The Printer Working Group

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White Paper

IPP 3D Printing Extensions 0.1 (3D)

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

This document is a White Paper. For a definition of a "White Paper", see: http://ftp.pwg.org/pub/pwg/general/pwg-process30.pdf

This document is available electronically at:

http://ftp.pwg.org/pub/pwg/ipp/ws/wd-sweet-ipp3d-20150123.docx
http://ftp.pwg.org/pub/pwg/ipp/ws/wd-sweet-ipp3d-20150123.pdf

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About the IEEE-ISTO PWG

The Printer Working Group (or PWG) is a Program of the IEEE Industry Standards and Technology Organization (ISTO) with member organizations including printer manufacturers, print server developers, operating system providers, network operating systems providers, network connectivity vendors, and print management application developers. The group is chartered to make printers and the applications and operating systems supporting them work together better. All references to the PWG in this document implicitly mean “The Printer Working Group, a Program of the IEEE ISTO.” In order to meet this objective, the PWG will document the results of their work as open standards that define print related protocols, interfaces, procedures and conventions. Printer manufacturers and vendors of printer related software will benefit from the interoperability provided by voluntary conformance to these standards.

In general, a PWG standard is a specification that is stable, well understood, and is technically competent, has multiple, independent and interoperable implementations with substantial operational experience, and enjoys significant public support.

For additional information regarding the Printer Working Group visit:

http://www.pwg.org

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About the Internet Printing Protocol Workgroup

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

For additional information regarding IPP visit:

http://www.pwg.org/ipp/

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

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1. Introduction

This white paper defines an extension to the Internet Printing Protocol (IPP) that supports printing of physical objects by Additive Manufacturing devices such as three-dimensional (3D) printers. The attributes and values defined in this document have been prototyped using the CUPS software [CUPS].

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

This document also does not address the larger issue of choosing a common Object Definition Language (ODL) for interoperability, however there are suggested MIME media type names listed in section 0 for several formats in common use.

2. Terminology

2.1 Terms Used in This Document

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

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

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

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

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

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

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

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

218 *Subtractitive Manufacturing*: A 3D printing process where material is progressively
219 removed to produce the final output.

220 ## 2.2 Acronyms and Organizations

221 *CNC*: Computer Numerical Control

222 *DLP*: Digital Light Processing

223 *FDM*: Fused Deposition Modeling

224 *IANA*: Internet Assigned Numbers Authority, http://www.iana.org/

225 *IETF*: Internet Engineering Task Force, http://www.ietf.org/

226 *ISO*: International Organization for Standardization, http://www.iso.org/

227 *PWG*: Printer Working Group, http://www.pwg.org/

228 *SD*: SD Card Association, http://www.sdcard.org/

229 *SDL*: Selective Deposition Lamination

230 *SL*: Stereo Lithography

231 *USB*: Universal Serial Bus, http://www.usb.org/
232

3. Rationale for IPP 3D Printing Extensions

Existing specifications define the following:

1. IPP/2.0 Second Edition [PWG5100.12] defines version 2.0, 2.1, and 2.2 of the Internet Printing Protocol which defines a standard operating and data model, interface protocol, and extension mechanism to support traditional Printers;
2. IPP Everywhere [PWG5100.14] defines a profile of existing IPP specifications, standard Job Template attributes, and standard document formats;
3. The Standard Specification for Additive Manufacturing File Format (AMF) Version 1.1 [ISO52915] defines an XML schema and file format for describing 3D objects with one or more materials;
4. The SLC File Specification [STLFORMAT] defines a file format for describing 3D object with a single material;
5. The Interchangeable Variable Block Data Format for Positioning, Contouring, and Contouring/Positioning Numerically Controlled Machines [RS274D] defines the "G-code" format that is commonly used by 3D printers; and
6. The S3G protocol [S3G] defines a simple network protocol and file format for controlling 3D printers.

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

3.1 Use Cases

3.1.1 Print a 3D Object

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

3.2 Exceptions

3.2.1 Clogged Extruder

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

3.2.2 Extruder Temperature Out of Range

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

3.2.3 Filament Feed Jam

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

3.2.4 Material Empty

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

3.2.5 Print Bed Temperature Out of Range

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

3.3 Out of Scope

The following are considered out of scope for this document:

1. Definition of new file formats; and
2. Support for Subtractive Manufacturing technologies such as CNC milling machines.

3.4 Design Requirements

The design requirements for this document are:

1. Define attributes and values to describe supported and loaded (ready) materials used for FDM; and
2. Define attributes and values to describe FDM printer capabilities and state

The design recommendations for this document are:

1. Support 3D printing technologies other than FDM

4. Technical Solutions/Approaches

Current 3D printers offer limited connectivity and status monitoring capabilities. Many printers simply print G-code files from SD memory cards, with all interaction and status monitoring happening at the printer's console.

Makerbot Industries uses a proprietary protocol [S3G] and file format that generalizes some aspects of the interface between a host device and 3D printer, and this interface does offer an improved printing experience from the host device. However, this solution is highly specific to FDM printing and does not offer any spooling or security functionality.

Various other proprietary protocols and interfaces are also in use, typically based on the USB serial protocol class for direct connection to a host device. And there are a number of Cloud-based solutions emerging that utilize a proxy device that communicates with the Cloud and 3D printer.

Given that the 3D printing industry and technologies are still undergoing a great deal of change and development, certain aspects of 3D printing may be difficult or infeasible to standarized. However, a stable, reliable, and secure interface between host device (IPP Client) and 3D printer (IPP Printer) can be defined today in a way that allows for future changes to be incorporated without difficulty.

4.1 High-Level Model

IPP [RFC2911] and the IETF Printer MIB [RFC3805] already define a comprehensive model for the operation and data elements of a typical 2D printer. The IPP Job processing model matches how 3D printers process Jobs and Documents. However, more types of subunits are used in a 3D printer, requiring additions to the model and state values. Table 1 lists the subunits of 3D printers for different technologies.

Table 1 - 3D Printer Subunits

Subunit	Technology
Build Platforms	All
Cameras	All
Cutters	SDL
Doors	All
Fans	FDM
Input Trays	SDL
Lamps	DLP
Lasers	Laser Sintering, SL
Marker Supplies	All
Markers (or Extruders)	Many
Media Path	SDL
Motors	All
Reservoirs	DLP, Laser Sintering, SL

4.1.1 Build Platforms

Build Platforms hold the printed object. The platform moves up or down during printing as layers are applied.

4.1.2 Cameras

Cameras typically show the Build Platforms, offering a visual progress/status reporting for remote users.

4.1.3 Cutters

Cutters are used to trim support material on printed objects and/or remove regions of media that are not part of the final printed object.

4.1.4 Fans

Fans are used to cool printed material and maintain proper extruder temperature.

4.1.5 Lamps

Lamps are used by DLP printers to provide an ultraviolet light source for curing the liquid material while printing a layer.

4.1.6 Lasers

Lasers are used by Laser Sintering and Stereo Lithography (SL) printers to fuse powdered material or cure liquid material while printing a layer.

4.1.7 Markers (or Extruders)

Markers can be traditional subunits where an image is printed on sheets of paper (SDL), extruders that place material onto the Build Platform or previous layer, or projectors that display an inverse image on the surface of a liquid material (DLP).

4.1.8 Motors

Motors are used to move the Build Platforms and (in some cases) move the Markers.

4.1.9 Reservoirs

Reservoirs hold liquid or powdered material used to create the printed object.

4.2 Coordinate System

3D printers operate in three dimensions and thus have three axis of movement. The X axis represents the width of the object, the Y axis represents the depth of the object, and the Z axis represents the height of the object. [Editor's note: probably want a figure for this]

5. New Attributes

5.1 Job Template Attributes

5.1.1 materials-col (1setOf collection)

This Job Template attribute defines the materials to be used for the Job.

5.1.1.1 material-color (type2 keyword)

This member attribute provides a PWG media color value representing the color of the material.

5.1.1.2 material-diameter (integer)

This member attribute provides the diameter of the printed material in nanometers. This attribute is only applicable for Printers that extrude their material.

5.1.1.3 material-feed-rate (integer)

This member attribute provides the material feed rate in nanometers per second. This attribute is only applicable for Printers that extrude their material.

5.1.1.4 material-key (keyword)

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

5.1.1.5 material-name (name(MAX))

This member attribute provides a localized name of the material.

5.1.1.6 material-type (type2 keyword)

This member attribute specifies the type of material. Values include:

'abs_filament': Acrylonitrile Butadiene Styrene (ABS) filament.

'chocolate_powder': Chocolate powder.

'gold_powder': Gold (metal) powder.

'photopolymer-resin_liquid': Photopolymer (liquid) resin.

'pla_filament': Polylactic Acid (PLA) filament.

'pla-flexible_filament': Flexible PLA filament.

'silver_powder': Silver (metal) powder.

5.1.1.7 filament-retraction-distance (integer(0:MAX))

This member attribute specifies the filament retraction distance in nanometers. This attribute is only applicable to FDM Printers.

5.1.1.8 filament-retraction-speed (integer(0:MAX))

This member attribute specifies the filament retraction speed in nanometers per second. This attribute is only applicable to FDM Printers.

5.1.1.9 extruder-temperature (integer | rangeOfInteger)

This member attribute specifies the desired extruder temperature (or range of temperatures) in degress Celsius. This attribute is only applicable to Printers that extrude their material.

5.1.1.10 print-speed (integer(1:MAX))

This member attribute specifies the print speed in nanometers per second.

5.1.2 print-fill-density (integer(0:100))

This Job Template attribute specifies the fill density of interior regions in percent.

5.1.3 print-fill-thickness (integer(0:MAX))

This Job Template attribute specifies the thickness of any fill walls in nanometers, with 0 representing the thinnest possible walls.

5.1.4 print-layer-thickness (integer(0:MAX))

This Job Template attribute specifies the thickness of each layer in nanometers, with 0 representing the thinnest possible layers.

5.1.5 print-rafts (type2 keyword)

This Job Template attribute specifies whether to print rafts under the object. Values include:

'none': Do not print rafts.

'standard': Print rafts using implementation-defined default parameters.

'material-N': Print rafts using the Nth material, where N is an integer from 1 to the number of materials for the Job.

400 **5.1.6 print-shell-thickness (integer(0:MAX))**

401 This Job Template attribute specifies the thickness of exterior walls in nanometers, with 0
402 representing the thinnest possible wall.

403 **5.1.7 print-supports (type2 keyword)**

404 This Job Template attribute specifies whether to print supports under the object. Values
405 include:

406 'none': Do not print supports.

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

408 'material-N': Print supports using the Nth material, where N is an integer from 1 to
409 the number of materials for the Job.

410 **5.1.8 printer-bed-temperature (integer | no-value)**

411 This Job Template attribute specifies the desired Build Platform temperature in degrees
412 Celsius. The 'no-value' value is used to disable temperature control on the Build Platform.

413 **5.1.9 printer-fan-speed (integer(0:100))**

414 This Job Template attribute specifies the desired fan speed in percent of maximum. A
415 value of 0 turns the fans off during printing.

416 ## 5.2 Printer Description Attributes

417 **5.2.1 materials-col-database (1setOf collection)**

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

421 **5.2.2 materials-col-default (1setOf collection)**

422 This Printer Description attribute lists the default materials that will be used if the
423 "materials-col" Job Template attribute is not specified.

424 **5.2.3 materials-col-ready (1setOf collection)**

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

5.2.4 materials-col-supported (1setOf type2 keyword)

This Printer Description attribute lists the "materials-col" member attributes that are supported by the Printer.

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

This Printer Description attribute lists the supported diameters (or ranges of diameters) of extruded material in nanometers.

5.2.6 material-feed-rate-supported (1setOf (integer | rangeOfInteger))

This Printer Description attribute lists the supported feed rates (or ranges of feed rates) in nanometers per second.

5.2.7 material-type-supported (1setOf type2 keyword)

This Printer Description attribute lists the supported material types for the Printer.

5.2.8 print-fill-density-default (integer(0:100))

This Printer Description attribute specifies the default "print-fill-density" value in percent.

5.2.9 print-fill-thickness-default (integer(0:MAX))

This Printer Description attribute specifies the default "print-fill-thickness" value in nanometers.

5.2.10 print-fill-thickness-supported (1setOf (integer(0:MAX) | rangeOfInteger(0:MAX)))

This Printer Description attribute lists the supported "print-fill-thickness" values (or ranges of values) in nanometers.

5.2.11 print-layer-order (type1 keyword)

This Printer Description attribute specifies the order of layers when printing, either 'top-to-bottom' or 'bottom-to-top'.

5.2.12 print-layer-thickness-default (integer(0:MAX))

This Printer Description attribute specifies the default "print-layer-thickness" value in nanometers.

453 **5.2.13 print-layer-thickness-supported (1setOf (integer(0:MAX) |**
454 **rangeOfInteger(0:MAX)))**

455 This Printer Description attribute lists the supported values (or ranges of values) for the
456 "print-layer-thickness" Job Template attribute.

457 **5.2.14 print-rafts-default (type2 keyword)**

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

459 **5.2.15 print-rafts-supported (1setOf type2 keyword)**

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

461 **5.2.16 print-shell-thickness-default (integer(0:MAX))**

462 This Printer Description attribute specifies the default "print-shell-thickness" value in
463 nanometers.

464 **5.2.17 print-shell-thickness-supported (1setOf (integer(0:MAX) |**
465 **rangeOfInteger(0:MAX)))**

466 This Printer Description attribute lists the supported "print-shell-thickness" values (or
467 ranges of values) in nanometers.

468 **5.2.18 print-supports-default (type2 keyword)**

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

470 **5.2.19 print-supports-supported (1setOf type2 keyword)**

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

472 **5.2.20 printer-bed-temperature-default (integer | no-value)**

473 This Printer Description attribute specifies the default "printer-bed-temperature" value in
474 degrees Celsius.

475 **5.2.21 printer-bed-temperature-supported (1setOf (integer | rangeOfInteger))**

476 This Printer Description attribute lists the supported "printer-bed-temperature" values (or
477 ranges of values) in degrees Celsius.

478 **5.2.22 printer-fan-speed-default (integer(0:MAX))**

479 This Printer Description attribute specifies the default "printer-fan-speed" value in percent.

480 **5.2.23 printer-fan-speed-supported (boolean)**

481 This Printer Description attribute specifies whether the "printer-fan-speed" Job Template
482 attribute is supported.

483 **5.2.24 printer-head-temperature-supported (1setOf integer | rangeOfInteger)**

484 This Printer Description attribute specifies the supported "printer-head-temperature" values
485 (or ranges of values) in degrees Celsius.

486 **5.2.25 filament-retraction-distance-supported (1setOf (integer(0:MAX) |**
487 **rangeOfInteger(0:MAX)))**

488 This Printer Description attribute specifies the supported "filament-retraction-distance"
489 values (or ranges of values) in nanometers.

490 **5.2.26 filament-speed-supported (1setof (integer(0:MAX) | rangeOfInteger(0:MAX)))**

491 This Printer Description attribute specifies the supported "filament-speed" values (or
492 ranges of values) in nanometers per second.

493 **5.2.27 print-speed-supported (1setOf integer(1:MAX) | rangeOfInteger(1:MAX))**

494 This Printer Description attribute lists the supported "print-speed" values (or ranges of
495 values) in nanometers per second.

496 **5.2.28 printer-accuracy-supported (collection)**

497 This Printer Description attribute specifies the absolute accuracy of the Printer. The "x-
498 accuracy (integer(1:MAX))", "y-accuracy (integer(1:MAX))", and "z-accuracy
499 (integer(1:MAX))" member attributes specify the accuracy in nanometers along each axis.

500 **5.2.29 printer-volume-supported (collection)**

501 This Printer Description attribute specifies the maximum build volume supported by the
502 Printer. The "x-dimension (integer(1:MAX))", "y-dimension (integer(1:MAX))", and "z-
503 dimension (integer(1:MAX))" member attributes specify the size in millimeters along each
504 axis.

505 ## 5.3 Printer Status Attributes

506 **5.3.1 printer-bed-temperature-current (integer | no-value)**

507 This Printer Status attribute provides the current Build Platform temperature in degrees
508 Celsius. If the Build Platform is not temperature controlled, the 'no-value' value is returned.

5.3.2 printer-fan-speed-current (integer(0:100))

This Printer Status attribute provides the current fan speed in percent.

5.3.3 printer-head-temperature-current (1setOf (integer | no-value))

This Printer Status attribute provides the current extruder head temperatures in degrees Celsius. The 'no-value' value is returned when the extruder head is not temperature controlled.

5.4 Other Potential Attributes

Based on existing 3D printer software, the following parameters could also be candidates for standardization:

1. Initial layer thickness in nanometers
2. Initial layer line width in percent
3. Dual extrusion overlap in nanometers
4. Travel speed in nanometers per second
5. Bottom layer speed in nanometers per second
6. Infill speed in nanometers per second
7. Outer shell speed in nanometers per second
8. Inner shell speed in nanometers per second
9. Minimum layer time in seconds or milliseconds

6. New Values for Existing Attributes

6.1 ipp-features-supported (1setOf type2 keyword)

This document defines the new value 'ipp-3d'. [Editor's note: do we want to include a version number here, e.g., 'ipp-3d-0.1'?]

6.2 printer-state-reasons (1setOf type2 keyword)

This document defines the following new values:

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

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

'cutter-failure': A cutter has failed.

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

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

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

'fan-failure': A fan has failed.

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

'lamp-failure': A lamp has failed.

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

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

'laser-failure': A laser has failed.

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

'material-empty': One or more build materials have been exhausted.

'material-low': One or more build materials may need replenishment soon.

'material-needed': One or more build materials need to be loaded for a processing Job.

'motor-failure': A motor has failed.

'reservoir-empty': One or more reservoirs are empty.

553 'reservoir-low': One or more reservoirs are almost empty.

554 'reservoir-needed': One or more reservoirs are empty but need to be filled for a
555 processing Job.
556

7. Object Definition Languages (ODLs)

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

7.1 Additive Manufacturing Format (AMF)

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

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

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

7.2 Standard Tessellation Language (STL)

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

7.3 G-Code

The G-code [RS274] format has long been a common low-level format used by 3D printers, with higher level formats being processed on the Client to produce G-code. The suggested (but not registered) MIME media type is 'application/g-code'.

7.4 S3G Protocol and X3G File Format

The S3G protocol [S3G] defines a simple network protocol for communicating with a 3D printer as well as a low-level file format, typically using a "x3g" extension, that provides a serialization of extrusion commands similar to G-code. The suggested (but not registered) MIME media type is 'application/vnd.makerbot-x3g'.

8. Internationalization Considerations

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

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

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

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

9. Security Considerations

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

[Editor's note: the rest is TBD but will include explosions, fires, and other physical risks that have been documented in the news and various documents and studies]

10. References

[ISO10646] "Information technology -- Universal Coded Character Set (UCS)", ISO/IEC 10646:2011

[ISO52915] "Standard Specification for Additive Manufacturing File Format (AMF) Version 1.1", ISO/ASTM 52915, 2013

[PWG5100.12] R. Bergman, H. Lewis, I. McDonald, M. Sweet, "IPP/2.0 Second Edition", PWG 5100.12-2011, February 2011, http://www.pwg.org/pub/pwg/candidates/cs-ipp20-2011MMDD-5100.12.pdf

[PWG5100.14] M. Sweet, I. McDonald, A. Mitchell, J. Hutchings, "IPP Everywhere", PWG 5100.14, January 2013, http://ftp.pwg.org/pub/pwg/candidates/cs-ippeve10-20130128.pdf

[RFC2911] T. Hastings, R. Herriot, R. deBry, S. Isaacson, P. Powell, "Internet Printing Protocol/1.1: Model and Semantics", RFC 2911, September 2000, http://www.ietf.org/rfc/rfc2911.txt

[RFC3805] R. Bergman, H. Lewis, I. McDonald, "Printer MIB v2", RFC 3805, June 2004, http://www.ietf.org/rfc/rfc3805.txt

[RFC5198] J. Klensin, M. Padlipsky, "Unicode Format for Network Interchange", RFC 5198, March 2008, http://www.ietf.org/rfc/rfc5198.txt

[RS274D] "Interchangeable Variable Block Data Format for Positioning, Contouring, and Contouring/Positioning Numerically Controlled Machines", EIA Standard RS-274-D, February 1979

[S3G] Makerbot Industries, "S3G protocol (formerly RepRap Generation 3 Protocol Specification", https://github.com/makerbot/s3g/blob/master/doc/s3gProtocol.md

[STD63] F. Yergeau, "UTF-8, a transformation format of ISO 10646", RFC 3629/STD 63, November 2003, http://www.ietf.org/rfc/rfc3629.txt

[STLFORMAT] 3D Systems, Inc., "SLC File Specification", 1994

[UAX15] M. Davis, M. Duerst, "Unicode Normalization Forms", Unicode Standard Annex 15, March 2008, http://www.unicode.org/reports/tr15/

[UNICODE] The Unicode Consortium, “The Unicode Standard, Version 6.2.0”, ISBN 978-1-936213-07-8, September 2012, http://www.unicode.org/versions/Unicode6.2.0/

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TBD

12. Change History

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