1347	print-supports (type2 keyword)	[PWG5100.21]
1348		
1349	Printer Description attributes:	Reference
1350	-----	-----
1351	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.21]
1352	chamber-humidity-default (integer(0:100) no-value)	[PWG5100.21]
1353	chamber-humidity-supported (boolean)	[PWG5100.21]
1354	chamber-temperature-default (integer(-273:MAX) no-value)	[PWG5100.21]
1355		
1356	chamber-temperature-supported (1setOf (integer(-273:MAX)	
1357	rangeOfInteger(-273:MAX))	[PWG5100.21]
1358	material-amount-units-supported (1setOf type2 keyword)	[PWG5100.21]
1359	material-diameter-supported (1setOf (integer(0:MAX)	
1360	rangeOfInteger(0:MAX)))	[PWG5100.21]
1361	material-nozzle-diameter-supported (1setOf (integer(0:MAX)	
1362	rangeOfInteger(0:MAX)))	[PWG5100.21]
1363	material-purpose-supported (1setOf type2 keyword)	[PWG5100.21]
1364	material-rate-supported (1setOf (integer(1:MAX) rangeOfInteger(1:MAX)))	[PWG5100.21]
1365		
1366	material-rate-units-supported (1setOf type2 keyword)	[PWG5100.21]
1367	material-shell-thickness-supported (1setOf (integer(0:MAX)	
1368	rangeOfInteger(0:MAX)))	[PWG5100.21]
1369	material-temperature-supported (1setOf (integer(-273:MAX)	
1370	rangeOfInteger(-273:MAX)))	[PWG5100.21]
1371	material-type-supported (1setOf type2 keyword)	[PWG5100.21]
1372	materials-col-database (1setOf collection)	[PWG5100.21]
1373	< member attributes are the same as materials-col >	[PWG5100.21]
1374	materials-col-default (1setOf collection)	[PWG5100.21]
1375	< member attributes are the same as materials-col >	[PWG5100.21]
1376	materials-col-ready (1setOf collection)	[PWG5100.21]
1377	< member attributes are the same as materials-col >	[PWG5100.21]
1378	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1379	max-materials-col-supported (integer(1:MAX))	[PWG5100.21]
1380	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1381	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1382	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1383	platform-shape (type2 keyword)	[PWG5100.21]
1384	platform-temperature-default (integer(-273:MAX))	[PWG5100.21]
1385	platform-temperature-supported (1setOf (integer(-273:MAX)	
1386	rangeOfInteger(-273:MAX)))	[PWG5100.21]

1387	print-accuracy-supported (collection)	[PWG5100.21]
1388	< member attributes are the same as print-accuracy >	[PWG5100.21]
1389	print-base-default (type2 keyword)	[PWG5100.21]
1390	print-base-supported (1setOf type2 keyword)	[PWG5100.21]
1391	print-objects-supported (1setOf type2 keyword)	[PWG5100.21]
1392	print-supports-default (type2 keyword)	[PWG5100.21]
1393	print-supports-supported (1setOf type2 keyword)	[PWG5100.21]
1394	printer-volume-supported (collection)	[PWG5100.21]
1395	x-dimension (integer(1:MAX))	[PWG5100.21]
1396	y-dimension (integer(1:MAX))	[PWG5100.21]
1397	z-dimension (integer(1:MAX))	[PWG5100.21]
1398		
1399	Printer Status attributes:	Reference
1400	-----	-----
1401	chamber-humidity-current (integer(0:100) unknown)	[PWG5100.21]
1402	chamber-temperature-current (integer(-273:MAX) unknown)	[PWG5100.21]
1403	printer-camera-image-uri (1setOf uri)	[PWG5100.21]

1404 13.2 Attribute Value Registrations

1405 The attributes defined in this specification will be published by IANA according to the
 1406 procedures in IPP/1.1 Model and Semantics [STD92] section 7.1 in the following file:

1407 <http://www.iana.org/assignments/ipp-registrations>

1408 The registry entries will contain the following information:

1409	Attributes (attribute syntax)	
1410	Keyword Attribute Value	Reference
1411	-----	-----
1412	accuracy-units (type2 keyword)	[PWG5100.21]
1413	mm	[PWG5100.21]
1414	nm	[PWG5100.21]
1415	um	[PWG5100.21]
1416	accuracy-units-supported (1setOf type2 keyword)	[PWG5100.21]
1417	< any accuracy-units values >	[PWG5100.21]
1418	ipp-features-supported (1setOf type2 keyword)	[PWG5100.13]
1419	ipp-3d	[PWG5100.21]
1420	material-amount-units (type2 keyword)	[PWG5100.21]
1421	g	[PWG5100.21]
1422	kg	[PWG5100.21]
1423	l	[PWG5100.21]
1424	m	[PWG5100.21]
1425	ml	[PWG5100.21]
1426	mm	[PWG5100.21]
1427	material-color (type2 keyword)	[PWG5100.21]
1428	< any "media" color name >	[PWG5100.21]
1429	material-purpose (1setOf type2 keyword)	[PWG5100.21]
1430	all	[PWG5100.21]
1431	base	[PWG5100.21]
1432	in-fill	[PWG5100.21]
1433	shell	[PWG5100.21]
1434	support	[PWG5100.21]
1435	material-rate-units (type2 keyword)	[PWG5100.21]

1436	mg_second	[PWG5100.21]
1437	ml_second	[PWG5100.21]
1438	mm_second	[PWG5100.21]
1439	material-type (type2 keyword)	[PWG5100.21]
1440	abs	[PWG5100.21]
1441	abs-carbon-fiber	[PWG5100.21]
1442	abs-carbon-nanotube	[PWG5100.21]
1443	chocolate	[PWG5100.21]
1444	gold	[PWG5100.21]
1445	nylon	[PWG5100.21]
1446	pet	[PWG5100.21]
1447	photopolymer	[PWG5100.21]
1448	pla	[PWG5100.21]
1449	pla-conductive	[PWG5100.21]
1450	pla-dissolvable	[PWG5100.21]
1451	pla-flexible	[PWG5100.21]
1452	pla-magnetic	[PWG5100.21]
1453	pla-steel	[PWG5100.21]
1454	pla-stone	[PWG5100.21]
1455	pla-wood	[PWG5100.21]
1456	polycarbonate	[PWG5100.21]
1457	silver	[PWG5100.21]
1458	titanium	[PWG5100.21]
1459	wax	[PWG5100.21]
1460	materials-col-supported (1setOf type2 keyword)	[PWG5100.21]
1461	< any materials-col member attribute name >	[PWG5100.21]
1462	multiple-object-handling (type2 keyword)	[PWG5100.21]
1463	auto	[PWG5100.21]
1464	best-fit	[PWG5100.21]
1465	best-quality	[PWG5100.21]
1466	best-speed	[PWG5100.21]
1467	one-at-a-time	[PWG5100.21]
1468	multiple-object-handling-actual (1setOf type2 keyword)	[PWG5100.21]
1469	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1470		[PWG5100.21]
1471	multiple-object-handling-default (type2 keyword)	[PWG5100.21]
1472	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1473		[PWG5100.21]
1474	multiple-object-handling-supported (1setOf type2 keyword)	[PWG5100.21]
1475	< any multiple-object-handling Job Template attribute value >	[PWG5100.21]
1476		[PWG5100.21]
1477	pdf-features-supported (1setOf type2 keyword)	[PWG5100.21]
1478	prc	[PWG5100.21]
1479	u3d	[PWG5100.21]
1480	platform-shape (type2 keyword)	[PWG5100.21]
1481	ellipse	[PWG5100.21]
1482	rectangle	[PWG5100.21]
1483	print-base (type2 keyword)	[PWG5100.21]
1484	brim	[PWG5100.21]
1485	none	[PWG5100.21]
1486	raft	[PWG5100.21]
1487	skirt	[PWG5100.21]
1488	standard	[PWG5100.21]
1489	print-base-actual (1setOf type2 keyword)	[PWG5100.21]
1490	< any print-base Job Template attribute value >	[PWG5100.21]
1491	print-base-default (type2 keyword)	[PWG5100.21]

1492	< any print-base Job Template attribute value >	[PWG5100.21]
1493	print-base-supported (1setOf type2 keyword)	[PWG5100.21]
1494	< any print-base Job Template attribute value >	[PWG5100.21]
1495	print-objects-supported (1setOf type2 keyword)	[PWG5100.21]
1496	< any print-objects member attribute name >	[PWG5100.21]
1497	print-supports (type2 keyword)	[PWG5100.21]
1498	material	[PWG5100.21]
1499	none	[PWG5100.21]
1500	standard	[PWG5100.21]
1501	print-supports-actual (1setOf type2 keyword)	[PWG5100.21]
1502	< any print-supports Job Template attribute value >	[PWG5100.21]
1503	print-supports-default (type2 keyword)	[PWG5100.21]
1504	< any print-supports Job Template attribute value >	[PWG5100.21]
1505	print-supports-supported (1setOf type2 keyword)	[PWG5100.21]
1506	< any print-supports Job Template attribute value >	[PWG5100.21]
1507	printer-state-reasons (1setOf type2 keyword)	[RFC8011]
1508	camera-failure	[PWG5100.21]
1509	chamber-cooling	[PWG5100.21]
1510	chamber-failure	[PWG5100.21]
1511	chamber-heating	[PWG5100.21]
1512	chamber-temperature-high	[PWG5100.21]
1513	chamber-temperature-low	[PWG5100.21]
1514	extruder-cooling	[PWG5100.21]
1515	extruder-failure	[PWG5100.21]
1516	extruder-heating	[PWG5100.21]
1517	extruder-jam	[PWG5100.21]
1518	extruder-temperature-high	[PWG5100.21]
1519	extruder-temperature-low	[PWG5100.21]
1520	fan-failure	[PWG5100.21]
1521	lamp-at-eol	[PWG5100.21]
1522	lamp-failure	[PWG5100.21]
1523	lamp-near-eol	[PWG5100.21]
1524	laser-at-eol	[PWG5100.21]
1525	laser-failure	[PWG5100.21]
1526	laser-near-eol	[PWG5100.21]
1527	material-empty	[PWG5100.21]
1528	material-low	[PWG5100.21]
1529	material-needed	[PWG5100.21]
1530	motor-failure	[PWG5100.21]
1531	platform-cooling	[PWG5100.21]
1532	platform-failure	[PWG5100.21]
1533	platform-heating	[PWG5100.21]
1534	platform-temperature-high	[PWG5100.21]
1535	platform-temperature-low	[PWG5100.21]

1536 13.3 Service Type Registration

1537 The DNS-SD service type defined in this specification will be published by IANA according
 1538 to the procedures in Internet Assigned Numbers Authority (IANA) Procedures for the
 1539 Management of the Service Name and Transport Protocol Port Number Registry [BCP165].

1540 The registration template is as follows:

1541 Service Name: ipp3d

1542
1543 Transport Protocol(s): tcp
1544
1545 Assignee/Contact: Michael Sweet, msweet@apple.com
1546
1547 Description: 3D Print services (3D printers) using the Internet Printing
1548 Protocol over HTTPS.
1549
1550 Reference: [http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-](http://ftp.pwg.org/pub/pwg/candidates/cs-ipp3d10-20170210-5100.21.pdf)
1551 5100.21.pdf
1552
1553 Port Number:
1554
1555 Service Code:
1556
1557 Known Unauthorized Uses:
1558
1559 Assignment Notes: Change controller is The Printer Working Group, c/o The
1560 IEEE Industry Standards and Technology Organization, 445 Hoes Lane,
1561 Piscataway, NJ 08854, USA

1562 **14. References**

1563 **14.1 Normative References**

- 1564 [3MF] "3D Manufacturing Format Core Specification & Reference Guide
1565 v1.2.1", August 2017, <https://3mf.io/specification/>
- 1566 [3MF-SLICE] "3MF Slice Extension Specification and Reference Guide", August
1567 2016, <https://3mf.io/specification/>
- 1568 [BCP14] S. Bradner, "Key words for use in RFCs to Indicate Requirement
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1715 **15. Author's Address**

1716 Primary author:

1717 Michael Sweet
1718 Apple Inc.
1719 One Apple Park Way
1720 MS 111-HOMC
1721 Cupertino, CA 95014
1722 msweet@apple.com

1723 The authors would also like to thank the following individuals for their contributions to this
1724 standard:

1725 Olliver Schinagl, Ultimaker B.V.
1726 Michael Scrutton, Adobe Systems
1727 Emmet Lalish, Microsoft Corporation
1728

1729 **16. Object Definition Languages (ODLs)**

1730 This section provides information on several commonly used ODLs with either existing
1731 (registered) or suggested MIME media types.

1732 **16.1 3D Manufacturing Format (3MF)**

1733 3MF [3MF] is a freely-available format based on the Open Packaging Conventions that
1734 provides geometry, material, and texture information necessary to support a wide variety of
1735 3D printers. Materials can be named and composed within the geometry, facilitating multiple
1736 material support in coordination with a Job Ticket.

1737 The registered MIME media type for the original Microsoft published specification is
1738 "application/vnd.ms-3mfdocument". The MIME media type for the 3MF Consortium's
1739 published specification is "model/3mf".

1740 **16.2 Additive Manufacturing Format (AMF)**

1741 AMF [ISO52915] is a relatively new format that was designed as a replacement for the
1742 Standard Tessellation Language (STL). Its use has been hampered by the lack of a freely-
1743 available specification, but has several advantages over STL including:

- 1744 1. Shared vertices which eliminates holes and other breaks in the surface
1745 geometry of objects,
- 1746 2. Specification of multiple materials in a single file,
- 1747 3. Curved surfaces can be specified, and
- 1748 4. Coordinates use explicit units for proper output dimensions.

1749 The suggested (but not registered) MIME media type is 'model/amf'.

1750 **16.3 Portable Document Format (PDF)**

1751 PDF [ISO32000] is widely supported for 2D printing and has two 3D formats that are used
1752 to embed 3D objects - PRC [ISO14739-1] and U3D [ECMA363]. The registered MIME media
1753 type for PDF is "application/pdf".

1754 [For discussion: define a "model/pdf" MIME media type for PDFs containing 3D content?]

1755 **16.4 Standard Tessellation Language (STL)**

1756 STL [STLFORMAT] is widely supported by existing client software. The registered MIME
1757 media type is 'application/sla'.

1758

1759 **17. Design Choices**

1760 This section documents some of the design choices that were made during the development
1761 of this specification.

1762 **17.1 Units for Length Values**

1763 The default unit for most length values is hundredths of millimeters (1/2540th of an inch),
1764 matching the units for 2D printing and providing a range of 0.01mm to 21.47km. This was
1765 determined to be sufficient for the class of printers this specification targets.

1766 **17.2 Units for Thickness Values**

1767 The default unit for most thickness values is nanometers, which provides a range of
1768 0.000001mm to 2.147m. This was determined to be sufficient for the class of printers this
1769 specification targets.

1770 **17.3 Use of Celsius for Temperatures**

1771 The various integer attributes for temperature use degrees Celsius. This was done because
1772 most existing printers and materials are specified using degrees Celsius. There is no
1773 advantage to using degrees Fahrenheit or Kelvin, and forcing Clients and Printers to perform
1774 additional unit conversions could cause safety issues. All temperature attributes use a range
1775 of -273 (absolute zero) to MAX (2147483647 - significantly hotter than our sun) to allow
1776 flexibility.

1777 **17.4 Explicit Units for Other Values**

1778 Some attributes have a companion "xxx-units" attribute that specifies an explicit unit for the
1779 given measurement(s). The initial list of unit values for each attribute has been limited to
1780 those necessary for current printers and technologies at the time of writing of this
1781 specification in order to minimize interoperability issues.

1782 **17.5 Intent vs. Process**

1783 The IPP Model [RFC8011], and more generally the PWG Semantic Model [PWG5108.1],
1784 have long focused on Job Tickets specifying "what" is wanted for the printed output vs. "how"
1785 that output is produced. This focus has served IPP well and allowed it to be used with wildly
1786 different printing technologies.

1787 During the development of this specification, attributes that define a specific process or
1788 technological parameter have been introduced and later replaced by intent-based
1789 alternatives that allow an implementation to select suitable process-based parameters at

1790 print time, preserving the intrinsic value of such parameters without burdening the Client or
1791 End User with such things.

1792 At the same time, some process parameters are needed for things like material specification.
1793 For example, a particular brand of PLA may require a higher melting temperature - this
1794 information might only be known to the End User, so the "materials-col" collection contains
1795 an member attribute to convey this process-specific parameter. The Printer advertises
1796 whether temperature is a valid material property in the "materials-col-supported" Printer
1797 Description attribute.

1798 Finally, IPP does not prohibit the definition or use of process-based Job Template attributes
1799 for specific implementations. Such extension attributes can be listed in the "job-creation-
1800 attributes-supported" Printer Description attribute to notify Clients of their existence.

1801 **17.6 Choosing a Required Document Format**

1802 One of the design consideration of this specification is to choose an open, freely available
1803 file format for use as required document format. Having a required document format makes
1804 interoperability significantly easier, and using an open and freely available format allows
1805 developers of "consumer" printers to support IPP 3D. Several formats were considered,
1806 including STL, AMF, PDF, and 3MF.

1807 While STL is a widely-implemented, open, and freely available file format, it lacks support
1808 for multiple materials and colors/textures, and has technical issues that cause "holes" in
1809 generated models.

1810 While AMF supports multiple materials and does not have the "holes" issue, it is not freely
1811 available nor widely-implemented.

1812 PDF is the most capable 3D format but is not freely available and has the interoperability
1813 problem of two separate and incompatible 3D object encodings: U3D and PRC. The "pdf-
1814 features-supported" Printer Description attribute (section 8.3.22) allows Clients to determine
1815 whether a 3D PDF file can be printed by the Printer.

1816 3MF is open and freely available, supports multiple materials and color/textures, does not
1817 have the "holes" issue of STL, and has a freely available open source implementation that
1818 supports both creation and consumption of 3MF files.
1819

1820 **18. Overview of Changes**

1821 **18.1 IPP 3D Printing Extensions v1.1**

1822 The following changes were made since v1.0 of this document:

- 1823 1. Made 3MF CONDITIONALLY REQUIRED for Printers that do Slicing,
1824 RECOMMEND support for a standard layered format otherwise.
- 1825 2. Added the CONDITIONALLY REQUIRED "material-nozzle-diameter" and
1826 "material-retraction" member attributes for the "materials-col" Job Template
1827 attribute.
- 1828 3. Added the RECOMMENDED "platform-shape" Printer Description attribute
- 1829 4. Added the CONDITIONALLY REQUIRED "chamber-humidity" and "chamber-
1830 temperature" Job Template attributes.
- 1831 5. Defined a naming convention for standard "material-type" values.
- 1832

1833 **19. Change History**

1834 **19.1 July 4, 2018**

- 1835 • Status: Prototype
- 1836 • RFC 8011 is now STD 92.
- 1837 • Added missing chamber-humidity-actual and chamber-temperature-actual attributes.
- 1838 • Updated IANA registrations.

1839 **19.2 June 5, 2018**

- 1840 • Renamed "printer-volume-xxx" to "chamber-xxx".
- 1841 • Added "chamber-humidity" to Table 10.
- 1842 • All new attributes that were CONDITIONALLY REQUIRED are now
1843 RECOMMENDED.
- 1844 • Added definition of material-type keyword format for standard materials.
- 1845 • Update Unicode reference now that v11 has been published.

1846 **19.3 April 26, 2018**

1847 Initial revision.