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Diploma Thesis

Resource Description for Additive Manufacturing Domain

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Abstract

Machine-to-Machine (M2M) communication and Cloud Computing (CC) are gain in importance. Human interaction is often not sufficient to administrate machines. This also brings up the automation topic. Therefore, a demand for a Resource Description Language (RDL) is raised up. When machines speak the same language, at least in a specific area, facilitate implementing interfaces to unknown source.
In this thesis, a RDL in additive manufacturing area was evaluated. Therefore, information about resources were gathered à la properties of the additive manufacturing process. This has been done by literature research, for example printer manuals. Due to the fact that in additive manufacturing are several different technologies, they were highlighted to state out the general as well as the technology specific properties.
After the evaluation of properties, they were structured in a hierarchical tree depending on the classification in the process and the evaluated categories. The output is an ontology over hardware and service resources including restrictions and dependencies among them. This ontology was created by the ontology editor Protégé. Afterwards an example implementation of the ontology was given. It is integrated in a software of the university.
Therefore, the thesis is arranged in the ontology and RDL field as well as in Additive Manufacturing (AM) and strips the CC and the Cloud Manufacturing (CM), due to the field of application. The resource description can be adopted by AM operators and providers of AM services, such as the 3D printing platforms which are available over the internet.

Kurzfassung

Automatisierung und Cloud Computing gewinnen in Zeiten der Digitalisierung immer mehr an Bedeutung. Gerade im Bereich der Administration von Netzwerken ist Automatisierung gefragt. Netzwerke werden immer größer und daher ist eine manuelle Administration oft nicht mehr effizient. Die Nachfrage an Ressource Beschreibung steigt damit. Da es mit einer allgemeinen Beschreibung der verfügbaren Ressourcen im Netzwerk möglich ist, diese auszulesen und entsprechend zu verarbeiten oder weiter zu leiten.
In dieser Diplomarbeit wird eine Ressourcen Beschreibung im Bereich der additiven Fertigung entwickelt. Dafür werden Informationen über existierende Technologien gesammelt und Eigenschaften, bezüglich des additiven Fertigungsprozesses, daraus abgeleitet. Diese werden mittels eine Literatur Recherche, vor allem von Drucker Spezifikationen und Handbücher, evaluiert. Aufgrund der verschiedenen Technologien ist es dabei wichtig, darauf zu achten, dass die Technologien im Allgemeinen betrachtet werden als auch die spezifischen Ausprägungen.
Im Anschluss daran werden die gesammelten Informationen in eine logische, hierarchische Struktur gebracht und dann mittels einer Ontologie abgebildet. Die Hierarchie orientiert sich an dem Prozess selbst, wie auch an der ermittelten Ressource. Das Ergebnis ist eine Ontologie über die Hardware und Service Ressourcen mit deren Abhängigkeiten und Einschränkungen. Die Ontologie wird mithilfe des Onologie Editors Protégé erstellt.
Anschließend wird eine kurze Implementierung der Ontology aufgezeigt.
Diese Arbeit ist in den Gebieten Ontologie, Ressourcen Beschreibung und additive Fertigung anzuordnen. Cloud Computing und Cloud Manufacturing werden, aufgrund der Anwendbarkeit der Ontologie, ebenfalls angerissen. Die Ressourcen Beschreibung kann von additiven Fertigungsbetreibern und Service Providern übernommen werden.

Contents

List of Figures

List of Tables

List of Listings

Abbreviations

3DP 3D Printing. 33, 40

ABS Acrylonitrile Butadiene Styrene. 33, 36

AM Additive Manufacturing. 3, 14–17, 19–23, 25, 38, 58, 64, 67, 68, 71

AMF Additive Manufacturing File. 21

API Application Programming Interface. 67

ASTM American Society for Testing and Materials. 19, 27

CAD Computer-Aided-Design. 19–21

CC Contour Crafting. 36

CC Cloud Computing. 3, 13, 14, 16, 17

CLIP Continuous Liquid Interface Production. 45, 71

CM Cloud Manufacturing. 3, 13, 17–19, 71

CNC Computerized Numerical Control. 22

CPU Central Processing Unit. 61

DED Directed Energy Deposition. 33

DLP Digital Light Processing. 44, 45

EBM Electron Beam Melting. 41

FDM Fused Deposition Modeling. 23, 36

FFF Fused Filament Fabrication. 36

FTI Film Transfer Imaging. 44, 45

ISO International Organization for Standardization. 16, 19, 20, 27, 32, 34, 35, 38, 39, 42, 43, 47

KLV Key Length Value. 22

LED Light-Emitting Diode. 44

LENS Laser Engineered Net Shaping. 33, 34

LOM Laminated Object Modeling. 41, 42

M2M Machine-to-Machine. 3, 13, 22

MIT The Massachusetts Institute of Technology. 33

MJM Multi Jet Modeling. 37, 38

MSDL Manufacturing Service Description Language. 23

NIST National Institute of Standards and Technology. 17

OEM Original Equipment Manufacturer. 18

OS Operating System. 59, 61

PA Polyamide. 33, 40

PC Polycarbonat. 33, 36, 40

PLA Polyactide. 36

PPSF Polyphenylsulfone. 36

RDF Resource Description Framework. 23, 59

RDL Resource Description Language. 3, 13–16, 22, 37, 47, 57, 59, 64, 71, 87

RFID Radio Frequency IDentification. 44

RM Rapid Manufacturing. 19

RP Rapid Prototyping. 14, 19

SDL Selective Deposition Lamination. 42

SDM Stick Deposition Modeling. 36

SHS Selective Heat Sintering. 40

SL Stereolithography. 44, 45

SLM Selective Laser Melting. 40

SLS Selective Laser Sintering. 38, 40, 41

SLT Scan LED Technology. 44

STL STereoLithography. 21

U3DP Unified 3D Printing. 67

UMRM Unified Manufacturing Resource Model. 22

VDI Verein Deutscher Ingenieure. 19, 22, 25, 26

XML Extensible Markup Language. 22–24, 87

1. Introduction

This chapter introduces the context and motivation of this thesis. It discusses the need of a RDL for Additive Manufacturing Domain. At first an example is given and basic conditions are mentioned. In addition, the problem statement and the outline are given.

1.1. Motivating Example

Nowadays M2M networks are increasing because of the important role of CC in manufacturing, also called CM [SPKR12]. Another significant effect are new technologies, especially in the robotic area. More and more jobs can be performed from machines instead of humans. This makes human interaction more and more inefficient [SPKR12]. In the future, this thesis will help to automate configuration, operation and communication between machines. For example, in future networks the devices, which take part in networks, should easily be added and removed without manual configuration. So, the devices have to communicate with each other to recognize a new/missing one. To integrate the new device and route jobs forward (operate), information over the devices must be available [SPKR12]. Therefore, the resources in the network should be readable by machines to interact with them. This leads to a generic resource description and to resource-aware applications [YCWY16]. The description has to be generic because of the variety of resources in networks, which it has to handle. The application has to be resource-aware to handle the available information and to exhaust full potential.

This thesis focus on a RDL for 3D printers to read available resources of 3D printers and later match them with requirements of 3D print jobs. Therefore, a collection of existing 3D printer attributes has to be listed in a hierarchical structure. After evaluating them, an ontology of the resources will be implemented.

To solve the above-named requirements, the Resource Description Language has to be uniform, flexible and adaptable. The printers and the corresponding application should be able to communicate and to control the jobs, printing order, and the available resources for themselves through Cloud Computing by including the RDL in their algorithm. This will only be possible if there are enough information about e.g. material, properties of print dimension etc. Therefore, the Resource Description Language includes information about hardware and services of the printer. In detail this means information about material, software, process and technology. For utilization and scheduling, the performance attributes should also be included in the RDL.

This thesis should help to manufacture automatically, without human interaction, prototypes, end products etc. A definition and limitation of automation in meaning to this thesis is given in the next section. It will be done by establish an ontology for 3D print resources and a corresponding language to communicate in networks. According to Balogun et al. [Vin15] Rapid Prototyping (RP) and therefore 3D Print will bring a great advantage to the industry, especially for medium sized companies and smaller ones. It will be anchored in the research field of Additive Manufacturing (AM) coupled with Cloud Computing.

Another positive effect is that this kind of manufacturing is economic because of the low input and zero waste [Vin15].

1.2. Problem Statement

Nowadays automation is all around us and it is still an increasing area. At an airport, for example, it is normal to check in at a kiosk system. Some airports even have an automatic passport control system [CMM15]. That is why it is an important research area. However, it is also a difficult area. The lack of knowledge what the future will bring and how to deal with it is a challenge. Because of this it is important to have standards in the development process and a clear definition of automation. The International Society of Automation has developed their own definition of automation [Theny].

> "The creation and application of technology to monitor and control the production and delivery of products and services."

This definition is suitable for this thesis, because it is limited to technology and to the activities monitor and control the production. Only the "delivery of product" part of the definition is beyond this thesis. It means that construction of devices or retrieve the object out of the 3D printer are not in the scope of automation. If automation is mentioned in this thesis it is in the meaning of operating networks and/or device communication, of monitor the print jobs and control the devices. To achieve automation, communications between the devices plays a key role. Monitoring and controlling is based on information. The devices have to provide their function and services, so that other devices can react and process the information. A general defined language makes the communication easier and more information can be processed. Because sometimes information is only process from one system. It is not because there is no need of it, but there is ignorance about the existing or what they represent. Therefore, a RDL is an important tool in automation. In the passport control system mentioned above provides a camera data about person face. Meanwhile a scanner scans the passport with the information about the face. This information has to be verified against each other. To ensure that it is the same person on the passport and the one who walks physically through the control. Simultaneously the personal data, like name and birthday, has to be verified against a wanted list to make sure that the person is not a criminal. All the steps will be processed automatically

by communication between devices. In the AM domain, it is similar. It is important that all resources of the printing process are available, so that it is possible to monitor and control printer in an efficient manner or to find the perfect printer for printing an object.

In the related research areas, described in chapter 2, exist a solid base of information. But in the specific field of RDL there are many open questions. The most RDLs are concentrate to a specific resource description [SPKR12]. The different printers and their different properties have to be unified in one description language. Often the same properties have different names. The large variety is not only due to machine vendor, but also limited in the specific tool depending on technology [VNKN09]. The variety of 3D Printing technologies is another challenge the RDL has to handle. The different technologies consider in this thesis are described in chapter 3. The technologies differ for example in material, quality of manufactured object as well as in the process itself. The different technologies have different properties at different levels, which all have to be considered in the RDL. Because of the multidimensional of the printing process, it is a challenge to cluster them and get them in a hierarchical structure. The range of 3D Printing technologies are still increasing which means that still unknown technologies should also be able to use the RDL. The Resource Description Language should reflect all currently available 3D Printing properties and information. The different materials also have a variety of attributes, which has to be distinguish. The RDL should provide information about the final objects attribute, for example surface, porosity etc., so the user can decide, if it is suitable for his purpose. The ontology for the RDL and the RDL itself should differentiate between a general object class and an instance of the class. Therefore, an evaluation has to be performed to discover all possible instances of a class. Another challenge is to detect the huge number of possible variances besides the general properties. Each user could have their own property settings at a printer. Defects on the printer itself are also possible.

To cover the whole life-cycle in AM, a RDL is probably not powerful enough and it is out of the scope of this thesis. But it should provide as much information as possible. At least all information about the printer and the main information about the material. Beside of that the RDL has to be machine readable and adaptable. That implies that the RDL has to be generic but specific enough to extract information and to guarantee service process. So, that applications can communicate and control 3D printers and their running jobs to reduce human interaction.

1.3. Outline

This document describes fundamentals and concepts of resource description in the AM domain. For a common understanding of terms a table including definitions can be found in the appendix A.

Foremost, the needed fundamentals of this research will be discussed in chapter 2. It covers the research fields and the state of the art of them as well as definition of main concepts. First

an explanation about Cloud Computing is given, where the language can be applied to. In section 2.2 the AM research field is introduced inclusive main terms and the actual situation. The usual process steps of 3D Printing is launched. Afterwards Resource Description Language is introduced with example, which are interesting for the scope of this thesis. Section 2.4 contains information about a file format specification of Adobe [Inc14], this specification is a kind of RDL for printing from Adobe point of view. The last section of this chapter introduces ontology in informatics and gives some current state examples.

After the basics are introduced, chapter 3 provides a deep view into the technology of 3D Printing. First of all, a general overview of the technologies and the advantages of additive manufacturing are given. Afterwards the actual situation in economics and the related branches are introduced. In section 3.3 an overview of the process categories of technologies is given, following the International Organization for Standardization (ISO) standard 2792-12 [F4212a]. Afterwards a more detailed description per process category is given. The subsection of these descriptions introduces a specific technology of respective category, including the advantages, disadvantages and the framework such as material.

In chapter 4 the determination of properties is described. The properties and their dependencies are introduced in section 4.1, including the corresponding data type. Accordingly, to the evaluated properties the implementation in the ontology, including the hierarchical structure is presented in section 4.2. The implementation of the property restriction in the ontology is explained in section 4.2.2.

The implementation of the ontology will be integrated in a framework described in chapter 5. Finally, the work of this document will be wrapped up in a summary and an outlook will be given in chapter 6.

2. Fundamentals and State of the Art

This chapter gives an overview about the related research fields as well as about Additive Manufacturing in general. The sections outline actual situation of the corresponding field and definition of main concepts. Aim of the chapter is to lay down the approach of the thesis and to communicate a good understanding of terms. Thus, the basic knowledge of this thesis is set in the chapter.

2.1. Cloud Manufacturing

In the article by Zhang et al. [ZLT+12] the changing; over the last decades; in the manufacturing area is described. According to this article, the reasons for the significant change are "...rapid development of advanced manufacturing, information, computer and management technologies...", besides of solving globalization issues etc. The motivation for changing manufacturing in the present is that the themes knowledge and services have increasingly come into focus. New manufacturing technologies and the internet enable a new manufacturing process, Cloud Manufacturing (CM) [ZLT+12]. In [RCL+15] CM is described as a transformation "... from traditional production-oriented manufacturing to service-oriented manufacturing." This is also an approach which place special emphasize to the service topic.

Another approach from 1998 [RPL+98], published by Rajagopalan et al., sees Cloud Manufacturing as an internet infrastructure with "...the separation of design and manufacturing..." in geographic as well as organizational way. The emphasize here is isolation of the manufacturing steps which lead to a special service model. The separation in organizational way is in traditional manufacturing present. The geographic separation is only possible due to Cloud Computing (CC). As in [WGRS13] mentioned CC combines many different fields. A combination of those fields gives the base of Cloud Manufacturing. Significant literature is anchored in the late 90s. In [GJ90] the authors see CM as a service to perform demanded job (regardless of size) and the skill to make the factory intelligent. According to the Cloud Computing (CC) definition of NIST [MG11] it is a model, which arise out of the three attributes: ubiquitous, convenient and on-demand network access. Based on this definition of Wu et al. [WGRS13] has evaluated the following definition for CM:

> "Cloud Manufacturing (CM) is a customer-centric manufacturing model that exploits on-demand access to a shared collection of diversified and distributed

> manufacturing resources to form temporary, reconfigurable production lines which enhance efficiency, reduce product life-cycle costs, and allow for optimal resource loading in response to variable-demand customer generated tasking."

This definition unions the geographical separation as well as the customer-centric manufacturing model. It also emphasizes the variety of resources. Therefore, this thesis build up on the CM definition of Wu et al. [WGRS13].

According to them CM consists of the following three groups for interaction:

- Users
  The key characteristic of a user in Cloud Manufacturing is that they have the requirement to manufacture objects without having the capabilities to do that. Users can be everything from individuals up to large Original Equipment Manufacturers (OEMs). There are no borders regarding the size of the group.
- Application providers
  Application providers offer and control the cloud based application layer. This layer manages the interaction between the users and the physical resource providers. The application layer finds the required resources, maps it to the users request and cares about service interruption.
- Physical resource providers
  Physical resource providers own and operate the capabilities to satisfy user requirements. Referring to [WGRS13] a physical resource providers equipment includes but is "... not limited to machining technologies, finishing technologies, inspection technologies, packaging technologies, and testing resources." Besides of the hardware they also have the knowledge to maintain and use the machines efficient.

A traditional manufacturing is product-oriented in contrast to Cloud Manufacturing which is service-oriented as well as customer-oriented. The main goal of CM as a service-oriented process is the reduce of costs and to supply the resources a wider mass. Because of the pool of physical resource providers, the users can manufacture their objects by a professional with corresponding equipment. On the other way, physical resource providers have a higher utilization of their machines. They can serve production requests of many customers. And they also can take small orders, which would not be economic in a traditional production [WGRS13]. Another advantage over traditional manufacturing is the dynamic and flexible resource provisioning, which facilitates the higher utilization. It is possible to create a small amount of objects as well as a huge amount. In case of reconfigurable the product, flexibility and automation is important to map the requirements to the capabilities with minimal effort. Some commercial companies which have implemented a Cloud Manufacturing offers their services over the internet.

MFG.com [MFGny] provides its users access to 200.000 manufactures. According to themselves they are the lead market place in manufacturing industry. MFG.com supports the "Request for

Quotes" and covers the audit of the manufactures right up to choosing a manufacturer and order status. The request for quotes, including technical specification and CAD files, will be compared to manufacturer all over the world.

According to Wu et al. [WGRS13], the opportunities at Cloud Manufacturing (CM) are among others the ability to perform every job. No matter how small it is. CM is also demand-intelligent, which means it is highly adaptable to new environment and performance problems.

2.2. Additive Manufacturing or 3D Print

In the book by Gibson et al. [GRS15] and also in the status report of the association German engineers "Verein Deutscher Ingenieure (VDI)" from 2014 [Ver14a], Rapid Prototyping (RP) and 3D Print are the famous terms in public for Additive Manufacturing. According to the article by Wong et al. [WH12] the beginning of Additive Manufacturing was in the early 80's and it was called RP. In general RP represents a manufacturing process which is fast (rapidly) and produce a component but not the final product. The term is used under management consultants as well as under software engineers [GRS15]. Nowadays and in the context of product development, RP technology has a Computer-Aided-Design (CAD) input and a three-dimensional object output. All the following technologies in this area are basically RP technologies even 3D Printing. In the middle of 2000th the use of RP in industry has increased extremely. This brought up a need for Rapid Manufacturing (RM) [WGRS13]. Therefore, the American Society for Testing and Materials (ASTM) suggests a new terminology to make the difference clear to the former use. This brings the term Additive Manufacturing, instead of RM, in focus [GRS15].

In contrast to RP, AM can produce prototypes as well as final products. It arises out of CAD file [GRS15]. As the name implies, "additive" manufacturing is a process to produce a product in successive layer. In detail this means the material will be add as a layer, step by step, to the previous layer. Mostly used materials in praxis are plastic and metal, but it is also possible to process ceramic [Ver14a].

To stand out the difference between the terminologies, in the research area AM, this thesis is based on the ISO/ASTM 52900 standard [ISO15]. In table 2.1 is an overview about main terminologies.

The research field Additive Manufacturing is getting more and more important for economy but it also finds its way in private households. That is because the 3D Printers getting cheaper and easier to handle than at the beginning [Fas14]. There is also an increasing amount of applications in AM. There was also a big step in material, accuracy as well as in quality of produced product [GRS15]. Additive Manufacturing improves not only production itself, it also improves product development by reducing time and cost. And as mentioned before, it is possible to produce final objects [GRS15].

Term	Definition
3D Printing	fabrication of objects through the deposition of a material using a print head, nozzle, or another printer technology
Additive Manufacturing (AM)	process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies
Prototype Tooling	moulds, dies, and other devices used for prototyping purposes; sometimes referred to as bridge tooling or soft tooling
Prototype	physical representation of all or a component of a product that, although limited in some way, can be used for analysis, design and evaluation
Rapid Prototyping	<in additive manufacturing> application of additive manufacturing intended for reducing the time needed for producing prototypes
Rapid Tooling	<in additive manufacturing> application of additive manufacturing intended for the production of tools or tooling components with reduced lead times as compared to conventional tooling manufacturing

Table 2.1.: Terminology Definition – Source: following ISO 52900 [ISO15]

Technologies which are used for 3D print can be clustered in different technology categories based on the process. Each relevant technology is described in chapter 3. Due to laser technology, it is even possible to create objects, with AM, out of metal.

The main challenge in the research area is still the scalability. In the scope of 3D Printing the researcher work with full speed on new technologies or improving the existent to achieve a better scalability. As mentioned in [WGRS13] Cloud Manufacturing has the capability to solve this issue. Also or just because of 3D Printing technologies.

According to Gibson et al. [GRS15] there are statements that AM can change the way of manufacturing objects completely. This statement based on the fact that computers are everywhere, today.

The general process of AM consists usually of eight steps. But it depends on the point of time, AM takes part of. It also depends on the scope of production. For example, if the product is a prototype or the final object. If it is a prototype the time scope is in the early phase of product development and maybe the post-process can be neglected. By Gibson et al. [GRS15] the generic steps are the following ones:

- CAD
  At the beginning of AM the product has to be designed by CAD software. On the market

there are several software programs for CAD available. It is important that the output is a 3D surface representation. Besides there are also other methods like reverse engineering techniques such as object laser scanning [Louny].

- Conversion to STereoLithography (STL)\Additive Manufacturing File (AMF) format
  Hence the data is AM machine readable they had to be converted to STL or AMF format. STL is meanwhile standard in economy. Thus, the most CAD programs can produce this file format. Additionally to Gibson et al. [GRS15] the Loughborough University [Louny] mentioned also that the conversion will tessellate the object shapes so that it can be sliced into layers.
- Transfer to AM Machine and STL File\AMF Manipulation So that the AM machine can process the file, it has to be transferred to the machine. Then the positioning should be checked. It will be print more than one object at once. So sometimes reposition or changing of orientation is required.
- Machine Setup
  Before starting the build process, the machine has to be setup, depending on building objects as well as the machine itself. At some machines, it is possible to configure settings such as print speed, or resolution. Physical preparation has also been done in this phase. For example, ensuring material stock for the print, insert and level build plate.
- Build
  The build step nearly does not need human interaction. Only monitoring activities are necessary for example to control material supply.
- Removal
  If the build process is complete the object has to be removed out of the machine. Depending on the machine there are a variety of interaction and time exposure. At some machines, it can be easily removed in others it has to be released of constructions. The time exposure depends on the temperature of the object.
- Post-processing
  After removing the objects, it could be necessary to clean it up. Some objects have to be relieved from support structure or the surface has to be polished. Therefore, this process includes sanding, surface preparation, painting, etc.
- Application
  This step depends on the scope of application the object is designated for. For example, the objects must receive electronic components before it can be used. And This step can also be left out.

In other process description are often five steps instead of eight. Most of them are summaries "Transfer to AM Machine and STL File Manipulation" and "Machine Setup" to one step. And

they left out the step "Application" [Louny, Cusny]. The VDI guideline 3405 [Ver14b] even clusters the process into three steps pre-process, in-process and post-process.

2.3. Resource Description Language

A Resource Description Language (RDL) is for extracting information about the devices and forward them. Some parts of a RDL are optional and some are required. So not all parts of an RDL are implemented. A RDL is a specification of objects which are not exist as content. Through a RDL it is possible to cross layering data from hardware and it is possible to communicate in an M2M network automatically [SPKR12].

In the article by Santos et al. [SPKR12] a Resource Description Language for embedded resources is introduced. The RDL is able to handle a variety of resources, entire networks, or individual nodes. Due to the fact that the RDL represents a uniform way, the specification is reusable and extensible. The authors decided to support Extensible Markup Language (XML) and Key Length Value (KLV) protocol for their RDL and implemented a Java applet tool. They distinguish between requirement and capability. As the term implies requirements are necessary resources the object should own. Requirement resources also include alternatives to a specific resource. On the other side, capabilities are optional characteristics of the object. The resources are scalar or service resource. Scalar resources are a description of objects and the corresponding characteristics (qualitatively and quantitatively). Services describe a bundle of scalar resources that export functionality. It is also possible to describe constraints of scalar or service resources for further alignment. The RDL also includes scope definitions. They are describing where the resource is and how it can be used.

Challenges of RDL are, among others, changes in the environment, heterogeneity of devices, manageability without human interaction. As a fact of these a RDL has to be reusable and reconfigurable, which is only given by a standard and interchangeable description of the resource. Santos [SPKR12] also mentioned that the functionality of the algorithm has to be separated from the resources definition to use the RDL in management algorithm. The most RDLs focus on specific resources and therefore are not or less adaptable.

Vichare describes in the article "A Unified Manufacturing Resource Model for representing CNC machining systems" [VNKN09] also a RDL in AM domain. This RDL is focused on Computerized Numerical Control (CNC) machines. The authors stand out that there is no generic methodology for describing resources in AM. So, they develop a Unified Manufacturing Resource Model (UMRM) for CNC machines. They divide the needed data into three categories product, process, or resource data.

2.4. Adobe Work

Adobe describes in its File Format Specification [Inc14] 3D Printing resources. The definition has 3 main categories:

Printer (Hardware)

Material

Plate Leveling

In these categories, Adobe identifies required or optional keywords and clusters them in sub categories. If these keywords are relevant attributes for this thesis will later be evaluated. The file format of the description is XML, probably due to the corresponding software products. A disadvantage of the work by Adobe [**?**] is the limitation to Fused Deposition Modeling (FDM) technology. This is a special 3D Printing process, which is described in chapter 3. Nevertheless, it will be essential for this thesis.

2.5. Ontology

According to the dictionary of the German association for computer science [Ges] the most noted definition for ontology is from Gruber. It says that ontology is shared conceptualization through an explicit formal specification. An ontology is based on the idea of semantic networks as a graph. The association supplement that an ontology describes a knowledge domain and the contain relations as well as rules for derivation of terms. Beside of ontologies which are build up on scope of application, there are other forms of ontologies which are not relevant for this thesis. For the development of an ontology the instruments XML and Resource Description Framework (RDF) have to be named. In this case RDF is for describing resources through settings and associate them with values and/or references. XML is the instrument to describe the data structure. The advantages of an ontology are the power of the description and that it is still human readable, especially if there is a RDF or XML Schema available.

In the article by Ameri [Farny] the process of evaluating a Manufacturing Service Description Language (MSDL) is described. MSDL is a domain ontology. It is suggested for describing manufacturing services in a formal way. The process has four main steps (identify key terms and concepts, identify classes and properties, formally define classes through logical constraints, apply rules). They also introduce six dimensions of manufacturing capabilities. Technological capabilities, Operational capabilities, Geometric capabilities, Quality capabilities, Relational capabilities and Stochastic capabilities which will probably adduced to cluster the identify capabilities and requirements of this thesis.

Another approach is given in the article by Yao et al. [YCWY16]. In this article an ontology in AM scope is developed, as part of the collaborative peer-robot control system. This ontology

dived the resources into software, hardware, manual process, or monitoring resources. Subdivision thereof are status information and capability information. The considered resources are in the pre-process, in-process and post-process. The authors describe the ontology in XML and provide an example of it. This approach will also have an impact of the ontology in this thesis.

3. 3D Printing Technologies

This chapter provides a general approach of Additive Manufacturing/3D Printing technologies. The scope of application will be introduced and a listing of the current process categories. Furthermore, an example of the available technologies per process category is given. Each subsection describes one of these technologies including material, advantages and disadvantages of the corresponding technology. After reading this chapter, the reader has a good understanding of the available 3D printing process categories as well as the different technologies and their functionality.

3.1. General Overview

3D Printing offers a variety of technologies. Those can be clustered in different processes. The VDI report [Ver14a] mentioned the extrusion and the powder based procedure. The extrusion procedure consists of a plastic filament. This filament will be fused through a nozzle and then deposit on a geometric defined place. This procedure is common at private user as well as in professional assignment [Ver14a]. For the powder based process pulverized material will be brushed as a thin layer on the working plate. After that a laser will fuse the material point for point. A huge advantage of the laser procedure is that it not only works with plastic. It is also possible to create objects out of metal. VDI calls the procedure with metal "laser steel melt" and procedure with plastic "laser sinter".

Which material and which technology is suitable depends on many factors like time, possibility etc. but also at the boundary conditions like support structure, post process, thermal characteristics etc. The post process takes place after the build process is finished. This means that the product has to be removed and cleaned. And if the used technology made it necessary the product has to be heat-threated and mechanical post-edit [Cusny].

3.2. Typical Field of Applications and Branch

According to the status report 2014 of VDI [Ver14a] the field of applications below are suitable for 3D Printing at the moment. Of course, the original mode of use "Prototyping" is a typical field of application. Through 3D Printing it is possible to test an object without high acquisition

costs. Based on low adjustment and no need for special machines, it is also possible to produce a customized or small amount of end products. Another field of application is producing the objects right in the place of use. Especially this is interesting for production on other planets in the cosmos. Actual this is a vision for the future but the NASA has also researches in this scope [BCE+ny]. Nevertheless, this is also interesting for long expedition, especially in food and tool print area. So, it is possible to take place-saving materials with instead of meals. And you do not have to take all repair tools with, which you eventually need. Broadly speaking it is possible to reduce space an amount of material if the production takes place locally. So, local production and the short distances are also an advantage for the earth, including the environment. Producing spare parts for obsolete series production is also a possibility of 3D Printing. Another advantage of 3D Printing is minimizing the time between draft of an object and the availability of product. This means that another field of application is, when iteration-cycles has to be improved like at polymer processing. And the last field of application named in the VDI report [Ver14a] is lightweight construction because of the accessible qualities.

The following branches arise from the before called field of applications. They are also named in the VDI report [Ver14a] and in the article by Wu et al. [WGRS13].

- Aerospace and arm industry
- Automotive industry
- Automatic control engineering, machine and investment construction
- Lightweight machines
- Architectural modeling
- Medical applications
- Improving the Manufacturing of Fuel Cells
- Art
- Electronic
- Furniture industry
- Foods industry
- Sport equipment industry
- Clothing industry
- Toy industry

3.3. Process category of technologies

Currently there are different terms for the technology categories. According to Standard Terminology for Additive Manufacturing Technologies [F4212b] there are seven categories for additive manufacturing process. These categories are also contained in ISO/ASTM 52900 [ISO15]. The terms are underline the process overlapping. The technologies are clustered according to their approach. This means that the seven categories are represent the underlying process. The categories distinguish between extrusion, jetting, lamination, etc. procedure. But it exists also the clustering into physical condition of the used material like powder, liquid, or solid [Louny, Fas14]. Even for this clustering are a variety of terminologies exists and it is possible to put a finer point to the clustering. For example, if after categorized them by material a clustering about the used process is done additionally [BHS13]. Another approach is to define them in terms of the used hardware technology, for example laser, beam, or UV light. Nevertheless, this thesis is based on the standardize terminologies, which were evaluated for a uniform understanding and using for educational and standards-development purposes. At this clustering, there are most similarities within the categories. The table 3.1 shows the categories including the definition. An overview of the technologies is given in table 3.2.

Technology	**Definition**
Binder Jetting	an additive manufacturing process in which a liquid bonding agent is selectively deposited to join powder materials.
Directed Energy Deposition	an additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being deposited.
Material Extrusion	additive manufacturing process in which material is selectively dispensed through a nozzle or orifice.
Material Jetting	an additive manufacturing process in which droplets of build material are selectively deposited.
Powder Bed Fusion	an additive manufacturing process in which thermal energy selectively fuses regions of a powder bed.
Sheet Lamination	an additive manufacturing process in which sheets of material are bonded to form an object.
Vat Photopolymerization	an additive manufacturing process in which a pre-deposited photopolymer in a vat is selectively cured by light-activated cross linking of adjoining polymer.

Table 3.1.: Process Categories – Source: following ISO 52900 [ISO15]

Technology	Materials	Advantages	Disadvantages	Publisher
3D Print with powder (3DP)	-variety of polymers (PA, ABS, PC, etc.) - stainless steel - bronze - ceramic	- production of components with bad release property - multicolored objects - fast building process	- no support structure but post -processing (Compressed air) - not infiltrated parts could be brittle - detail resolution: low	MIT
Continuous Liquid Interface Production (CLIP)	photopolymer	- speed (25-100 times faster) - smooth surface - consistent tensile strength		EiPi Systems, Inc 3DCarbon
Contour Crafting (CC)	concrete, loam	- large prints (e.g. complete house) - low noise		University of Southern California
Digital Light Processing (DLP)	photopolymer	-fine and good quality surface - razor edge possible	- need of support structure (mechanical remove) - low heat load	Texas Instruments
Electron Beam Melting (EBM)	metal (titanium, cobalt chromium)	- high flexibility and good control (speed and temperature) - high level of efficiency - for some materials better absorption	- abrasive surface	Arcam
Film Transfer Imaging (FTI)	photopolymer	-fine and high surface quality	- need of support structure - material intensive	3D Systems

Fused Deposition Modeling (FDM)	- thermoplastics (PC, ABS, PLA etc.) - researches in: plasticine Play-Doh or the high tech silicon material Sugru (ABS), Polyactide (PLA), Polyphenylsulfone (PPSF) and wax	- no chemical process - production of components with bad release property - cost-effective	- support structure - PLA: less temperature resistance - less surface quality	Stratasy
Laminated Object Modeling (LOM)	- paper - plastic - ceramic - aluminum	- high detail resolution - low cost effectiveness	- need of support structure - high material loss - no hollow structure - infiltrate for strength	Helisys of Torrance, CA
Laser Engineered Net Shaping (LENS)	- metals (titanium, steel etc.) - combination is possible	- full density - efficient regarding traditional AM processes for metal - possibility to repair existing metal objects		Sandia National Laboratories
Multi-Jet Modeling (MJM)	- waxy thermoplastic - UV sensitive photopolymer	- high surface quality - high print resolution - high detail solution	- support structure - long print process	Stratasy (formerly Objet)
PolyJet	photopolymer	- fine surface - thin walls are possible - different materials are possible	- support structure - weaker objects than SLT or SLS	Stratasy (formerly Objet)
Scan LED Technology (SLT) (advancement of STL)	- photopolymer - bio compatible and non bio compatible plastics	- no RFID		

Selective Deposition Lamination (SDL)	paper	- detail resolution: high - cost effectiveness: low	- no infiltration - hollow structure are limited to "easy" one	Mcor Technologies
Selective Heat Sintering (SHS)	- thermoplastic powder	- production: movable components possible - recycling of material overhang - more cost effective than SLS	- low detail resolution	BluePrinter
Selective Laser Melting (SLM)	- metal (aluminum, stainless, stool or titanium), - plastic - ceramic	- production: 100% densly components - no need of support structure	- low detail resolution - crystal boundaries at the layer boundaries -> influence of final strength - abrasive surface	Frauenhofer ILT
Selective Laser Sintering (SLS)	- thermoplastics (PC, PA, etc.) - metal - ceramic - sand - combination is possible	- production: end products (air plane components) - no need of support structure - high mechanical resilience - amount of materials	- no support structure but post-processing (Compressed air) - low detail resolution - when cool down clamping and deviation are possible (Correction before printing by software) - abrasive surface and little porosity	University of Texas/DTM Corporation patent lies at 3D Systems(01)
Stereolithography (SL, STL or SLA)	- liquid duromer (epoxy resin, acrylate) - elastomer	- fine and smooth surface - high detail resolution	- low heat and mechanical load - UV light-sensitive - high material costs - long print process	3D Systems

Stick Deposition Modeling (SDM)	- ABS, PLA - flexible and woody plastics	- good control over melted amount and layer thickness		Sintermask

Table 3.2.: Technology Overview

3.4. Binder Jetting Technologies

Binder Jetting technologies has a bed full of powder. A binder is deposit on the powder so that there occurs a chemical reaction. It is similar to Powder Bed Fusion where a thermal source is used to cure the powder. The binder can be mixed with colored pigments to printing colored objects. Depending on the count of nozzle, printing of multicolored objects is possible. For example, if the printer has three nozzles it is possible to print objects with three colors, by using each nozzle for a new color. After one layer is finished the powder bed is layered down and new powder will be distributed above the underlying bonded layer [GRS15]. An example schematic of the Binder Jetting technology is shown in 3.1 [Louny]. Table 3.3 gives an overview about the framework of Binder Jetting technologies [DIN16a].

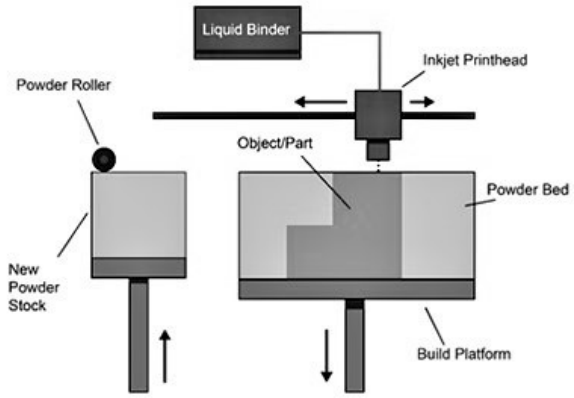


Figure 3.1.: Example schematic of Binder Jetting technology – Source: Loughborough University [Louny]

Binder Jetting Framework	
Definition	an additive manufacturing process in which a liquid bonding agent is selectively deposited to join powder materials.
Feedstock	powders, powder blends or particulate materials, and a liquid adhesive/bonding agent.
Binding mechanism	chemical and/or thermal reaction bonding.
Source of activation	depending on the bonding agent: chemical reaction.
Secondary processing	removal of loose powder, impregnation or infiltration of suitable liquid material depending on the powder material and intended application.

Table 3.3.: Binder Jetting Framework – Source: following ISO 17296-2 [DIN16a]

3.4.1. 3D Printing (3DP)

The Massachusetts Institute of Technology (MIT) has developed the technology 3D Printing (3DP) [Cusny]. The process has a powder chamber and a build chamber. A roller spreads the powder from the powder chamber to the build chamber and lays therefore a thin powder layer in it. Then a liquid water-based binder runs through the jet, on top of the powder, and glue them together. The name is derived from inkjet printing because of the resemblance [WH12]. It is possible to mix the binder with colored ink, so the printer is able to print objects with different colors without to interrupt the process [Fas14]. The material possibilities includes a variety of polymers [WH12], such as Polyamide (PA), Acrylonitrile Butadiene Styrene (ABS), or Polycarbonat (PC) [Louny]. Stainless steel, bronze, or ceramics could also be processed with this technology [Cusny]. But not every material is economical. For example, metal powder is too expensive by 3DP. There are other technologies which are more economical, which will be shown later. Polymer, lime, or plaster powder are more suitable for 3DP [Cusny].

The advantage of this technology is that it is possible to print objects with a bad release property, because the remaining powder can be removed even through pinholes. The opportunity to print multi colored objects are also a benefit [Fas14]. Furthermore, it is a fast building process (2-4 layers per minute) [Cusny]. The disadvantage is that despite the fact that there is no support structure, post-processing is necessary. The adhering particles of powder have to be removed by compressed air. It is also feasible that not infiltrated parts are brittle and the detail resolution is low [Fas14].

3.5. Directed Energy Deposition Technologies

Directed Energy Deposition technologies are extremely suitable for metals. But it also works with polymer and ceramic. The material will be melted when it is deposit. This is done by a heat source, for example laser, or electron beam. It is similar to Material Extrusion technologies [GRS15]. An example schematic of the Directed Energy Deposition technology is shown in 3.2 [Louny]. Table 3.4 gives an overview about the framework of Directed Energy Deposition technologies [DIN16a].

3.5.1. Laser Engineered Net Shaping (LENS)

Laser Engineered Net Shaping (LENS) was developed by Sandia National Laboratories. This technology is made to handle metal. Laser Engineered Net Shaping (LENS) appertain to the Directed Energy Deposition (DED) procedures. The metal powder is liquefied and deposit on the build plate by a focused laser beam. Meanwhile the build platform moves in x and y direction so that the liquid powder is put down on the predefined point of the object. After one layer is finished the laser moves one layer thickness up and start the next layer. The

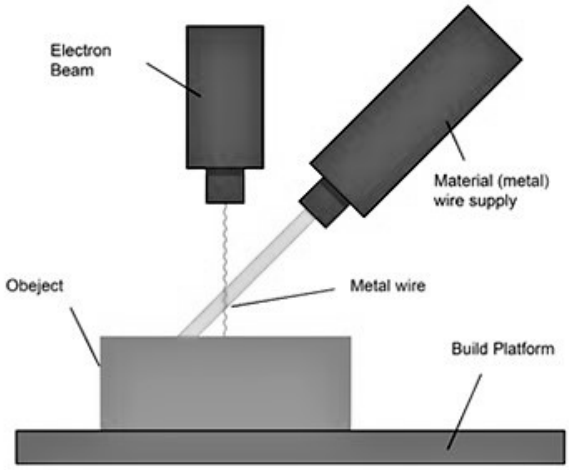


Figure 3.2.: Example schematic of Directed Energy Deposition technology – Source: Loughborough University [Louny]

Directed Energy Deposition Framework	
Definition	additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being deposited.
Feedstock	powder or wire, typically metal, for certain applications ceramic particles can be added to the base material.
Binding mechanism	thermal reaction bonding: melting and solidification.
Source of activation	laser, electron beam, or plasma transferred arc.
Secondary processing	improving the surface finish, for example: machining, micro blasting, laser remelting, grinding, or polishing and improving material properties (e.g. heat treatments).

Table 3.4.: Directed Energy Deposition Framework – Source: following ISO 17296-2 [DIN16a]

materials for this technology are metals like titanium, steel etc. but a combination is also possible [San02].

The advantage of LENS is the full density of the metal object. It is also more cost and time effective compared to traditional manufacturing processes in the metal area. Another advantage is the possibility to repair existing metal objects [San02].

3.6. Material Extrusion Technologies

At Material Extrusion technologies, the material is extruded with pressure through a nozzle or orifice. It is molten in a reservoir before it will be extruded. The material has to be in a semisolid state during extrusion. It will be bond to already extruded material and fully solidify. The state of the material is mostly being controlled with temperature. But it is also possible to control it by chemical reaction, for example drying out [GRS15]. An example schematic of the Material Extrusion technology is shown in 3.3 [Louny]. Table 3.5 gives an overview about the framework of Material Extrusion technologies [DIN16a].

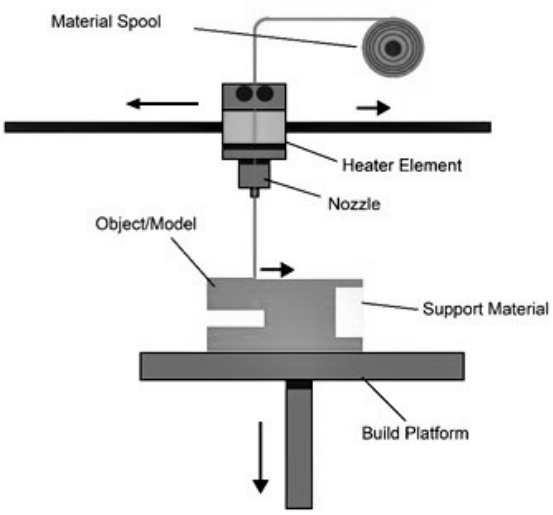


Figure 3.3.: Example schematic of Material Extrusion technology – Source: Loughborough University [Louny]

Material Extrusion Framework	
Definition	additive manufacturing process in which material is selectively dispensed through a nozzle or orifice.
Feedstock	filament or paste, typically thermoplastics and structural ceramics.
Binding mechanism	thermal or chemical reaction bonding.
Source of activation	heat, ultrasound, or a chemical reaction between components.
Secondary processing	removal of support structure.

Table 3.5.: Material Extrusion Framework – Source: following ISO 17296-2 [DIN16a]

3.6.1. Fused Deposition Modeling (FDM)

The probably best known technology is Fused Deposition Modeling (FDM). This technology was developed by the company Stratasys. The term Fused Deposition Modeling (FDM) is protected, however it is a common term in this area. An alternative term is Fused Filament Fabrication (FFF) [Fas14]. At this process a filament of fusible plastic will be extruded layer by layer at the predefined geometrical position, with a nozzle. The material is heated just over the melting point. Typically, a layer has a thickness of 0.25 mm [WH12] but it depends on the printer. The building material are thermoplastics like Polycarbonat (PC), Acrylonitrile Butadiene Styrene (ABS), Polyactide (PLA), Polyphenylsulfone (PPSF) and wax. There are also experiments with other materials like the plasticine Play-Doh or the high-tech silicon material Sugru [Fas14], [WH12]. 3D printers in private households are mostly fitted with this technology [Fas14].

The main advantage of Fused Deposition Modeling is that there is no chemical post process needed [WH12], although support structure exists. Another aspect is that this technology is suitable for components, which have bad release property and cost-effective [Fas14]. The disadvantage, besides the need of support structure, is the less surface quality because of the low resolution on the z axis [WH12]. If the PLA material is used the building object is not really temperature resistant [Fas14].

3.6.2. Stick Deposition Modeling (SDM)

Stick Deposition Modeling (SDM) technology is used by the company Sintermask. They manufacture printer for private use. In principle, it is the same technology like FDM. The difference is how the extruder will be filled. SDM will be fed through two sideway profiled sticks. This happens automatically by a feed magazine [Fas14]. Materials are as well as at FDM ABS, PLA and flexible and woody plastics.

The advantages towards FDM are the good control over the melted amount of material and the layer thickness due to the fact that the sticks are plastic injection molding [Fas14].

3.6.3. Contour Crafting (CC)

Contour Crafting (CC) is not a typical 3D Print technology. It was developed by the University of Southern California [Uni]. This technology enables to print whole houses. The printer is a portable robot which of course is bigger than the house itself. The building material is similar to concrete or loam and will be applied layer by layer with the help of an aluminum framework or a movable robot. CC makes it possible to build a house in 24 hours [Fas14].

This technology cannot be compared to other 3D Print technologies. It can only be compared to traditional house building methods. It will not be considered when evaluating the resources for the RDL and is only mentioned for completeness that such a technology exists. However, the advantages are the speed and that the process is very quiet [Fas14].

3.7. Material Jetting Technologies

At Material Jetting technologies, the material itself flows as droplets through a print head. Materials are photopolymer or wax. But there are also researches for metal and ceramics. To provide good resolutions the deposit droplets has to be very small. Material Jetting machines have at least two jets. One for the building material and one for the support structure. A jet is a type of nozzle. After the photopolymer droplets are deposit a UV light cured them out. Material Jetting technologies are cost-effective, fast and it is possible to print different colors [GRS15]. An example schematic of the Material Jetting technology is shown in 3.4 [Louny]. Table 3.6 gives an overview about the framework of Material Jetting technologies [DIN16a].

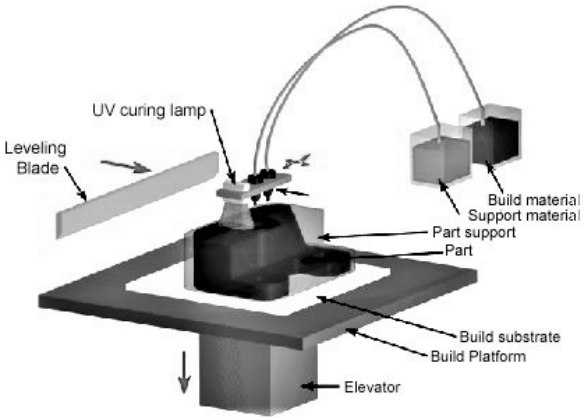


Figure 3.4.: Example schematic of Material Jetting technology – Source: Loughborough University [Louny]

3.7.1. Multi-Jet Modeling (MJM)

The Multi Jet Modeling (MJM) technology is similar to the inkjet printer technology. Indeed, at MJM the print head can move in x and y direction and the building platform can move in z direction. The liquid building material will be cure through UV light layer by layer. Possible materials are waxy thermoplastics and UV light sensitive photopolymer [Fas14].

Material Jetting Framework	
Definition	additive manufacturing process in which droplets of build material are selectively deposited.
Feedstock	liquid photopolymer or melted wax, with or without filler.
Binding mechanism	chemical reaction bonding or adhesion by solidification of melted material.
Source of activation	radiation light source for chemical reaction bonding.
Secondary processing	support material removal, post-curing by further radiation light exposure.

Table 3.6.: Material Jetting Framework – Source: following ISO 17296-2 [DIN16a]

The advantages are high surface quality as well as high print resolution. This results in a high detail solution. A negative aspect is that the print process takes a long time. And support structure is required for this technology [Fas14].

3.7.2. PolyJet

The company Objet, since 2012 they appertain to Stratasys, has patent PolyJet. This technology is similar to MJM and therefore an inkjet printer technology. The printers have two or more print heads. One is for the building material the other one is for the support material [Fas14]. The print head can move in x and y directions. Thereby they distribute a photopolymer substance on the building platform. Immediately after that a UV light cures the material. The support structure is jelly-like and can be washed up by water [WH12]. With this technology, it is possible to print more than one material at the same time. So, it is feasible to print multi colored or with different hardness objects. These has to be defined in the geometrical file before printing [Fas14].

The main advantage is the possibility of printing different materials but also the fine surface and the opportunity to build thin walls are of advantage. On the opposite, the mechanical post process to remove the support structure and the building objects are weaker compared to SLT or SLS are of disadvantage [WH12].

3.8. Powder Bed Fusion Technologies

Powder Bed Fusion technology includes Selective Laser Sintering (SLS) which was developed in 89. Therefore, Powder Bed Fusion technology was being present from the beginning of commercialized AM. All different kinds of this technology have on ore more thermal sources.

Mostly this source is a laser. Thus, the term "laser sintering" in the process names. Besides of lasers there are also technologies with thermal energy source or an electron beam [DIN16a]. The powder is being fused by the thermal source. After that the powder will be smoothed [GRS15]. An example schematic of the Powder bed Fusion technology is shown in 3.5 [Louny]. Table 3.7 gives an overview about the framework of Powder Bed Fusion technology [DIN16a].

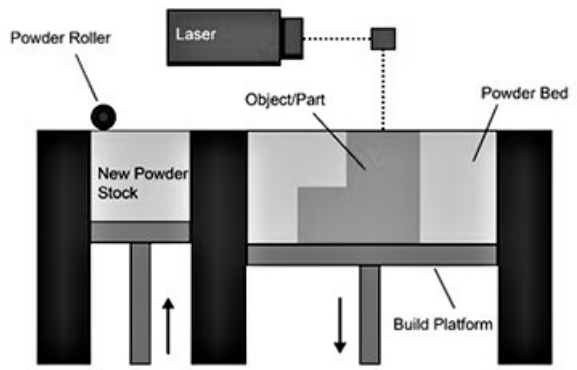


Figure 3.5.: Example schematic of Powder Bed Fusion technology – Source: Loughborough University [Louny]

Powder Bed Fusion Framework	
Definition	additive manufacturing process in which thermal energy selectively fuses regions of a powder bed.
Feedstock	various powders: thermoplastic polymers, typically pure metals or metal alloys, structural for industrial ceramics. Any of the powder materials could be used with, or without, fillers and binders depending on the specific process.
Binding mechanism	thermal reaction bonding.
Source of activation	thermal energy, typically transferred from laser, electron beam, and/or infrared lamps.
Secondary processing	removal of loose powder and, if applicable, support material, and various operations to improve surface finish, dimensional accuracy and material properties; for example micro blasting, finishing milling, grinding, polishing and heat treatments.

Table 3.7.: Powder Bed Fusion Framework – Source: following ISO 17296-2 [DIN16a]

3.8.1. Selective Laser Sintering (SLS)

The University of Texas has engineered the Selective Laser Sintering (SLS) technology. The patent for SLS lies by 3D Systems, Inc. after they acquired DTM Corporation [Cusny]. This process has also a powder bed and a build chamber. The powder in the build chamber will be heated close to the melting temperature of the material. A laser sinters the powder on the basis of the given geometrical input file. Due to the fact that the material temperature is only closed to the melting point, it is not melted. Instead of this, the material particle will be deformed so that they grow together. In this way, the powder will be fused with the layer before. After one layer a roller distributes the material from powder bed to build chamber, each layer in the same thickness [WH12]. Possible materials are thermoplastic, like PC, PA, Polyvinyl chloride, as well as metal, ceramic and sand [Fas14]. Combination of materials are also feasible, for example a combination of metals and polymer. To process metal, a binder is necessary which will be removed later [WH12].

The main advantage of SLS is the high amount of material opportunities [WH12]. The finished objects are end products, for example air plane components. Another advantage is that the objects have a high mechanical resilience and the technology copes without support structure [Fas14]. The disadvantages of SLS are a low detail resolution and the necessity of post-processing through compressed air, as well as 3DP. Besides of that objects often have an abrasive surface and slight porosity. When the object is cooling down, clamping and deviation are possible. This can be countered by correction before printing by a software.

3.8.2. Selective Heat Sintering (SHS)

The patent for Selective Heat Sintering (SHS) lies by the company BluePrinter [Fas14]. They also developed a printer therefore and introduced the technology 2011 at the Euromold. In principle, it is the same technology as SLS mentioned before. But instead of using a laser to fuse the powder a thermal print head is used. The process material is a thermoplastic powder.

The advantages are that the procedure is suitable for movable objects. The material overhang can be recycled. Furthermore, is this technology more cost effective compared to SLS. The disadvantage is the low detail resolution [Fas14].

3.8.3. Selective Laser Melting (SLM)

Selective Laser Melting (SLM) is also the same technology as SLS mentioned before. The difference to SLS is that the powder will be fully melted [Fas14]. Therefore, also the change of sintering to melting in the name. The material for this technology has to be mono, there are no

combinations possible due to the melting point [Rapny]. Materials are metal like aluminum, stainless and stool or titanium, but plastic and ceramic is also possible.

This technology has the advantage that the objects are 100 percent densely and there is also no need of support structure. Disadvantages are that there can be crystal boundaries at the layer boundaries, which will have an influence to the final strength. The detail resolution is low and the surface is abrasive.

3.8.4. Electron Beam Melting (EBM)

The patent for Electron Beam Melting (EBM) lies by the company Arcam [Fas14]. Even this technology is similar to SLS. The difference to SLS is the energy source, which is not a laser but a 30 to 60 KV electron beam. The building material is metal like titanium, or cobalt chromium. The combination of electron beam and material implicates that the process has to be performed under vacuum to avoid oxidation. This made EBM interesting for the outer space area [WH12].

The advantages of EBM are high flexibility and good control over temperature and speed of print process. It has also a high-level efficiency as well as a better absorption for some material towards a traditional laser. The surface is abrasive.

3.9. Sheet Lamination Technologies

At Sheet Lamination technologies, sheets mostly out of paper or foil are laminated together. This will be done by thermal or chemical reaction. The overlapping material will be cut out, but only the outer contours [GRS15]. An example schematic of the Sheet Lamination technology is shown in 3.6 [Louny]. Table 3.8 gives an overview about the framework of Sheet Lamination technology [DIN16a].

3.9.1. Laminated Object Modeling (LOM)

Laminated Object Modeling (LOM) is not a typical additive manufacturing technology because it combines additive and subtractive techniques [WH12]. A sheet which could be paper or foil will be bonded to the lower layer through pressure and heat. A knife or a hot wire cuts the overlapping material according to the geometrical file. The material besides of the already named could be plastic, ceramic, or aluminum [WH12] [Fas14].

The technology has the advantage of high detail resolution and cost-effectiveness. The disadvantages are high loss of material because of overlapping. And that there is no opportunity

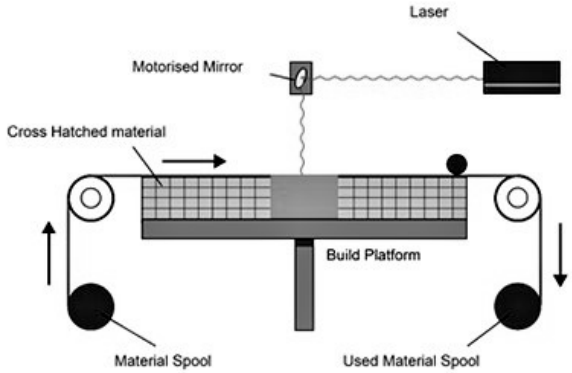


Figure 3.6.: Example schematic of Sheet Lamination technology – Source: Loughborough University [Louny]

Sheet Lamination Framework	
Definition	additive manufacturing process in which sheets of material are bonded to form an object.
Feedstock	sheet material: typically paper, metal foil, polymers or composite sheets predominately formed of metal or ceramic powder material held together by a binder.
Binding mechanism	thermal reaction, or chemical reaction bonding, ultrasound.
Source of activation	localized or large scale heating, chemical reaction and ultrasonic transducers.
Secondary processing	removal of waste material, and optionally sintering, infiltration, heat treatment, sanding or machining to improve surface finish.

Table 3.8.: Sheet Lamination Framework – Source: following ISO 17296-2 [DIN16a]

for hollow structures [WH12]. The high mechanical effort for the post processing is another disadvantage [Fas14].

3.9.2. Selective Deposition Lamination (SDL) (advancement of LOM)

The technology Selective Deposition Lamination (SDL) is an advancement to the LOM technology. It was developed by the company Mcor Technologies. The difference to LOM is reducing of the mechanical post process by sticking only the predefined object parts together, instead of glue the whole sheet together and cut them out. So, in the post processing of SDL overlapping

components can easily be broken off. The material for this technology is paper. The printer "iris" from Mcor Technology can color the sheets before printing on each site and is therefore able to print multicolored objects [Fas14].

3.10. Vat Photopolymerization Technologies

Vat Photopolymerization technologies mostly uses UV radiation to cure the material. Materials for this technology are typically photoreactive resin in liquid or paste form [DIN16a]. The material resin includes in this context polymers with photoactivators [Ver14b]. An example schematic of the Vat Polymerization technology is shown in 3.7 [Louny]. Table 3.9 gives an overview about the framework of Vat Photopolymerization technologies [DIN16a].

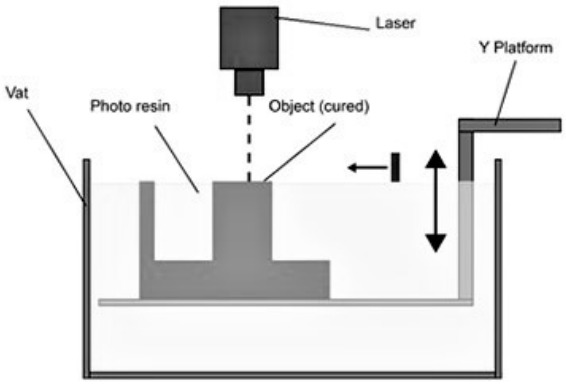


Figure 3.7.: Example schematic of Vat Polymerization technology – Source: Loughborough University [Louny]

Vat Photopolymerization Framework	
Definition	additive manufacturing process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization.
Feedstock	liquid or paste: photoreactive resin with or without filler.
Binding mechanism	chemical reaction bonding.
Source of activation	typically UV radiation from lasers or lamps.
Secondary processing	cleaning, support material removal, post-curing by further UV exposure.

Table 3.9.: Vat Photopolymerization Framework – Source: following ISO 17296-2 [DIN16a]

3.10.1. Stereolithography (SL, but also STL or SLA)

Stereolithography (SL) was developed in 1983 from Charles Hull, he founded later the company 3D Systems, Inc. [Fas14] and was the first, therefore most widely used, process in the area of rapid prototyping [WH12]. The process uses an UV laser to cure liquid material. To be more specific, the build platform is placed in a vat filled with liquid photopolymer. Once the UV laser gets in contact with the material it will cure. In the next step the building platform will be lowered down about the layer thickness and then a wiper distributes the material [Fas14]. Possible materials are liquid duromer, like epoxy resin and acrylate, or elastomer.

The advantages are fine and smooth surface and a high detail solution. But this results in a long print process. Other disadvantages are high material costs, the building objects often have a low heat and mechanical load. Due to the UV light-sensitivity, the objects are limited in long-lasting period [Fas14].

3.10.2. Scan LED Technology (SLT) (advancement of SLA)

The Scan LED Technology (SLT) is an advancement of SL. Instead of using a laser to cure the material, a Digital Light Processing (DLP) Light-Emitting Diode (LED) based UV light is used. This technology reduces the maintenance and repair costs. The scope of Scan LED Technology (SLT) is especially in medicine area for objects in precision technology like hearing aid. The used materials are photopolymer, biocompatible and non-biocompatible plastics [Fas14].

The advantage is that the system has no Radio Frequency IDentification (RFID) codes, so that users can develop their own material and therefore reduce costs [Fas14].

3.10.3. Film Transfer Imaging (FTI)

The Film Transfer Imaging (FTI) was also developed by 3D Systems, Inc. It is similar to SL Technology. Instead of using a laser to cure the material, a beamer is used. Another difference is the absence of the vat. Nevertheless, it is placed under Vat Photopolymerization because of the photopolymer material and its similarity to SL. A thin layer of material will be distributed on a transport foil. After that the material will be exposed through the transport foil with the beamer according to the geometrical file [Fas14].

The advantages are fine and high surface quality and therefore a high detail resolution. The disadvantage is that the process is material intensive and the need of support structure [Fas14].

3.10.4. Digital Light Processing (DLP)

The Digital Light Processing (DLP) was developed by the company Texas Instruments and is a combination of FTI and Stereolithography (SL). It is the same process as FTI but it has a vat as well as Stereolithography (SL). These has the result that the building platform is moving in z direction after the exposure of the FTI projector. The material is also a photopolymer substance [Fas14].

The advantages are the fine and good surface quality and due to the precise light control, razor edges are possible. The disadvantage is the expensive mechanical removal of support structure [Fas14].

3.10.5. Continuous Liquid Interface Production (CLIP)

Continuous Liquid Interface Production (CLIP) is one of the newest technology. It was developed by Joseph Desimone [Des15]. The patent lies by EiPi Systems, Inc. which founded therefore the trademark Carbon3D, Inc. in 2014 [JUS14]. The revolution of this technology is the speed. According to Desimone the process is 25-100 times faster than the already known technologies. As its names implies the process is continuous, no layers exist. The object is built in a UV curable resin bath. The build platform is above the resin. Below the resin is an oxygen permeable window, similar to a contact lens, and a projector. Through this window the process is controlled over oxygen and UV curable. Above the window is a so-called dead zone. It is there so that the resin could not stick at the window. The thickness of the dead zone depends on the oxygen concentration. The build platform pull the object out of the resin during the projector polymerize the geometrical defined parts. The material for CLIP are all photopolymer [Des15, TSE$^+$15].

The main advantage of this technology is the already named improvement of speed. By performing all steps in one instead of pull the object out of the resin for oxidation, it is 25-100 times faster. Another advantage is the smooth surface and the good and consistent tensile strength [Des15].

4. Resource Description for 3D Printers

This chapter introduces a guideline for the RDL and the requirements the RDL has to be able to handle. It also introduces the detected properties of 3D printing. Afterwards the ontology with the properties and their hierarchical structure is described. This implementation of the ontology is being done by using the tool Protégé. At the end of this chapter the RDL and the corresponding ontology is fully presented and can be found in the appendix B.

4.1. Resource Description Language

For the RDL, information of 3D printing has to be evaluated. The description must reflect required properties of available 3D printing technologies. To satisfy all existing technologies and future ones and their unforeseen properties, the classification has to be flexible and independent from any schema [BR17], such as described in chapter 3. Therefore, properties which all technologies have in common will be evaluated. Additionally, properties bounded to a specific technology will also be evaluated for all existing technologies. For these properties, the linking to the respective technology has to be deposit. All the properties have to be extensible. There are also restrictions which the RDL should be able to handle. That means properties are only valid in certain situation, for example the already mentioned technology specific restriction. Besides of the obvious hardware properties the RDL includes also non-hardware properties. That reaches from properties of the used material for printing over process attributes up to the physical location of the printer. Evaluating the properties is being done by 3D printer operation manual and specification reviews. The RDL should be able to distinguish between a general property class and their instances [BR17].

The ISO list of quality characteristics (e.g. bulk raw material requirements, surface requirements, etc.) [DIN16b] is also part of the RDL, including the identified but not yet listed ones. Status information such as failure information are not part of this thesis, even when it is mentioned by ISO [DIN16b]. Also, out of the scope of this thesis are properties restriction for a period of time such as user specific settings.

The evaluated properties will be clustered into groups of information. Following the idea of Baumann [BR17] there will be a separation into the four main categories: material, software, process and technology. The table 4.1 shows the definition of those categories according to Baumann et al. [BR17], which will be the basis of separating the properties.

Category	Definition
Materials	Encompasses all physical materials that are processed, or used during the digital fabrication. Also includes physical materials that are required for the digital fabrication process as indirect or auxiliary material.
Software	Encompasses all software and IT components that are involved in the model creation phase, the object fabrication phase or that are used for the control and management of digital fabrication equipment.
Process	Encompasses all intangible processes, data and information that is generated, consumed, transformed or influenced by any phase of the digital fabrication process. Business processes are part of this grouping.
Technology	Encompasses all hardware and machine equipment that are used for the object fabrication, as well as pre- and post-processing.

Table 4.1.: RDL Category Definition – Source: Resource Description for Additive Manufacturing - Supporting Scheduling and Provisioning [BR17]

4.1.1. Properties

In this section the evaluated properties are listed. The following table includes the property, a short description and the source, where it was first found. The name of the property is not necessary the name of the property in the source. The name was adapted to a generic name to be independent from manufacturer. For example, the term for the number of heads a printer has, depends on the head type. Instead of calling the property "Number of Jets", or "Number of Extruders", it is named "Number of Heads". Another adaption is, when a property has a minimum and a maximum value and is listed as two entries in the source, it is summarized to one property. For example, a layer has a minimum thickness, which specifies the thin layer the printer is able to. It also has a maximum thickness, which specifies the thick layer the printer is able to. These two properties will be summarized to the property "Layer Thickness". For collecting the property and allocate them in a hierarchical structure there is no difference in minimum and maximum value. Later the specificity will be done when developing the ontology 4.2.

Property	Description	Source
Absolute Density	Material property	[3D 17]
Acceleration	The maximum acceleration that the print head is capable of.	[BR17]
Accepted File Formats	A list of file formats that the 3D printer is capable of processing.	[Goo12]
Active Cooling	Indicator if the printer is actively cooled using a fan or not.	[BR17]
Allowed Groups	A list of all user-groups allowed to work on or with the 3D printer.	[BR17]
Allowed Material	A list of materials that are processable by the 3D printer.	[LULny]
Allowed Users	A list of all users allowed to work on or with the 3D printer.	[BR17]
Beam Focus	The diameter of the laser beam.	[SLMny]
Binder	A list of materials that can be used as a binder for a 3D printer, if a binder is neccessary.	[ExO15]
Build Envelope Depth	The depth of the build envelope.	[SLMny]
Build Envelope Height	The height of the build envelope.	[SLMny]
Build Envelope Material	Description of the material of which the build envelope is made of.	[Ultny]
Build Envelope Radius	The radius of the build envelope, for polar coordinate based systems.	[Delny]
Build Envelope Width	The width of the build envelope.	[SLMny]
Build Plate Depth	The depth of the build plate/print bed.	Own research
Build Plate Height	The height of the build plate/print bed.	Own research
Build Plate Width	The width of the build plate/print bed.	Own research
Carbon Content	Material Property	[DIN16b]
Cathode Type	Describes the cathode, i.e. the electron source, of the 3D printer.	[Arcny]

Certificates	A list of legal conformity certificates for the 3D printer.	[BR17]
Certification	Describes the certification for the laser unit in the 3D printer.	[Forny]
Class	Classification for the laser system of the 3D printer.	[Forny]
Clearance	Distance required between any parts of the object or between objects to avoid fusing.	[BR17]
Coefficient of Thermal Expansion	Material Property	[3D 17]
Cold Pause	Ability to halt and resume a print for a longer period of time.	[CEL16]
Color Range	The range of colors that are printable by the 3D printer, i.e. black, white, red.	[3D 13]
Communication Interfaces	The connection from the 3D printer to workstation or network.	[3D 17]
Compressed Air	Specification of the required compressed air connection to the 3D printer.	[EOS13]
Compressive Strenght	Material Property	[DIN16b]
Connection	The connection of the 3D printer for externally connected atmospheric supply systems.	[SLMny]
Consumables	A list of consumables which required for the printing process.	[SLMny], [Arcny]
Consume	Specification of the amount of externally supplied atmosphere the 3D printer is consuming during a printing process.	[SLMny]
Content	The required atmospheric makeup for the 3D printers build envelope. Content_AtmosphereProcess	[SLMny]
Corrosion	Material Property	[DIN16b]
Crystalline Structure	Material Property	[DIN16b]
Cytotoxicity	Material Property	[3D 17]
Deposition Rate	Rate of which material is deposited, i.e. at which rate an object is printed.	[Opt16]
Diameter Nozzle	The diameter of each extruder installed in a 3D printer.	[Mak16]

Dielectric Constant	Material Property	[3D 13]
Dielectric Strength	Material Property	[3D 13]
Distribution Mechanism	Describes the method the powder is spread for the next layer.	[3D 17]
Ductility	Material Property	[DIN16b]
Electrical Input	The power consumption of the 3D printer.	[3D 17]
Electrical Resitivity	Material Property	[3D 17]
Enclosed	Indicator for presence of an enclosed build envelope.	[CEL16]
Filament Diameter	Diameter of the filament usable with the 3D printer.	[Mak16]
Flammability	Material Property	[3D 13]
Flexural Modulus	Material Property	[3D 17]
Flexural Strength	Material Property	[3D 17]
Frictional Coefficient	Material Property	[DIN16b]
Heat Deflection Temperature	Material Property	[3D 17]
Heat up Time	Time required for the build plate/print bed to heat up to operating temperature.	[Ultny]
Heater Cartridge	Power consumption of the heating cartridge.	[BR17]
Hot Pause	Ability to pause a print without cooling the extruders.	[BR17]
Idle	The amount of noise emitted by the 3D printer while idle.	[BR17]
Impact Strength	Material Property	[3D 17]
Infill Pattern	A list of available infill patterns for non solid printing.	[BR17]
Interlocking Parts	Indicator if the printing of interlocking parts is feasible.	[BR17]
Internal Lightning	Describes if and what kind of internal lighting is present in the 3D printer.	[CEL16]

Internal Seria lNumber	To be distinguished between the manufacturer assigned serial number, and possibly a serial number within the institution that utilizes the 3D printer.	[BR17]
Laser Type	A specification of the laser type.	[3D 17]
Lead Time	The time the printer needs until it is ready to print.	Own research
Leveling Mode	Describes the mechanism that is used to level the build plate/print bed.	[UP3ny]
Location Printer	Deinfition of the printers location.	Own research
Machine Property Depth	The machine dimension (Depth).	[3D 17]
Machine Property Height	The machine dimension (Height)	[3D 17]
Machine Property Weight	The machine dimension (Weight).	[LULny]
Machine Property Width	The machine dimension (Width).	[3D 17]
Macro Rockwell C	Material Property	[3D 17]
Magnetic Permeability	Material Property	[3D 17]
Manufacturer	The manufacturer of the 3D printer.	[EOS15]
Material Format	Describes the format in which the material is provided to the 3D printer.	[Pro]
Material Recognition	Indicator for the presence of any kind of automatic material recognition system in the 3D printer.	[CEL16]
Material Types	Catgory of available material state. For example, a instance could be solid, liquid, or powder.	Own research
Max Angle	The angle up to which slopes can be constructed without the requirement of supporting structures.	[BR17]
Max Surface Roughness	The maximum average achievable surface roughness for a 3D printer.	[3D 17]
Max Weight	Denotes the maximum weight, all objects of a build can have without skewing or damaging the build plate.	[Pro]

Melting Point	Material Property	[3D 17]
Micro Vickers	Material Property	[3D 17]
Min CPU	The minimum CPU speed required for the workstation controlling the 3D printer.	[BR17]
Min Hole Diameter	Description of the minimum hole diameter possible to print.	[BR17]
Min Installation Depth	The depth required for the installation/placement of the 3D printer.	[SLMny]
Min Installation Height	The height required for the installation/placement of the 3D printer.	[SLMny]
Min Installation Width	The width required for the installation/placement of the 3D printer.	[SLMny]
Min RAM	The minimum amount of RAM required for the workstation controlling the 3D printer.	[BR17]
Min Wall Thickness	Minimum thickness of any wall (that is supported) of an object that is to be printed.	[BR17]
Motor	Description of printers motors.	[BR17]
Name	Describes the firmware that is installed on the 3D printer.	[BR17]
Net	The specification for the network connection required for the workstation controlling the 3D printer.	[BR17]
Network Connectivity	Describes kind and speed of the network connectivity of the 3D printer.	[BR17]
Nozzle Heat up Time	Time required for the extruder to heat up to operating temperature, most commonly about 240 deg C.	[Ultny]
Nozzle Offset X	For multi-nozzle systems, the offset of each nozzle to the middle of the print head (X axis).	[BR17]
Nozzle Offset Y	For multi-nozzle systems, the offset of each nozzle to the middle of the print head (Y axis).	[BR17]
Nozzle Offset Z	For multi-nozzle systems, the offset of each nozzle to the middle of the print head (Z axis).	[BR17]
Number	The manufactureres assigned serial number.	[BR17]
Number of Color	The number of colors that are printable by the 3D printer.	[Goo12]

Number of Heads	The number of heads installed in a 3D printer.	[Mak16]
Operation	The amount of noise emitted by the 3D printer during operation	[Pro]
Origin	Denotes the origin of the 3D printer that is used for referencing (X, Y, Z).	[BR17]
OS	A list of possible operating systems required for the workstation controlling the 3D printer.	[BR17]
Output Energy	The energy that is put out by the laser.	[SLMny]
Peel Mechanism	Describes the mechanism that is used to peel (i.e. wet the top surface, of an object).	[Forny]
Personal Attendance	Indicator that states if personal attendance during the printing process is required or not.	[BR17]
Photostability	Material Property	[DIN16b]
Post Process Manual Interaction	Indicator that states if personal attendance during the stopping process is required or not.	[Strny]
Pourability	Material Property	[DIN16b]
Pre Process Manual Interaction	Indicator that states if personal attendance during the preparatory process is required or not.	[Strny]
Preparation	The amount of noise emitted by the 3D printer during preparation	[BR17]
Pressure	The required atmospheric pressure for the 3D printer build envelop.	[SLMny]
Print Speed Support Structure	The speed of printing the support structure.	Own research
Relative Density	Material Property	[3D 17]
Resolution X	Description of the accuracy achievable by the machine in printing the X axis.	[BR17]
Resolution Y	Description of the accuracy achievable by the machine in printing the Y axis	[BR17]
Resolution Z	Description of the accuracy achievable by the machine in printing the Z axis.	[BR17]
Series	The manufactureres assigned serial.	[BR17]
Shore	Material Property	[3D 13]

Shrinkage Build	Indicator that states if there is systematic shrinkage of the object during the printing process.	[BR17]
Signature	Signature of the firmware.	Own research
Softening Temperatures	Material Property	[DIN16b]
Solidification Point	Material Property	[DIN16b]
Specific Heat Capacity	Material Property	[3D 17]
Support Structure	Describes if the object to be printed requires a support structure or if it can be printed without.	[EOS14]
Surface Texture	The texture of the material surface after printing.	[DIN16b]
Tensile Modulus	Material Property	[3D 17]
Tensile Strength	Material Property	[3D 17]
Thermal Conductivity	Material Property	[3D 17]
Third Party Compatible	Indicator for the (allowed) use of compatible third party material.	[CEL16]
Toxicity	Material Property	[DIN16b]
Translucence	Material Property	[DIN16b]
Type	Cartesian, Polar, Spherical or other coordinate system that is used by the printer for movement and positioning.	[BR17]
Vacuum Pressure	The pressure of the vacuum required for operation of the 3D printer.	[Arcny]
Vat Fill Mechanism	Describes the mechanism that is used to fill the vat with resin.	[Forny]
Version	Firmware version indicator.	[BR17]
Viscosity	Material Property	[3D 17]
Volume Resistivity	Material Property	[3D 13]
Water Absorption	Material Property	[DIN16b]

Wave Length	Wavelength of the laser unit in the 3D printer.	[3D 17]
Yield Strentgh	Material Property	[3D 17]
Youngs Modulus	Material Property	[3D 17]

Table 4.2.: Property Overview

4.1.2. Hierarchical Structure of the Properties

The properties of the section 4.1.1 before will now be grouped together and clustered in a logical, hierarchical structure. The fundament of this structure builds the categories mentioned in section 4.1. At first the properties are assigned to a category. All material properties, such as density, are assigned to the material category. They are grouped together to a material property subcategory, which is anchored in the material category. Then the properties which are not material properties but depends on the used material, such as clearance or the surface texture, are also assigned to the material category.
All properties describing a hardware component of the printer, like number of heads, belong to the technology category, because the printer is anchored there. Then there are also properties of non-hardware components but depends on hardware, such as layer thickness. These properties are also assigned to the technology category. All these properties are grouped together to the printer category, which is anchored in the technology category. The hardware properties build printer component the subcategory and the non-hardware properties build the printer property subcategory. Printer specific properties which describe the printer itself, like information about the manufacturer or printer type, are assigned to the printer category in the technology category. Then there are properties of the workstation the printer is able to work with. These properties also belong to the technology category. As described in section 4.1, the technology category also includes properties of the pre-, in-, and post-process, so these are subcategories of technology. Therefore, properties, such as manual interaction, are assigned to the respective subcategory. The in-process subcategory also includes properties which describe information or requirements during the build process. These are, for example, the suitable operating temperature, or the required vacuum pressure.
At least there are properties which belong to the software or process category. The properties, respective the firmware, are assigned to the software category. All properties which depends on the firmware and therefore could be changed with an update are also assigned to the software category. The process category includes all the surrounding information. This means it includes properties which specify the requirements at the atmosphere around the printer as well as installation requirements. But also information about permission restrictions of the printer and the location.

4.2. Ontology

The Resource Description Language is mapped in an ontology. Therefore, all defined restrictions and basic conditions of the RDL in section 4.1 are also valid and necessary for the ontology. The evaluated properties of section 4.1 will also be mapped into the ontology. Additional to them the ontology should be able to consider the following requirements, given from the article by Baumann et al. [BR17]:

RQ1 The ontology and properties list must be flexible and extensible. Flexibility means that for specific application scenarios where only subsets of properties and relations are of interest, these must be expressible within the proposed ontology or resource description. Extensibility denotes the property to be able to incorporate future, currently unforeseen, properties of technology and materials.

RQ2 The resource description must be able to reflect temporal, local and other ranges of validity and restrictions. Conditional validity is to be reflected. With this requirement we reflect the necessity that certain properties, e.g. material strength, are only valid and guaranteed for a certain period.

RQ3 The resource description must be able to distinguish between general concepts of things, e.g. printers and materials, that form a class and its individual instantiation that might have differing properties and attributes.

Usual methods for developing an ontology are expert questionnaires, practical experiments or/and literature researches [NMny]. Due to the fact that the ontology has to be general and should be able to handle unforeseen properties, a practical experiment would be too complex. Expert questionnaire are not suitable for this thesis because of the time and it is also being too complex to find enough and suitable experts. Therefore, the used method for this ontology is the literature research and the expertise of Baumann. The literature research for the ontology is developed from existing 3D Printer manuals, specifications and standards.

To create and represent the ontology the tool Protégé is used [Mus15]. It was developed at the University of Stanford. It is an editor for creating and maintaining ontologies. Protégé has a community which also provides a wiki for it [Pro16]. This wiki includes a manual for creating an ontology [NMny]. There it is recommended to answer questions at the beginning of developing an ontology, to define the domain and get an overview of it. Below these questions will be answered regarding to resource description for additive manufacturing/3D the ontology of this thesis.

- What is the domain that the ontology will cover?
  The domain of this ontology is the resource description for additive manufacturing/3D.
- For what we are going to use the ontology?
  The ontology should describe the resources and therefore the properties available in AM. It should be able to provide information about the available 3D printers. So, that it is possible to detect the best printer for a job. The best printer means a suitable combination of e.g. material (surface, density, lifetime), location, speed, availability, etc. Future scope of application is to schedule print jobs to suitable printers.
- For what types of questions the information in the ontology should provide answers?
  - What are the basic conditions for the printer?
    The following, non-exhaustive, list of questions specifies the above question.

How is the electrical input for the printer? How is the dimension of the printer? Which communication interfaces are possible? How are the properties regarding build envelope? Is there a distribution mechanism and if yes how is it distributed? Has the printer an official certification? How noisy is the printer?
Surrounding conditions also belongs to the question, for example the following ones.
How are the conditions for the atmosphere around the printer? Where is the printer located? Which persons are allowed to use the printer? Is there manual interaction necessary?

- What requirements is the printer able to serve, in general?
  For example: Which materials are available and is there a combination possible? Is support structure required? Is it possible to build hollow parts and what are the conditions therefore? Are different colors possible? Which is the maximum object size the printer can build? How are the speed properties of the printer? What is the minimum layer thickness?
- What are the available material properties?
  More defined questions for example are the following ones:
  How are the surface properties? Is shrinkage possible? Which degree of density could be achieved? Is it flammable?
- What are the possibilities and limitations of the involved software components?
  The following, non-exhaustive, list of questions underlines the meaning of the above question.
  Which possibilities provides the Operating System (OS) of the printer? Is it possible to take a pause during the print process? Which file formats are allowed so the printer is able to process?

- Who will use and maintain the ontology?
  It is a generic ontology which will not be supported in its existing form. It is the output of the RDL and therefore builds the RDF. It is possible that it will be adjusted or further developed at the university or from additive manufacturing operator.

The answers build the basic information for developing the ontology. It states out where the ontology is anchored and which information are necessary to match all the requirements. Next sections describe classes and their dependences of the ontology.

4.2.1. Classes of the Ontology and their Hierarchy

The information represented in the ontology are the evaluated properties of section 4.1.1 and their restrictions and dependences 4.1. The hierarchy of classes in the ontology represent the hierarchical structure of the properties evaluated in section 4.1.2. In this section the

composition of the ontology and the implementation of the restriction is described. The exact definitions of each class is given in the appendix B and in the table above 4.2. According to the Protégé manual [NMny] "OWL classes are interpreted as sets that contain individuals." In the domain of resource description for additive manufacturing/3D the individuals are the particular properties. Due to the fact that there are different terms for a property, because of different manufactures or technologies, a generic term is required. This generic term denotes the ontology class for the property.

A property consists mostly of three attributes: a name, a value and a unit. There are properties with a string value which does not necessary have a unit. In this case the unit will be left empty. To avoid redundancy the property is divided in its attributes for the ontology hierarchy. Otherwise each property would have a class for the value and one for the unit. So, there is one class for the value and one for the unit for all properties and each property has a class for the name. These attributes are combined in a class, which is simply called "Property". In Protégé, the combination is set through object properties. The part of ontology, where the names of the individuals take part, will also include the hierarchy of the properties. Here the Superclass is called "Category" and the first level is divided in the already mentioned four categories: Material, Software, Process and Technology. The first level structure, described so far, is shown in figure 4.1.

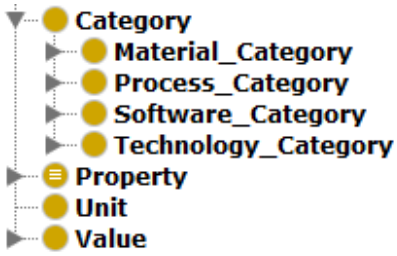


Figure 4.1.: First level structure of the Ontology

All the properties concerning the used material are subclasses of the material category class. The first subclass level of material consist of general properties such as a list of possible binder materials (if necessary) or the high and width definition of possible emboss detail. It also includes the "Property_Material" class which is only an accumulative superclass and not a property name for the ontology. The subclasses represent the chemical or physical material properties. These are for example density, melting point, flammability, etc. - characteristics of the used material. An overview of this classes is represent in figure 4.2.

The software category includes all properties concerning the firmware of the printer. For example, an indicator if a pause function is available or not and information about the installed firmware, etc.

The process category contains framework requirements of the domain. It includes permission information such as who is allowed to work at the printer. It also contains the property about the location of the printer. Other classes build the superclasses for the installation or atmosphere requirements.

The category "Technology_Category" includes major information. It consists out of the properties in the different stages of process which is needed for the different technologies as well as the requirements at the workstation, such as needed OS or Central Processing Unit (CPU). The "Pre_Process" class describes the properties before the print starts, such as lead time and manual interaction. "Post_Process" class is the corresponding class, which describes the properties after the printer has finished the print. The "In_Process" class consists of all properties which are not concerning the hardware but are necessary during the process. For example, the operating humidity and temperature, a list of consumables, etc.

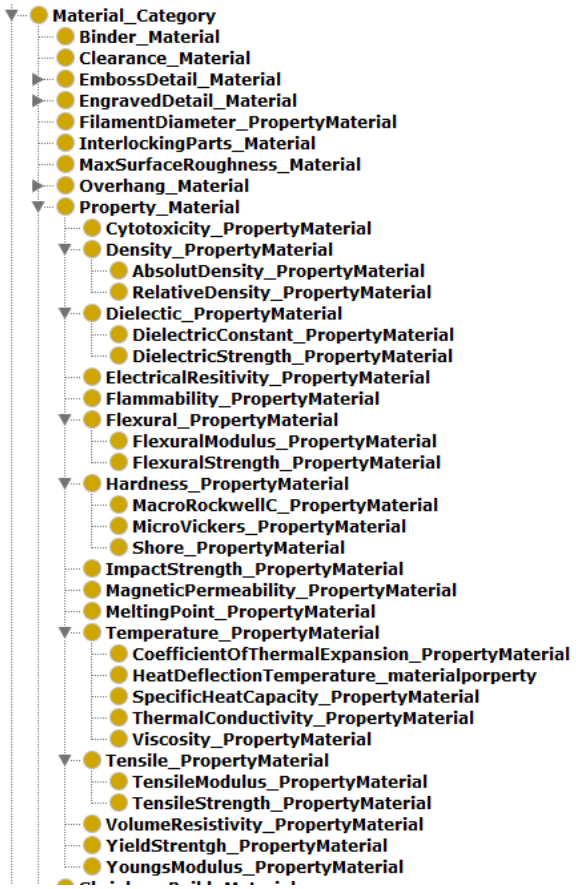
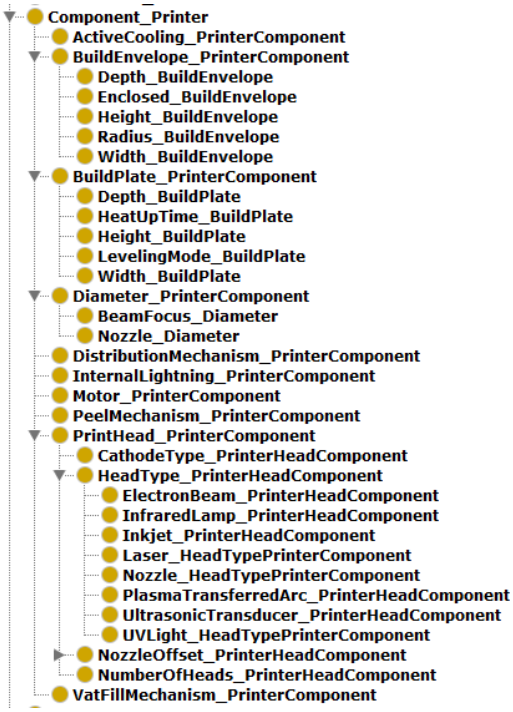


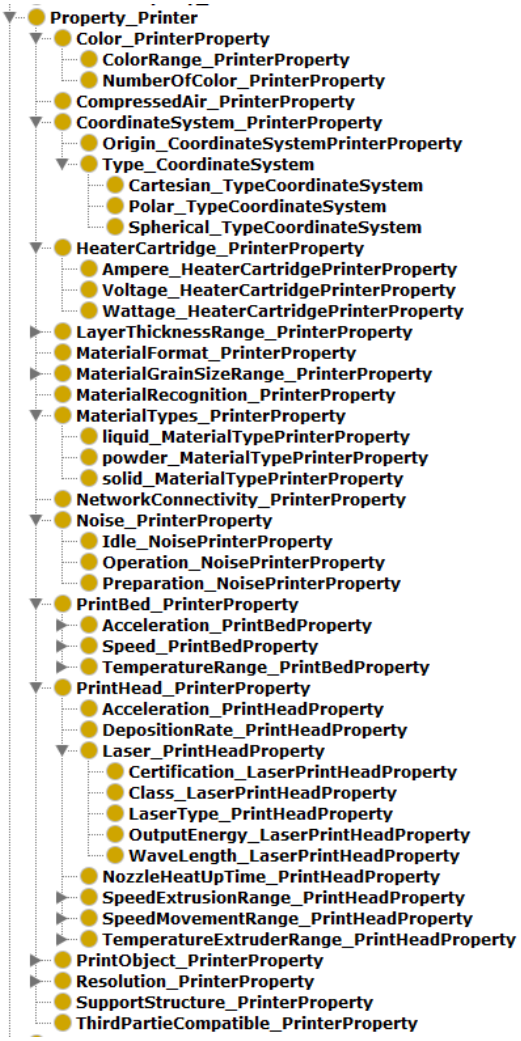
Figure 4.2.: Properties of the Material Category of the Ontology

Beside of the already mentioned subclasses of "Technology_Category" it includes the hardware specification as well as hardware concerning properties. These are subclasses of the class "Printer_Technology" and are separated into "Property_Printer" and "Component_Printer". The component class consists of all hardware parts of the printer, such as information about the print head, build plate, etc. An overview of this class is shown in figure 4.3a. Properties of these defined hardware components are in the extra "Property_Printer" class. These are properties such as the thickness of a layer, different speed properties and network connectivity, etc. An overview of the properties in this class is shown in figure 4.3b.

For all the properties with a minimum and maximum value as mentioned before 4.1.1, a property class is created with the additional postfix "Range". For the "Layer Thickness" property a class called "LayerThicknessRange" is created, for example. All the range classes have three subclasses with the prefix min, max, or exact. For the "LayerThicknessRange" they are called "MinLayerThicknessRange", "MaxLayerThicknessRange", and "ExactLayerThicknessRange". The exact range class is necessary to integrate individuals with only one value for this property.



(a) Printer Hardware Properties of the Ontology



(b) Printer Hardware concerning Properties of the Ontology

Figure 4.3.: Printer Properties of the Ontology

4.2.2. Restrictions of the Properties

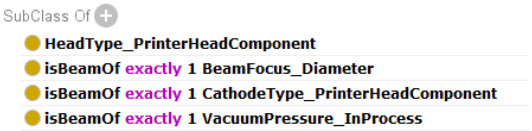
According to the following Protégé manual [NMny] vocabulary the properties describe relations/restrictions between individuals.

> "Properties are roughly equivalent to slots in Protégé. They are also known as roles in description logics and relations in UML and other object oriented notions. In GRAIL and some other formalisms they are called attributes."

There are object properties and data properties. To state out if the Protégé properties are meant or the property attribute of the resource description ontology the whole term will be used (object property or data property). Property as standalone term always represent the ontology concerning property.

Object properties describe the relation between two individuals. Data properties are the relation of an individual to a data value. So, the object property function is used to describe the dependences of the properties, such as a property is only available if another property is set. For example, the diameter of an electron beam is only of interest if an electron beam laser is used. To document this relation an object property "hasBeam" is used. The domain of "hasBeam" is the "HeadType_PrinterHeadComponent" class and the range is the instances of the subclass "ElectronBeam_PrinterHeadComponent". So, this object property is the restriction for the "BeamFocus_Diameter" class. Therefore, the "hasBeam" object property has to be entered as a superclass of the diameter class, shown in figure 4.4a. One diameter belongs to one electron beam therefore the linking term is "exactly 1". To ensure that the diameter instance is not linked to another head type it has also a superclass with linking term "only". This relation is inverse. That means that an electron beam has also a diameter property. Therefore, an object property "isBeamOf" exists with the attribute that it is an inverse function of "hasBeam". Inverse functions define that if a property A depends on B then B depends also on A. So, the object property "isBeamOf" has to be a superclass of "ElectronBeam_PrinterHeadComponent" with the linking term "exactly 1", shown in figure 4.4b. In this way all the dependences between to properties are represented in the ontology.

(a) Superclasses of BeamFocus_Diameter



(b) Superclasses of ElectronBeam

Figure 4.4.: Object Property Example - Electron Beam

It is useful to limit the type of values per property. This is done by data properties. For each major data type value a data property, in form of "isDatatype", was created. The range of

the data property is the respective data type. To reference the example above the "BeamFocus_Diameter" class has a sibling class named "Nozzle_Diameter". Both properties have a value from data type double. Due to the fact that there are no other siblings the restriction regarding the data type is also a restriction to the superclass "Diameter_PrinterComponent". So, that means that the "Value" class has to be linked to the "Diameter_PrinterComponent" class including the restriction by the data property "isDouble". This is implemented by creating an imaginary superclass. At first the object property "hasValue" links the two classes together ("hasValue some Value"). Then the value range gets the restriction "isDouble some xsd:double". The result is the imaginary superclass shown in figure 4.5. This is the way of the ontology to restrict data types per property.

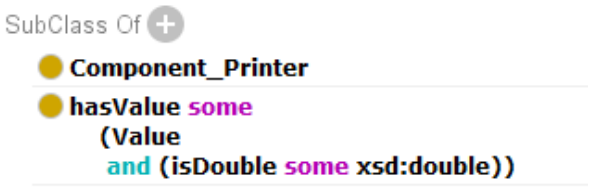


Figure 4.5.: Superclass of Diameter_PrinterComponent

4.2.3. Overview and Conclusion of the Ontology

The RDL was created by defining the requirements the RDL must be able to handle, evaluating the properties in the AM domain and bring them in a hierarchical structure 4.1 et seqq. The requirements of the ontology were stated it out in section 4.2.
The first requirement defines the flexibility and extensibility of the ontology. The flexibility was ensured in the evaluated ontology by restrictions of properties, described in section 4.2.2. The restrictions through object properties defines the scenarios if a property is of interest. For example, is the property "TemperatureNozzleRange" only of interest when the printer has a nozzle. This is express using the object property "hasNozzle", create a "only" relation with the "Nozzle" class to make sure that it only can be nozzle, and create a "exactly 1" relation with the nozzle class to ensure that each temperature instance belongs to one nozzle instance. All these restrictions are superclasses of the "TemperatureNozzleRange" class and therefore build the scope of interest. The extensibility is ensured by the structure of the ontology. Due to the fact that the value and unit of the property are extra classes and will be connect to the property by the property class, the ontology is generic and can be adapted. Normally at creating an ontology classes with only one subclass should be avoided. This ontology has intentional such classes to give the possibility to extend the class with respective subclasses. It is only being done if it is likely that there will be other properties in future, such as the "PostProcess" class. At the moment, it includes only the "ManualInteraction" subclass.
The second requirement is unfortunately not ensured in the ontology. Restrictions to properties

which not refer to another property could not be implicated. These restrictions could be implemented in the ontology by manual interaction. For example, when a property is temporarily restricted, the instance has to be manual updated after the restricted time. But temporarily restrictions of property classes and not instances are not implemented in the ontology and therefore could be an enhancement of the ontology.
The third requirement regarding differentiation between classes and individuals is being ensured by the structure of the ontology. Through the instances in the ontology the classes can have multiple individuals. It is possible to create an instance for a general printer and if something change, for example a print head is temporarily out of order, the instance could be adapted or a new one can be created and connect with the respective classes.

5. Implementation of the Ontology

This chapter describe an implementation of the evaluated ontology. It will be integrated in the already existing Unified 3D Printing (U3DP) software of the university, which is shortly introduced at the beginning.

5.1. Unified 3D Printing (U3DP) Platform Software

The U3DP Software was developed, in 2016, at the University of Stuttgart as a students project [KTKK16]. It is a platform for perform 3D printing jobs. But it is also able to manage users and projects over it. The ontology is integrated in the software to administrate printer and to search for suitable printers for requirements by the user. Therefore, a rudimentary matching algorithm is implemented. U3DP software has a server part as well as a client. The software is implemented through loopback [IBM17]. Loopback is a Framework which use nodejs [Fou17] to provide an Application Programming Interface (API). Nodejs is an asynchronous, server side JavaScript [ecm16] environment. Loopback also provides an AngularJS SDK. AngularJS [Mas17] is a model-view-controller framework based on JavaScript. The advancement of the software is given due to the fact that it is based on a flexible architecture.

The ontology will be integrated in the U3DP software as the data model structure. The information regarding AM domain, which should be available in the software, are the properties deposited in the ontology. The hierarchical structure of the ontology is also the structure of the respective data in the software. But in the software, the depth of the hierarchical structure is minimized, to avoid redundancy, in this case. The ontology has a logical hierarchical structure. In the software, the printer is the main object. So, every property in the printer category refers to one printer. That means when creating models of printer property, the model is related to the printer model and not to the model of the superclass in the ontology. It is described in detail below.
In the U3DP software already exists a printer and a material data model. These will be the main data model where all other models refer to. It can be seen has the printer and the material category class of the ontology. The evaluated properties of chapter 4 are the base of the new models, which are to be integrated. The superclass is the model itself and the subclasses are the properties of the model. Dependencies between classes is being implemented through relation between the models. For example, each data model in the printer area has a "belongsTo" relation to a specific printer. No matter which level the property has in the ontology. In this way,

Listing 5.1 Routing Definition

```
.state( 'upm.printer.printersearch', {
      url: "printersearch",
      templateUrl: "/modules/upm/printer/printer_search.html",
      controller: 'printer.printersearch'
      })
```

it is possible that one printer can have multiple instances of another model and the database is normalized. if it would refer to a data model one level above in the ontology it would be possible that there is only the relation entry in the data model and no other properties are set. This would be lead to redundancy and expand the database unnecessary. Another change towards the ontology is that the range properties are also implemented as a relation to the data model named "Range", This is also to avoid data redundancy and to keep the models slight, to have high adaptability. After all the models are set they can be read out by the controller and displayed in the web page. That means, that all the information about the resources in the AM domain is now available and can be processed for further tasks.
Before the page is available through a URL, it has to be defined in the rout.js file. An example for routing to a page where the user can search for a printer is shown in listing 5.1. Besides of the routing for HTML page, a specific controller is bind to the page.

Below the communication of client and server and the search algorithm will be described at a printer example. All the functions and communications are also available in other parts of the ontology, like material.

The algorithm, to find a printer on the basis of the user requirement, is being done by matching the requirements list to specific data model and their available values in the data base. In listing 5.2 this is exemplary shown with the data model "PrinterGeneral". At first, all deposit data base entries of the model are requested through a find request. In the next step, each property of the data model entry is compared to the users input, if it is provided. The findings are stored in an array as the respective printer id and matched property name. Due to the fact that the functions are call in an asynchronous manner, the function returns a promise that it is fully done. This is necessary to have the point of time to call an evaluation function over the found results. This can only be done when all requirements are compared to the data base.

The implementation is done by using the $q constructor. So, the promise return is available and can be bound at a "then" function. To wait for all matching functions, $q all is used. The function defined to execute after another will only be executed if all listed functions are done, shown in listing 5.3. Here in this function the already filled "matchlist" array is mapped to a new array "resultlist". This array includes the printer id and a counter how often the printer matches the requirements. In this rudimentary algorithm, the mostly found printer will be suggested to the user.

Listing 5.2 Matching the Search Requirements Example

```
//Match PrinterGeneral Properties
var general = function () {
      return PrinterGeneral.find( {}, function ( obj ) {
            $scope.printergenerallist = obj;
            if ($scope.printergenerallist != null) {
                  for ( var i = 0; i < $scope.printergenerallist.length; i++ ) {
                        if ($scope.printergenerallist[i].AllowedMaterial != null) {
                              for (var j=0; j<
                                   $scope.printergenerallist[i].AllowedMaterial.length; j++) {
                                    if ( $scope.printergenerallist[ i ].AllowedMaterial[j] ===
                                         searchreq.AllowedMaterial ) {
                                          matchlist.push([$scope.printergenerallist[i].printerId,
                                               'Allowed Material']);
                                    }
                              }
                        }
                        if ($scope.printergenerallist[i].Certificates != null) {
                              for (var j=0; j< $scope.printergenerallist[i].Certificates.length;
                                   j++) {
                                    if ( $scope.printergenerallist[ i ].Certificates[j] ===
                                         searchreq.Certificates ) {
                                          matchlist.push([$scope.printergenerallist[i].printerId,
                                               'Printer Certificates']);
                                    }
                              }
                        }
                  }
            }
      }).$promise;
};
```

Listing 5.3 Find Suitable Printer

```
$q.all([
      general(),
      component(),
      property(),
      plate(),
      envelope()
      ]).then(function () {
            var available = false;
            var maxValue=0;
            var printerId;
            for (var i=0; i<resultlist.length; i++) {
                  resultlist[i][1]= 1;
            }
            for (var k=0; k<matchlist.length; k++) {
                  for (var l=0; l<resultlist.length; l++) {
                        if (matchlist[k][0] === resultlist[l][0]) {
                              resultlist[l][1]= resultlist[l][1] +1;
                              available=true;
                              break;
                        }
                  }
                  if (!available) {
                        resultlist.push([matchlist[k][0],1]);
                  }
            }
            for (var m=0; m<resultlist.length; m++) {
                  if (resultlist[m][1]>maxValue) {
                        maxValue = resultlist[m][1];
                        printerId = resultlist[m][0];
                  }
            }
            Printer.findById( {id: printerId} ).$promise.then(function (printer) {
                alert('Suitable printer is: ' + printer.name); });
      });
```

6. Summary and Outlook

The thesis gives an overview about the variety of technologies in the Additive Manufacturing domain, at the current situation. But it is still an increasing research field, especially the technologies will be improved or new ones will be developed. This can be seen at the Continuous Liquid Interface Production (CLIP) technology published in 2015. Even the European Commission has a research programm in the AM domain, so called "Horizon 2020" and will intensified investigate in the next years [Ver14a]. The output of this thesis is the resource description and the respective ontology. The resource description was was evaluated on the base of the already existing technology and process requirements. So, the evaluated properties describe the resources at the current state. Out of the resource description an ontology was created. Because of the growth of AM, the ontology was developed with the expandability in mind and is therefore adaptable in its structure and relations. It provides a logical and hierarchical structure as a base ground and stands out the relations between the resources. The property names were chosen to be generic. So, a general understanding term was used, to stay manufacturing independent.

Many approaches developing a RDL often are very specific and therefore only valid and applicable under confined circumstances. The ontology of this thesis for the AM domain and in this domain applicable. But it is not manufacturer or technology specific. Therefore, it is valid in the domain without restrictions.

The resource description can be adopted by AM operators and providers of AM services. A typical field of application is the communication of additive manufacturing systems in private networks as well as in Cloud Manufacturing.
The RDL can be extended regarding status information about the printer itself such as how long the printer is still occupied. But also about the material like material stock. So, that a scheduling for automated processing of jobs can take place. This will also lead to optimizing business processes. Another extension could be the cost factor. Here the RDL already includes information about power consumption and consumables etc. So, when it will be extended about material wastage a formal could be deposit to calculate the whole costs for a print job.

The ontology is able to provide information in the AM domain to support automation. It can facilitate implementing interfaces for machine communication and to provide services to other participants in the network.

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All links were last followed on March 13, 2017.

A. Definition

Begriff	Definition	Quelle
3D printer	machine used for 3D printing.	DIN EN ISO/ ASTM 52900
3D printing	fabrication of objects through the deposition of a material using a print head, nozzle, or another printer technology Note 1 to entry: Term often used in a non-technical context synonymously with additive manufacturing; until present times this term has in particular been associated with machines that are low end in price and/or overall capability.	DIN EN ISO/ ASTM 52900
Accuracy	closeness of agreement between an individual result and an accepted reference value	DIN EN ISO/ ASTM 52900
Additive manufacturing	process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies Note 1 to entry: Historical terms: additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, solid freeform fabrication and freeform fabrication. Note 2 to entry: The meaning of "additive-", "subtractive-" and "formative-" manufacturing methodologies are further discussed in Annex A.	DIN EN ISO/ ASTM 52900

Additive Manufacturing File Format	file format for communicating additive manufacturing model data including a description of the 3D surface geometry with native support for colour, materials, lattices, textures, constellations and metadata Note 1 to entry: Additive Manufacturing File Format, the surface geometry is represented by a triangular mesh, but in AMF the triangles may also be curved. AMF can also specify the material and colour of each volume and the colour of each triangle in the mesh. ISO/ ASTM 52915 gives the standard specification of AMF.	DIN EN ISO/ ASTM 52900
Additive manufacturing process	Manufacturing process in which the workpiece is built up in successive layers or units.	VDI 3405
Additive system Additive manufacturing system Additive manufacturing equipment	machine and auxiliary equipment used for additive manufacturing	DIN EN ISO/ ASTM 52900
AM machine	section of the additive manufacturing system including hardware, machine control software, required set-up software and peripheral accessories necessary to complete a build cycle for producing parts	DIN EN ISO/ ASTM 52900
Binder jetting	additive manufacturing process in which a liquid bonding agent is selectively deposited to join powder materials	DIN EN ISO/ ASTM 52900
Build envelope	largest external dimensions of the x-, y-, and z-axes within the build space where parts can be fabricated Note 1 to entry: The dimensions of the build space will be larger than the build envelope.	DIN EN ISO/ ASTM 52900

Build platform	<of a machine> base which provides a surface upon which the building of the part/s, is started and supported throughout the build process Note 1 to entry: In some systems, the parts are built attached to the build platform, either directly or through a support structure. In other systems, such as powder bed systems, no direct mechanical fixture between the build and the platform may be required.	DIN EN ISO/ ASTM 52900 ISO/ ASTM 52921:2013(E)
Build space	location where it is possible for parts to be fabricated, typically within the build chamber or on a build platform	DIN EN ISO/ ASTM 52900
Build surface	area where material is added, normally on the last deposited layer which becomes the foundation upon which the next layer is formed Note 1 to entry: For the first layer, the build surface is often the build platform. Note 2 to entry: In the case of directed energy deposition processes, the build surface can be an existing part onto which material is added. Note 3 to entry: If the orientation of the material deposition or consolidation means, or both, is variable, it may be defined relative to the build surface.	DIN EN ISO/ ASTM 52900 ISO/ ASTM 52921:2013(E)
Build volume	total usable volume available in the machine for building parts	DIN EN ISO/ ASTM 52900
Curing	chemical process which results in the ultimate properties of a finish or other material	DIN EN ISO/ ASTM 52900
Direct manufacturing (rapid manufacturing)	Additive fabrication of end products. Note 1: In direct manufacturing the part has all the characteristics of the end product or is accepted by the customer as suitable for series production. Note 2: Post-processing treatments, e.g. to produce functional surfaces, for heat treatment, etc. may be required before delivery to the customer.	VDI 3405

Directed energy deposition	additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being deposited Note 1 to entry: "Focused thermal energy" means that an energy source (eg laser, electron beam, or plasma arc) is focused to melt the materials being deposited.	DIN EN ISO/ ASTM 52900
Feedstock DEPRECATED: source material, starting material, base material, original material	bulk raw material supplied to the additive manufacturing building process Note 1 to entry: For additive manufacturing building processes, the bulk raw material is typically supplied in various forms such as liquid, powder, suspensions, filaments, sheets, etc.	DIN EN ISO/ ASTM 52900
Fully dense	state in which the material of the fabricated part is without significant content of voids Note 1 to entry: In practice, material completely free of voids is difficult to produce by any manufacturing process and some micro-porosity will generally be present. Note 2 to entry: The significance and the permissible content of voids are typically determined based on the requirements for the application of the final product.	DIN EN ISO/ ASTM 52900
Fusion	act of uniting two or more units of material into a single unit of material	DIN EN ISO/ ASTM 52900
Initial build orientation	<of a part> orientation of the part as it is first placed in the build volume. Note 1 to entry: Initial build orientation is illustrated in ISO/ ASTM 52921.	DIN EN ISO/ ASTM 52900
Job Print Job	a job is the printing order and the tasks a printer must perform to execute the printing order	own research

Laser sintering LS	powder bed fusion process used to produce objects from powdered materials using one or more lasers to selectively fuse or melt the particles at the surface, layer upon layer, in an enclosed chamber Note 1 to entry: Most LS machines partially or fully melt the materials they process. The word "sintering" is a historical term and a misnomer, as the process typically involves full or partial melting, as opposed to traditional powdered metal sintering using a mould and heat and/or pressure.	DIN EN ISO/ ASTM 52900
Layer	<matter> material laid out, or spread, to create a surface	DIN EN ISO/ ASTM 52900
Material extrusion	additive manufacturing process in which material is selectively dispensed through a nozzle or orifice	DIN EN ISO/ ASTM 52900
Material jetting	additive manufacturing process in which droplets of build material are selectively deposited Note 1 to entry: Example materials include photopolymer and wax.	DIN EN ISO/ ASTM 52900
Multi-step process	type of additive manufacturing process in which parts are fabricated in two or more operations where the first typically provides the basic geometric shape and the following consolidates the part to the fundamental properties of the intended material (metallic, ceramic, polymer or composite) Note 1 to entry: Removal of the support structure and cleaning may be necessary, however in this context not considered as a separate process step. Note 2 to entry: The principle of single-step and multi-step processes are further discussed in Annex A.	DIN EN ISO/ ASTM 52900
Near net shape	condition where the components require little post-processing to meet dimensional tolerance	DIN EN ISO/ ASTM 52900
Nesting	situation when parts are made in one build cycle and are located such that their bounding boxes, arbitrarily oriented or otherwise, will overlap	DIN EN ISO/ ASTM 52900

Part	joined material forming a functional element that could constitute all or a section of an intended product Note 1 to entry: The functional requirements for a part are typically determined by the intended application.	DIN EN ISO/ ASTM 52900
Part cake	<in a powder bed fusion process that uses a heated build chamber > lightly bound powder surrounding the fabricated parts at the end of a build cycle.	DIN EN ISO/ ASTM 52900
Part reorientation	rotation around the geometric centre of the part"s bounding box from the specified initial build orientation of that part Note 1 to entry: Part reorientation is illustrated in ISO/ ASTM 52921.	DIN EN ISO/ ASTM 52900
Porosity	<property> presence of small voids in a part making it less than fully dense Note 1 to entry: Porosity may be quantified as a ratio, expressed as a percentage of the volume of voids to the total volume of the part.	DIN EN ISO/ ASTM 52900
Post-processing	<one or more> process steps taken after the completion of an additive manufacturing build cycle in order to achieve the desired properties in the final product	DIN EN ISO/ ASTM 52900
Powder batch	powder used as feedstock which could be used powder, virgin powder or a blend of the two Note 1 to entry: A powder batch could be used in one or more production runs using different process parameters.	DIN EN ISO/ ASTM 52900
Powder bed fusion	additive manufacturing process in which thermal energy selectively fuses regions of a powder bed	DIN EN ISO/ ASTM 52900
Powder bed part bed	build area in an additive manufacturing system in which feedstock is deposited and selectively fused by means of a heat source or bonded by means of an adhesive to build up parts	DIN EN ISO/ ASTM 52900
Production run	all parts produced in one build cycle or sequential series of build cycles using the same feedstock batch and process conditions	DIN EN ISO/ ASTM 52900

Property	is a characteristic description of a thing. In this thesis it describes the characteristics in the AM domain.	own research
Prototype	physical representation of all or a component of a product that, although limited in some way, can be used for analysis, design and evaluation Note 1 to entry: Requirements for parts used as prototypes depend on the individual needs for analysis and evaluation and will therefore typically be determined in agreement between supplier and end-user.	DIN EN ISO/ ASTM 52900
Prototype tooling	moulds, dies, and other devices used for prototyping purposes; sometimes referred to as bridge tooling or soft tooling Note 1 to entry: This type of tooling can sometimes be used to trial the tool design and/or to produce end-use parts while production tooling is being manufactured. On these occasions, the tooling is typically referred to as bridge tooling.	DIN EN ISO/ ASTM 52900
Rapid prototyping	<in additive manufacturing> application of additive manufacturing intended for reducing the time needed for producing prototypes Note 1 to entry: Historically, rapid prototyping (RP) was the first commercially significant application for additive manufacturing, and have therefore been commonly used as a general term for this type of technology.	DIN EN ISO/ ASTM 52900
Rapid tooling	<in additive manufacturing> application of additive manufacturing intended for the production of tools or tooling components with reduced lead times as compared to conventional tooling manufacturing Note 1 to entry: Rapid tooling may be produced directly by the additive manufacturing process or indirectly by producing patterns that are in turn used in a secondary process to produce the actual tools. Note 2 to entry: Besides additive manufacturing, the term "rapid tooling" may also apply to the production of tools with reduced lead times by subtractive manufacturing methods, such as CNC milling, etc.	DIN EN ISO/ ASTM 52900
Sheet lamination	additive manufacturing process in which sheets of material are bonded to form a part	DIN EN ISO/ ASTM 52900

Single-step process	type of additive manufacturing process in which parts are fabricated in a single operation where the basic geometric shape and basic material properties of the intended product are achieved simultaneously Note 1 to entry: Removal of the support structure and cleaning may be necessary, however in this context not considered as a separate process step. Note 2 to entry: The principle of single-step and multi-step processes are further discussed in Annex A.	DIN EN ISO/ ASTM 52900
Support structure	Auxiliary geometry designed to mechanically support overhanging sections of the part. Note: The support structure may be attached either to the build tray or to sections of the part beneath it. Support structures also provide an opportunity to control heat flow.	VDI 3405
Surface model	mathematical or digital representation of an object as a set of planar or curved surfaces, or both, that can, but does not necessarily have to, represent a closed volume	DIN EN ISO/ ASTM 52900
Used powder	powder that has been supplied as feedstock to an AM machine during at least one previous build cycle	DIN EN ISO/ ASTM 52900
Vat photopolymerization	additive manufacturing process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization	DIN EN ISO/ ASTM 52900

B. Ontology

This is the whole ontology of this thesis in RDL/XML format.

```
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xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:owl="http://www.w3.org/2002/07/owl#"
xmlns:xml="http://www.w3.org/XML/1998/namespace"
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xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
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<!--
//////////////////////////////////////////////////////////////////////////////////////
//
// Object Properties
//
//////////////////////////////////////////////////////////////////////////////////////
-->
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//
//
// Data properties
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//
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<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:DatatypeProperty>

<!-- http://www.semanticweb.org/AM#isByte -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isByte">

<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#byte"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isDatatype* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isDatatype"/>

<!-- *http://www.semanticweb.org/AM#isDateTime* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isDateTime">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#dateTime"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isDateTimeStamp* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isDateTimeStamp">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#dateTimeStamp"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isDecimal* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isDecimal">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#decimal"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isDouble* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isDouble">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isFloat* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isFloat">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#float"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isInteger* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isInteger">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isLong* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isLong">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#long"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isNegativeInteger* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isNegativeInteger">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#negativeInteger"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isPositiveInteger* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isPositiveInteger">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#positiveInteger"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isShort* -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isShort">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#short"/>
</owl:DatatypeProperty>

<!-- *http://www.semanticweb.org/AM#isString* -->

```
<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/AM#isString">
<rdfs:subPropertyOf rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:DatatypeProperty>

<!--
////////////////////////////////////////////////////////////////////////////////////
//
// Classes
//
////////////////////////////////////////////////////////////////////////////////////
-->
<!-- http://www.semanticweb.org/AM#AbsoluteDensity_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#AbsoluteDensity_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Density_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Acceleration_PrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Acceleration_PrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintBed_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">In case of moveable print bed this denotes the acceleration of the print bed.</rdfs:comment>
<rdfs:label xml:lang="en">Acceleration_PrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Acceleration_PrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Acceleration_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasHead"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The maximum acceleration that the print head is capable of.</rdfs:comment>
<rdfs:label xml:lang="en">Acceleration_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#AcceptedFileFormats_Software -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#AcceptedFileFormats_Software">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Software_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
```

<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">A list of file formats that the 3D printer is capable of processing.</rdfs:comment>
<rdfs:label **xml:lang**="en">AcceptedFileFormats_Software</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ActiveCooling_PrinterComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ActiveCooling_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Component_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Indicator if the printer is actively cooled using a fan or not.</rdfs:comment>
<rdfs:label **xml:lang**="en">ActiveCooling_PrinterComponent</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#AllowedGroups_printer* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#AllowedGroups_printer">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Process_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">A list of all user−groups allowed to work on or with the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">AllowedGroups_Printer</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#AllowedMaterial_printer* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#AllowedMaterial_printer">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Printer_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">A list of materials that are processable by the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">AllowedMaterial_Printer</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#AllowedUsers_printer* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#AllowedUsers_printer">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Process_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">A list of all users allowed to work on or with the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">AllowedUsers_Printer</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#AnchorLength_PreProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#AnchorLength_PreProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PreProcess_Technology"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Atmosphere_Process* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Atmosphere_Process">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Process_Category"/>
<rdfs:comment **xml:lang**="en">Atmosphere requirements of the printer</rdfs:comment>
<rdfs:label **xml:lang**="en">Atmosphere_Process</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#BeamFocus_Diameter* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#BeamFocus_Diameter">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Diameter_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasBeam"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#ElectronBeam_PrinterHeadComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasBeam"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#ElectronBeam_PrinterHeadComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The diameter of the laser beam.</rdfs:comment>
<rdfs:label **xml:lang**="en">BeamFocus_Diameter</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Binder_Material -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Binder_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">A list of materials that can be used as a binder for a 3D printer, if a binder is neccessary.</rdfs:comment>
<rdfs:label **xml:lang**="en">Binder_Material</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#BuildEnvelope_PrinterComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#BuildEnvelope_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Component_Printer"/>
<rdfs:comment **xml:lang**="en">Properties which are relevant for the build envelope like size etc.</rdfs:comment>
<rdfs:label **xml:lang**="en">BuildEnvelope_PrinterComponent</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#BuildPlate_PrinterComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#BuildPlate_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Component_Printer"/>
<rdfs:comment **xml:lang**="en">Properties which are relevant for the build plate/print bed like size etc.</rdfs:comment>
<rdfs:label **xml:lang**="en">BuildPlate_PrinterComponent</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#CarbonContent_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#CarbonContent_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Category -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Category">
<rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
<rdfs:comment **xml:lang**="en">The category, the information description depends on.</rdfs:comment>
<rdfs:label **xml:lang**="en">Category</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#CathodeType_PrinterHeadComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#CathodeType_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasBeam"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#ElectronBeam_PrinterHeadComponent"/>
</owl:Restriction>

```
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasBeam"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#ElectronBeam_PrinterHeadComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Describes the cathode, i.e. the electron source, of the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">CathodeType_PrinterHeadComponent</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Certificates_Printer -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Certificates_Printer">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Printer_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">A list of legal conformity certificates for the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">Certificates_Printer</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Certification_LaserPrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Certification_LaserPrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Laser_PrintHeadProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Describes the certification for the laser unit in the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">Certification_LaserPrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Class_LaserPrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Class_LaserPrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Laser_PrintHeadProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isInteger"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
```

<rdfs:comment **xml:lang**="en">Classification for the laser system of the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">Class_LaserPrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Clearance_Material* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Clearance_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Distance required between any parts of the object or between objects to avoid fusing.</rdfs:comment>
<rdfs:label **xml:lang**="en">Clearance_Material</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#CoefficientOfThermalExpansion_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#CoefficientOfThermalExpansion_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Temperature_PropertyMaterial"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ColdPause_Software* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ColdPause_Software">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Software_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Ability to halt and resume a print for a longer period of time.</rdfs:comment>
<rdfs:label **xml:lang**="en">ColdPause_Software</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ColorRange_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ColorRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Color_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The range of colors that are printable by the 3D printer, i.e. black, white, red.</rdfs:comment>
<rdfs:label **xml:lang**="en">ColorRange_PrinterProperty</rdfs:label>

```
</owl:Class>

<!-- http://www.semanticweb.org/AM#Color_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Color_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:comment xml:lang="en">Color properties of the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">Color_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#CommunicationInterfaces_MachineProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#CommunicationInterfaces_MachineProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#MachineProperty_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The connection from the 3D printer to workstation or network.</rdfs:comment>
<rdfs:label xml:lang="en">CommunicationInterfaces_MachineProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Component_Printer -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Component_Printer">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Printer_Technology"/>
<rdfs:comment xml:lang="en">Properties of the printers components.</rdfs:comment>
<rdfs:label xml:lang="de">Component_Printer</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#CompressedAir_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#CompressedAir_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Specification of the required compressed air connection to the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">CompressedAir_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#CompressiveStrenght_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#CompressiveStrenght_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Connection_AtmosphereProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Connection_AtmosphereProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Atmosphere_Process"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
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<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The connection of the 3D printer for externally connected atmospheric supply systems.</rdfs:comment>
<rdfs:label **xml:lang**="en">Connection_AtmosphereProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Consumables_InProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Consumables_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#InProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">A list of consumables which required for the printing process.</rdfs:comment>
<rdfs:label **xml:lang**="en">Consumables_InProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Consume_AtmosphereProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Consume_AtmosphereProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Atmosphere_Process"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Specification of the amount of externally supplied atmosphere the 3D printer is consuming during a printing process.</rdfs:comment>
<rdfs:label **xml:lang**="en">Consume_AtmosphereProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Content_AtmosphereProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Content_AtmosphereProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Atmosphere_Process"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>

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</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Content_AtmosphereProcess</rdfs:comment>
<rdfs:comment xml:lang="en">The required atmospheric makeup for the 3D printers build envelope.</rdfs:comment>
</owl:Class>

<!-- http://www.semanticweb.org/AM#CoordinateSystem_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#CoordinateSystem_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Cartesian, Polar, Spherical or other coordinate system that is used by the printer for movement and positioning and the origin
        point of the coordinate system.</rdfs:comment>
<rdfs:label xml:lang="en">CoordinateSystem_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Corrosion_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Corrosion_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#CrystallineStructure_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#CrystallineStructure_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Cytotoxicity_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Cytotoxicity_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isInteger"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Density_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Density_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
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<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#DepositionRate_PrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#DepositionRate_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasHead"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Rate of which material is deposited, i.e. at which rate an object is printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">DepositionRate_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Depth_BuildEnvelope* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Depth_BuildEnvelope">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildEnvelope_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The depth of the build envelope.</rdfs:comment>
<rdfs:label **xml:lang**="en">Depth_BuildEnvelope</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Depth_BuildPlate* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Depth_BuildPlate">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildPlate_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>

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</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The depth of the build plate/print bed.</rdfs:comment>
<rdfs:label xml:lang="en">Depth_BuildPlate</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Depth_MachineProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Depth_MachineProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#MachineProperty_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The machine dimension (Depth).</rdfs:comment>
<rdfs:label xml:lang="en">Depth_MachineProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Diameter_PrinterComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Diameter_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Descirption of relevant diameter.</rdfs:comment>
<rdfs:label xml:lang="en">Diameter_PrinterComponent</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#DielectricConstant_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#DielectricConstant_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Dielectric_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#DielectricStrength_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#DielectricStrength_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Dielectric_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Dielectric_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Dielectric_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
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<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#DistributionMechanism_PrinterComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#DistributionMechanism_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Component_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Describes the method the powder is spread for the next layer.</rdfs:comment>
<rdfs:label **xml:lang**="en">DistributionMechanism_PrinterComponent</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Ductility_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Ductility_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ElectricalInput_MachineProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ElectricalInput_MachineProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#MachineProperty_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The power consumption of the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">ElectricalInput_MachineProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ElectricalResitivity_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ElectricalResitivity_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>

```
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ElectronBeam_PrinterHeadComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ElectronBeam_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeadType_PrinterHeadComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBeamOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#BeamFocus_Diameter"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBeamOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#CathodeType_PrinterHeadComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBeamOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#VacuumPressure_InProcess"/>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#EmbossDetail_Material -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#EmbossDetail_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Size defintion of embossed detail on an object to be printed.</rdfs:comment>
<rdfs:label xml:lang="en">EmbossDetail_Material</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Enclosed_BuildEnvelope -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Enclosed_BuildEnvelope">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildEnvelope_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Indicator for presence of an enclosed build envelope.</rdfs:comment>
<rdfs:label xml:lang="en">Enclosed_BuildEnvelope</rdfs:label>
```

```
</owl:Class>

<!-- http://www.semanticweb.org/AM#EngravedDetail_Material -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#EngravedDetail_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Size defintion of engraved detail on an object to be printed.</rdfs:comment>
<rdfs:label xml:lang="en">EngravedDetail_Material</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactHeightRange_EmbossDetailMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactHeightRange_EmbossDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeightRange_EmbossDetailMaterial"/>
<rdfs:comment xml:lang="en">Possible height of embossed detail on an object to be printed.</rdfs:comment>
<rdfs:label xml:lang="en">ExactHeightRange_EmbossDetailMaterial</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactHeightRange_EngravedDetailMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactHeightRange_EngravedDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeightRange_EngravedDetailMaterial"/>
<rdfs:comment xml:lang="en">Possible height of engraved detail on an object to be printed.</rdfs:comment>
<rdfs:label xml:lang="en">ExactHeightRange_EngravedDetailMaterial</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactLayerThicknessRange_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactLayerThicknessRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#LayerThicknessRange_PrinterProperty"/>
<rdfs:comment xml:lang="en">The exact layer thickness that the 3D printer is capable of printing.</rdfs:comment>
<rdfs:label xml:lang="en">ExactLayerThicknessRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactMaterialGrainSizeRange_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactMaterialGrainSizeRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#MaterialGrainSizeRange_PrinterProperty"/>
<rdfs:comment xml:lang="en">The exact size of powder grains that the 3D printer can process.</rdfs:comment>
<rdfs:label xml:lang="en">ExactMaterialGrainSizeRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactOperatingHumidity_InProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactOperatingHumidity_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#OperatingHumidityRange_InProcess"/>
<rdfs:comment xml:lang="en">The exact ambient humidity the 3D printer is specified for operation, if available.</rdfs:comment>
<rdfs:label xml:lang="en">ExactOperatingHumidity_InProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactOperatingTemperature_InProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactOperatingTemperature_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#OperatingTemperatureRange_InProcess"/>
<rdfs:comment xml:lang="en">The exact ambient temperature the 3D printer is specified for operation.</rdfs:comment>
<rdfs:label xml:lang="en">ExactOperatingTemperature_InProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactScanningSpeedRange_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactScanningSpeedRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ScanningSpeedRange_PrinterProperty"/>
<rdfs:comment xml:lang="en">The exact speed that the laser beam can scan across the build surface.</rdfs:comment>
<rdfs:label xml:lang="en">ExactScanningSpeedRange_PrinterProperty</rdfs:label>
```

</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactSpeedExtrusionRange_PrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactSpeedExtrusionRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#SpeedExtrusionRange_PrintHeadProperty"/>
<rdfs:comment **xml:lang**="en">The speed that the print head can be moved while extruding.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactSpeedExtrusionRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactSpeedMovementRange_PrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactSpeedMovementRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#SpeedMovementRange_PrintHeadProperty"/>
<rdfs:comment **xml:lang**="en">The speed that the print head can be moved without any extrusion.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactSpeedMovementRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactTemperatureNozzleRange_PrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactTemperatureNozzleRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#TemperatureNozzleRange_PrintHeadProperty"/>
<rdfs:comment **xml:lang**="en">The temperature an extruder can achieve.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactTemperatureNozzleRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactTemperatureRange_PrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactTemperatureRange_PrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#TemperatureRange_PrintBedProperty"/>
<rdfs:comment **xml:lang**="en">The temperature the print bed can be set to.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactTemperatureRange_PrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactWidthRange_EmbossDetailMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactWidthRange_EmbossDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#WidthRange_EmbossDetailMaterial"/>
<rdfs:comment **xml:lang**="en">Possible width of embossed detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactWidthRange_EmbossDetailMaterial</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactWidthRange_EngravedDetailMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactWidthRange_EngravedDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#WidthRange_EngravedDetailMaterial"/>
<rdfs:comment **xml:lang**="en">Possible width of engraved detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactWidthRange_EngravedDetailMaterial</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactXRange_AccelerationPrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactXRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#XRange_AccelerationPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the exact acceleration of the print bed in the X axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactXRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactXRange_PrintObjectProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactXRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#XRange_PrintObjectProperty"/>
<rdfs:comment **xml:lang**="en">The exact size (along the X axis) of any object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactXRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactXRange_SpeedPrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactXRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#XRange_SpeedPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the exact speed that the print bed can be moved in the X axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactXRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactYRange_AccelerationPrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactYRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#YRange_AccelerationPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the exact acceleration of the print bed in the Y axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">ExactYRange_AccelerationPrintBedProperty</rdfs:label>

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</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactYRange_PrintObjectProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactYRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#YRange_PrintObjectProperty"/>
<rdfs:comment xml:lang="en">The exact size (along the Y axis) of any object to be printed.</rdfs:comment>
<rdfs:label xml:lang="en">ExactYRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactYRange_SpeedPrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactYRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#YRange_SpeedPrintBedProperty"/>
<rdfs:comment xml:lang="en">In case of a moveable print bed this denotes the exact speed that the print bed can be moved in the Y axis.</rdfs:comment>
<rdfs:label xml:lang="en">ExactYRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactZRange_AccelerationPrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactZRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ZRange_AccelerationPrintBedProperty"/>
<rdfs:comment xml:lang="en">In case of moveable print bed this denotes the exact acceleration of the print bed in the Z axis.</rdfs:comment>
<rdfs:label xml:lang="en">ExactZRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactZRange_PrintObjectProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactZRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ZRange_PrintObjectProperty"/>
<rdfs:comment xml:lang="en">The exact size (along the Z axis) of any object to be printed.</rdfs:comment>
<rdfs:label xml:lang="en">ExactZRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ExactZRange_SpeedPrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ExactZRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ZRange_SpeedPrintBedProperty"/>
<rdfs:comment xml:lang="en">In case of a moveable print bed this denotes the exact speed that the print bed can be moved in the Z axis.</rdfs:comment>
<rdfs:label xml:lang="en">ExactZRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Exact_Value -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Exact_Value">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Value"/>
<rdfs:comment xml:lang="en">The class of exact values, if available.</rdfs:comment>
<rdfs:label xml:lang="en">Exact_Value</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#FilamentDiameter_Material -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#FilamentDiameter_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:comment xml:lang="en">Diameter of the filament usable with the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">FilamentDiameter_Material</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Firmware_Category -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Firmware_Category">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Software_Category"/>
<rdfs:comment xml:lang="en">Information about the printers firmware.</rdfs:comment>
<rdfs:label xml:lang="en">Firmware_Category</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Flammability_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Flammability_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
```

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</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#FlexuralModulus_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#FlexuralModulus_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Flexural_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#FlexuralStrength_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#FlexuralStrength_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Flexural_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Flexural_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Flexural_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#FrictionalCoefficient_MaterialProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#FrictionalCoefficient_MaterialProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Hardness_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Hardness_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#HeadType_PrinterHeadComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#HeadType_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
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<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Description which head is installed in the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">HeadType_PrinterHeadComponent</rdfs:label>
</owl:Class>

<!– – *http://www.semanticweb.org/AM#HeatDeflectionTemperature_materialporperty* – – >

<owl:Class rdf:about="http://www.semanticweb.org/AM#HeatDeflectionTemperature_materialporperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Temperature_PropertyMaterial"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasPressure"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Atmosphere_Process"/>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!– – *http://www.semanticweb.org/AM#HeatUpTime_BuildPlate* – – >

<owl:Class rdf:about="http://www.semanticweb.org/AM#HeatUpTime_BuildPlate">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildPlate_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Time required for the build plate/print bed to heat up to operating temperature.</rdfs:comment>
<rdfs:label **xml:lang**="en">HeatUpTime_BuildPlate</rdfs:label>
</owl:Class>

<!– – *http://www.semanticweb.org/AM#HeaterCartridge_PrinterProperty* – – >

<owl:Class rdf:about="http://www.semanticweb.org/AM#HeaterCartridge_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Power consumption of the heating cartridge.</rdfs:comment>
<rdfs:label **xml:lang**="en">HeaterCartridge_PrinterProperty</rdfs:label>
</owl:Class>

<!– – *http://www.semanticweb.org/AM#HeightRange_EmbossDetailMaterial* – – >

<owl:Class rdf:about="http://www.semanticweb.org/AM#HeightRange_EmbossDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#EmbossDetail_Material"/>
<rdfs:comment **xml:lang**="en">Possible height range (from min to max) of embossed detail on an object to be printed.</rdfs:comment>

<rdfs:label **xml:lang**="en">HeightRange_EmbossDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#HeightRange_EngravedDetailMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#HeightRange_EngravedDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#EngravedDetail_Material"/>
<rdfs:comment **xml:lang**="en">Possible height range (from min to max) of engraved detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">HeightRange_EngravedDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Height_BuildEnvelope* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Height_BuildEnvelope">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildEnvelope_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The height of the build envelope.</rdfs:comment>
<rdfs:label **xml:lang**="en">Height_BuildEnvelope</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Height_BuildPlate* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Height_BuildPlate">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildPlate_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The height of the build plate/print bed.</rdfs:comment>
<rdfs:label **xml:lang**="en">Height_BuildPlate</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Height_MachineProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Height_MachineProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#MachineProperty_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The machine dimension (Height)</rdfs:comment>

<rdfs:label **xml:lang**="en">Height_MachineProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#HotPause_Software* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#HotPause_Software">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Software_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Ability to pause a print without cooling the extruders.</rdfs:comment>
<rdfs:label **xml:lang**="en">HotPause_Software</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Idle_NoisePrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Idle_NoisePrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Noise_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The amount of noise emitted by the 3D printer while idle.</rdfs:comment>
<rdfs:label **xml:lang**="en">Idle_NoisePrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ImpactStrength_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ImpactStrength_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#InProcess_Technology* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#InProcess_Technology">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Technology_Category"/>
<rdfs:comment **xml:lang**="en">Describes the manufacturing operations resulting from pre−processing which are performed by the additive manufacturing system. (VDI 3405)</rdfs:comment>
<rdfs:label **xml:lang**="en">InProcess_Technology</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#InfillPattern_Software* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#InfillPattern_Software">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Software_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>

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</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">A list of available infill patterns for  non solid  printing .</rdfs:comment>
<rdfs:label  xml:lang="en">InfillPattern_Software</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#InfraredLamp_PrinterHeadComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#InfraredLamp_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeadType_PrinterHeadComponent"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Installation_Process -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Installation_Process">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Process_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Requirements for installing the printer.</rdfs:comment>
<rdfs:label  xml:lang="en">Installation_Process</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#InterlockingParts_Material -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#InterlockingParts_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Indicator if the printing of interlocking parts is  feasible .</rdfs:comment>
<rdfs:label  xml:lang="en">InterlockingParts_Material</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#InternalLightning_PrinterComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#InternalLightning_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Component_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
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</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Describes if and what kind of internal lighting is present in the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">InternalLightning_PrinterComponent</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#InternalSerialNumber_ModelPrinterType -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#InternalSerialNumber_ModelPrinterType">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Model_PrinterType"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">To be distinguished between the manufacturer assigned serial number, and possibly a serial number within the institution that
        utilizes the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">InternalSerialNumber_ModelPrinterType</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#LaserType_PrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#LaserType_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Laser_PrintHeadProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">A specification of the laser type.</rdfs:comment>
<rdfs:label xml:lang="en">LaserType_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Laser_HeadTypePrinterComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Laser_HeadTypePrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeadType_PrinterHeadComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isLaserOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Certification_LaserPrintHeadProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isLaserOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Class_LaserPrintHeadProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isLaserOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#LaserType_PrintHeadProperty"/>
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</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isLaserOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#OutputEnergy_LaserPrintHeadProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isLaserOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#WaveLength_LaserPrintHeadProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Laser_PrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Laser_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasLaser"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#Laser_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasLaser"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Laser_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:label xml:lang="en">Laser_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#LayerThicknessRange_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#LayerThicknessRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The layer size that the 3D printer is capable of printing (min to max).</rdfs:comment>
<rdfs:label xml:lang="en">LayerThicknessRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#LeadTime_PreProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#LeadTime_PreProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PreProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
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</owl:Restriction>
</rdfs:subClassOf>
<rdfs:label xml:lang="en">LeadTime_PreProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#LevelingMode_BuildPlate -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#LevelingMode_BuildPlate">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildPlate_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Describes the mechanism that is used to level the build plate/print bed.</rdfs:comment>
<rdfs:label xml:lang="en">LevelingMode_BuildPlate</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#LocationofPrinter_Process -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#LocationofPrinter_Process">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Process_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Deinfition of the printers location.</rdfs:comment>
<rdfs:label xml:lang="en">LocationPrinter_Process</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MachineProperty_Printer -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MachineProperty_Printer">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Printer_Technology"/>
<rdfs:label xml:lang="en">MachineProperty_Printer</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MacroRockwellC_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MacroRockwellC_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Hardness_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MagneticPermeability_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MagneticPermeability_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
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</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ManualInteraction_PostProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ManualInteraction_PostProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PostProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Indicator that states if personal attendance during the stopping process is required or not.</rdfs:comment>
<rdfs:label xml:lang="en">ManualInteraction_PostProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ManualInteraction_PreProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ManualInteraction_PreProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PreProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Indicator that states if personal attendance during the preparatory process is required or not.</rdfs:comment>
<rdfs:label xml:lang="en">ManualInteraction_PreProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Manufacturer_PrinterType -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Manufacturer_PrinterType">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Type_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The manufacturer of the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">Manufacturer_PrinterType</rdfs:label>
</owl:Class>
```

<!-- *http://www.semanticweb.org/AM#MaterialFormat_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaterialFormat_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Describes the format in which the material is provided to the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaterialFormat_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaterialGrainSizeRange_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaterialGrainSizeRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The size of powder grains that the 3D printer can process (min to max).</rdfs:comment>
<rdfs:label **xml:lang**="en">MaterialGrainSizeRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaterialRecognition_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaterialRecognition_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Indicator for the presence of any kind of automatic material recognition system in the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaterialRecognition_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaterialTypes_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaterialTypes_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>

<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Catgory of available material state. For example, a instance could be solid, liquid, or powder.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaterialTypes_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Material_BuildEnvelope* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Material_BuildEnvelope">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildEnvelope_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Material_Category* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Material_Category">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Category"/>
<rdfs:comment **xml:lang**="en">Encompasses all physical materials that are processed, or used during the digital fabrication. Also includes physical materials that are required for the digital fabrication process as indirect or auxiliary material.</rdfs:comment>
<rdfs:label **xml:lang**="en">Material_Category</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxAngle_OverhangMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxAngle_OverhangMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Overhang_Material"/>
<rdfs:comment **xml:lang**="en">The angle up to which slopes can be constructed without the requirement of supporting structures.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxAngle_OverhangMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxHeightRange_EmbossDetailMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxHeightRange_EmbossDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeightRange_EmbossDetailMaterial"/>
<rdfs:comment **xml:lang**="en">Maximum height of embossed detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxHeightRange_EmbossDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxHeightRange_EngravedDetailMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxHeightRange_EngravedDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeightRange_EngravedDetailMaterial"/>
<rdfs:comment **xml:lang**="en">Maximum possible height of engraved detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxHeightRange_EngravedDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxLayerThicknessRange_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxLayerThicknessRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#LayerThicknessRange_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The maximum layer thickness that the 3D printer is capable of printing.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxLayerThicknessRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxMaterialGrainSizeRange_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxMaterialGrainSizeRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#MaterialGrainSizeRange_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The maximum size of powder grains that the 3D printer can process.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxMaterialGrainSizeRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxOperatingHumidity_InProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxOperatingHumidity_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#OperatingHumidityRange_InProcess"/>
<rdfs:comment **xml:lang**="en">The highest ambient humidity the 3D printer is specified for operation.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxOperatingHumidity_InProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxOperatingTemperature_InProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxOperatingTemperature_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#OperatingTemperatureRange_InProcess"/>
<rdfs:comment **xml:lang**="en">The highest ambient temperature the 3D printer is specified for operation.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxOperatingTemperature_InProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxScanningSpeedRange_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxScanningSpeedRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ScanningSpeedRange_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The maximum speed that the laser beam can scan across the build surface.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxScanningSpeedRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxSpeedExtrusionRange_PrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxSpeedExtrusionRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#SpeedExtrusionRange_PrintHeadProperty"/>
<rdfs:comment **xml:lang**="en">The maximun speed that the print head can be moved while extruding.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxSpeedExtrusionRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxSpeedMovementRange_PrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxSpeedMovementRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#SpeedMovementRange_PrintHeadProperty"/>
<rdfs:comment **xml:lang**="en">The maximum speed that the print head can be moved without any extrusion.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxSpeedMovementRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxSurfaceRoughness_Material* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxSurfaceRoughness_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The maximum average achievable surface roughness for a 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxSurfaceRoughness_Material</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxTemperatureNozzleRange_PrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxTemperatureNozzleRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#TemperatureNozzleRange_PrintHeadProperty"/>
<rdfs:comment **xml:lang**="en">The maximum temperature an extruder can achieve.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxTemperatureNozzleRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxTemperatureRange_PrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxTemperatureRange_PrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#TemperatureRange_PrintBedProperty"/>
<rdfs:comment **xml:lang**="en">The maximum temperature the print bed can be set to.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxTemperatureRange_PrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxWeight_PrintObjectProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxWeight_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintObject_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">Denotes the maximum weight, all objects of a build can have without skewing or damaging the build plate.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxWeight_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxWidthRange_EmbossDetailMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxWidthRange_EmbossDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#WidthRange_EmbossDetailMaterial"/>
<rdfs:comment **xml:lang**="en">Maxium width of embossed detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxWidthRange_EmbossDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxWidthRange_EngravedDetailMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxWidthRange_EngravedDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#WidthRange_EngravedDetailMaterial"/>
<rdfs:comment **xml:lang**="en">Maximum possible width of engraved detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxWidthRange_EngravedDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxXRange_AccelerationPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxXRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#XRange_AccelerationPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the maximum acceleration of the print bed in the X axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxXRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxXRange_PrintObjectProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxXRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#XRange_PrintObjectProperty"/>
<rdfs:comment **xml:lang**="en">The maximum size (along the X axis) of any object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxXRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxXRange_SpeedPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxXRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#XRange_SpeedPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the maximum speed that the print bed can be moved in the X
axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxXRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxYRange_AccelerationPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxYRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#YRange_AccelerationPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the maximum acceleration of the print bed in the Y axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxYRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxYRange_PrintObjectProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxYRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#YRange_PrintObjectProperty"/>
<rdfs:comment **xml:lang**="en">The maximum size (along the Y axis) of any object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxYRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MaxYRange_SpeedPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxYRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#YRange_SpeedPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the maximum speed that the print bed can be moved in the Y
axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxYRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MaxZRange_AccelerationPrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxZRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ZRange_AccelerationPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the maximum acceleration of the print bed in the Z axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxZRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MaxZRange_PrintObjectProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxZRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ZRange_PrintObjectProperty"/>
<rdfs:comment **xml:lang**="en">The maximum size (along the Z axis) of any object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxZRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MaxZRange_SpeedPrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MaxZRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ZRange_SpeedPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the maximum speed that the print bed can be moved in the Z
axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MaxZRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Max_Value -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Max_Value">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Range_Value"/>
<rdfs:comment **xml:lang**="en">The maximum of the value range.</rdfs:comment>
<rdfs:label **xml:lang**="en">Max_Value</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MeltingPoint_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MeltingPoint_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MicroVickers_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MicroVickers_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Hardness_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MinCPU_Workstation -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinCPU_Workstation">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Workstation_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>

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</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The minimum CPU speed required for the workstation controlling the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">MinCPU_Workstation</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MinHeightRange_EmbossDetailMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinHeightRange_EmbossDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeightRange_EmbossDetailMaterial"/>
<rdfs:comment xml:lang="en">Minimum height of embossed detail on an object to be printed.</rdfs:comment>
<rdfs:label xml:lang="en">MinHeightRange_EmbossDetailMaterial</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MinHeightRange_EngravedDetailMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinHeightRange_EngravedDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeightRange_EngravedDetailMaterial"/>
<rdfs:comment xml:lang="en">Minimum possible height of engraved detail on an object to be printed.</rdfs:comment>
<rdfs:label xml:lang="en">MinHeightRange_EngravedDetailMaterial</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MinHoleDiameter_InProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinHoleDiameter_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#InProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Description of the minimum hole diameter possible to print.</rdfs:comment>
<rdfs:label xml:lang="en">MinHoleDiameter_InProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MinInstallationDepth_InstallationProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinInstallationDepth_InstallationProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Installation_Process"/>
<rdfs:comment xml:lang="en">The depth required for the installation/placement of the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">MinInstallationDepth_InstallationProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MinInstallationHeight_InstallationProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinInstallationHeight_InstallationProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Installation_Process"/>
<rdfs:comment xml:lang="en">The height required for the installation/placement of the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">MinInstallationHeight_InstallationProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MinInstallationWidth_InstallationProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinInstallationWidth_InstallationProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Installation_Process"/>
<rdfs:comment xml:lang="en">The width required for the installation/placement of the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">MinInstallationWidth_InstallationProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MinLayerThicknessRange_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinLayerThicknessRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#LayerThicknessRange_PrinterProperty"/>
<rdfs:comment xml:lang="en">The minimum layer thickness that the 3D printer is capable of printing.</rdfs:comment>
<rdfs:label xml:lang="en">MinLayerThicknessRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#MinMaterialGrainSizeRange_PrinterProperty -->
```

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinMaterialGrainSizeRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#MaterialGrainSizeRange_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The minimum size of powder grains that the 3D printer can process.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinMaterialGrainSizeRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinOperatingHumidity_InProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinOperatingHumidity_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#OperatingHumidityRange_InProcess"/>
<rdfs:comment **xml:lang**="en">The lowest ambient humidity the 3D printer is specified for operation.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinOperatingHumidity_InProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinOperatingTemperature_InProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinOperatingTemperature_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#OperatingTemperatureRange_InProcess"/>
<rdfs:comment **xml:lang**="en">The lowest ambient temperature the 3D printer is specified for operation.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinOperatingTemperature_InProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinRAM_Workstation* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinRAM_Workstation">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Workstation_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The minimum amount of RAM required for the workstation controlling the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinRAM_Workstation</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinScanningSpeedRange_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinScanningSpeedRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ScanningSpeedRange_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The minimum speed that the laser beam can scan across the build surface.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinScanningSpeedRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinSpeedExtrusionRange_PrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinSpeedExtrusionRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#SpeedExtrusionRange_PrintHeadProperty"/>
<rdfs:comment **xml:lang**="en">The minimum speed that the print head can be moved while extruding.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinSpeedExtrusionRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinSpeedMovementRange_PrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinSpeedMovementRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#SpeedMovementRange_PrintHeadProperty"/>
<rdfs:comment **xml:lang**="en">The minimum speed that the print head can be moved without any extrusion.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinSpeedMovementRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinTemperatureNozzleRange_PrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinTemperatureNozzleRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#TemperatureNozzleRange_PrintHeadProperty"/>
<rdfs:comment **xml:lang**="en">The minimum temperature an extruder can achieve.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinTemperatureNozzleRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinTemperatureRange_PrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinTemperatureRange_PrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#TemperatureRange_PrintBedProperty"/>
<rdfs:comment **xml:lang**="en">The minimum temperature the print bed can be set to.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinTemperatureRange_PrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinWallThickness_InProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinWallThickness_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#InProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Minimum thickness of any wall (that is supported) of an object that is to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinWallThickness_InProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinWidthRange_EmbossDetailMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinWidthRange_EmbossDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#WidthRange_EmbossDetailMaterial"/>
<rdfs:comment **xml:lang**="en">Minimum width of embossed detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinWidthRange_EmbossDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinWidthRange_EngravedDetailMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinWidthRange_EngravedDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#WidthRange_EngravedDetailMaterial"/>
<rdfs:comment **xml:lang**="en">Minimum possible width of engraved detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinWidthRange_EngravedDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinXRange_AccelerationPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinXRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#XRange_AccelerationPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the minimum acceleration of the print bed in the X axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinXRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinXRange_PrintObjectProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinXRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#XRange_PrintObjectProperty"/>
<rdfs:comment **xml:lang**="en">The minimum size (along the X axis) of any object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinXRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinXRange_SpeedPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinXRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#XRange_SpeedPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the minimum speed that the print bed can be moved in the X
axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinXRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinYRange_AccelerationPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinYRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#YRange_AccelerationPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the minimum acceleration of the print bed in the Y axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinYRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinYRange_PrintObjectProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinYRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#YRange_PrintObjectProperty"/>
<rdfs:comment **xml:lang**="en">The minimum size (along the Y axis) of any object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinYRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinYRange_SpeedPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinYRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#YRange_SpeedPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the minimum speed that the print bed can be moved in the Y axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinYRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinZRange_AccelerationPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinZRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ZRange_AccelerationPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the minimum acceleration of the print bed in the Z axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinZRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinZRange_PrintObjectProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinZRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ZRange_PrintObjectProperty"/>
<rdfs:comment **xml:lang**="en">The minimum size (along the Z axis) of any object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinZRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#MinZRange_SpeedPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#MinZRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#ZRange_SpeedPrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the minimum speed that the print bed can be moved in the Z axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">MinZRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Min_Value* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Min_Value">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Range_Value"/>
<rdfs:comment **xml:lang**="en">The minimum of the value range.</rdfs:comment>
<rdfs:label **xml:lang**="en">Min_Value</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Model_PrinterType* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Model_PrinterType">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Type_Printer"/>
<rdfs:comment **xml:lang**="en">Properties which describes the printer model.</rdfs:comment>
<rdfs:label **xml:lang**="en">Model_PrinterType</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Motor_PrinterComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Motor_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Component_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Description of printers motors.</rdfs:comment>
<rdfs:label **xml:lang**="en">Motor_PrinterComponent</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Name_FirmwareCategory -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Name_FirmwareCategory">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Firmware_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Describes the firmware that is installed on the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">Name_FirmwareCategory</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Net_Workstation -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Net_Workstation">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Workstation_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The specification for the network connection required for the workstation controlling the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">Net_Workstation</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#NetworkConnectivity_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#NetworkConnectivity_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Describes kind and speed of the network connectivity of the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">NetworkConnectivity_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Noise_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Noise_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>

<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The amount of noise emitted by the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">Noise_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#NozzleHeatUpTime_PrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#NozzleHeatUpTime_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasHeatingCartridge"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/AM#HeaterCartridge_PrinterProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasHead"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasHead"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Time required for the extruder to heat up to operating temperature, most commonly about 240 deg C.</rdfs:comment>
<rdfs:label **xml:lang**="en">NozzleHeatUpTime_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#NozzleOffsetX_PrinterHeadComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#NozzleOffsetX_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#NozzleOffset_PrinterHeadComponent"/>
<rdfs:comment **xml:lang**="en">For multi−nozzle systems, the offset of each nozzle to the middle of the print head (X axis).</rdfs:comment>
<rdfs:label **xml:lang**="en">NozzleOffsetX_PrinterHeadComponent</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#NozzleOffsetY_PrinterHeadComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#NozzleOffsetY_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#NozzleOffset_PrinterHeadComponent"/>
<rdfs:comment **xml:lang**="en">For multi−nozzle systems, the offset of each nozzle to the middle of the print head (Y axis).</rdfs:comment>
<rdfs:label **xml:lang**="en">NozzleOffsetY_PrinterHeadComponent</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#NozzleOffsetZ_PrinterHeadComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#NozzleOffsetZ_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#NozzleOffset_PrinterHeadComponent"/>

<rdfs:comment **xml:lang**="en">For multi−nozzle systems, the offset of each nozzle to the middle of the print head (Z axis).</rdfs:comment>
<rdfs:label **xml:lang**="en">NozzleOffsetZ_PrinterHeadComponent</rdfs:label>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#NozzleOffset_PrinterHeadComponent* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#NozzleOffset_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasHead"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasHead"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">For multi−nozzle systems, the offset of each nozzle to the middle of the print head.</rdfs:comment>
<rdfs:label **xml:lang**="en">NozzleOffset_PrinterHeadComponent</rdfs:label>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#Nozzle_Diameter* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#Nozzle_Diameter">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Diameter_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The diameter of each extruder installed in a 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">Nozzle_Diameter</rdfs:label>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeadType_PrinterHeadComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/AM#PrintSpeed_InProcess"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Acceleration_PrintHeadProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>

<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#ActiveCooling_PrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#FilamentDiameter_Material"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#HeaterCartridge_PrinterProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#LayerThicknessRange_PrinterProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#NozzleHeatUpTime_PrintHeadProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#NozzleOffset_PrinterHeadComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Nozzle_Diameter"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#SpeedExtrusionRange_PrintHeadProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#SpeedMovementRange_PrintHeadProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isNozzleOf"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#TemperatureNozzleRange_PrintHeadProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#NumberOfColor_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#NumberOfColor_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Color_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>

<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isInteger"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The number of colors that are printable by the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">NumberOfColor_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#NumberOfHeads_PrinterHeadComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#NumberOfHeads_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isInteger"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The number of heads installed in a 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">NumberOfHeads_PrinterHeadComponent</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Number_ModelPrinterType* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Number_ModelPrinterType">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Model_PrinterType"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isInteger"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The manufactureres assigned serial number.</rdfs:comment>
<rdfs:label **xml:lang**="en">Number_ModelPrinterType</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#OS_Workstation* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#OS_Workstation">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Workstation_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>

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</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">A list of possible operating systems required for the workstation controlling the 3D printer.</rdfs:comment>
<rdfs:label xml:lang="en">OS_Workstation</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Object_PrintSpeed -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Object_PrintSpeed">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintSpeed_InProcess"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#OperatingHumidityRange_InProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#OperatingHumidityRange_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#InProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Suitable ambient humidity the 3D printer is specified for operation.</rdfs:comment>
<rdfs:label xml:lang="en">OperatingHumidityRange_InProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#OperatingTemperatureRange_InProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#OperatingTemperatureRange_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#InProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Suitable ambient tempertaure the 3D printer is specified for operation.</rdfs:comment>
<rdfs:label xml:lang="en">OperatingTemperatureRange_InProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Operation_NoisePrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Operation_NoisePrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Noise_PrinterProperty"/>
<rdfs:comment xml:lang="en">The amount of noise emitted by the 3D printer during operation</rdfs:comment>
<rdfs:label xml:lang="en">Operation_NoisePrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#OptionalProperties -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#OptionalProperties">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property"/>
<rdfs:comment xml:lang="en">Indicator if the property is optional.</rdfs:comment>
<rdfs:label xml:lang="de">OptionalProperties</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Origin_CoordinateSystemPrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Origin_CoordinateSystemPrinterProperty">
```

<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#CoordinateSystem_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">Denotes the origin of the 3D printer that is used for referencing (X, Y, Z).</rdfs:comment>
<rdfs:label **xml:lang**="en">Origin_CoordinateSystemPrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#OutputEnergy_LaserPrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#OutputEnergy_LaserPrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Laser_PrintHeadProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The energy that is put out by the laser.</rdfs:comment>
<rdfs:label **xml:lang**="en">OutputEnergy_LaserPrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Overhang_Material* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Overhang_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Properties which apply to the possible overhang of material.</rdfs:comment>
<rdfs:label **xml:lang**="en">Overhang_Material</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#PeelMechanism_PrinterComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PeelMechanism_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Component_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Describes the mechanism that is used to peel (i.e. wet the top surface, of an object).</rdfs:comment>
<rdfs:label **xml:lang**="en">PeelMechanism_PrinterComponent</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#PersonalAttendance_InProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PersonalAttendance_InProcess">

<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#InProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Indicator that states if personal attendance during the printing process is required or not.</rdfs:comment>
<rdfs:label **xml:lang**="en">PersonalAttendance_InProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Photostability_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Photostability_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#PlasmaTransferredArc_PrinterHeadComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PlasmaTransferredArc_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeadType_PrinterHeadComponent"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#PostProcess_Technology* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PostProcess_Technology">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Technology_Category"/>
<rdfs:comment **xml:lang**="en">Describes operations which are carried out after the part has been removed from the system. (VDI 3405)</rdfs:comment>
<rdfs:label **xml:lang**="en">PostProcess_Technology</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Pourability_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Pourability_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#PreProcess_Technology* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PreProcess_Technology">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Technology_Category"/>
<rdfs:comment **xml:lang**="en">Describes all the necessary operations which take place before the parts can be fabricated in the additive manufacturing system. (VDI 3405)</rdfs:comment>
<rdfs:label **xml:lang**="en">PreProcess_Technology</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Preparation_NoisePrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Preparation_NoisePrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Noise_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The amount of noise emitted by the 3D printer during preparation</rdfs:comment>
<rdfs:label **xml:lang**="en">Preparation_NoisePrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Pressure_AtmosphereProcess* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Pressure_AtmosphereProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Atmosphere_Process"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>

```
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The required atmospheric pressure for the 3D printer build envelop.</rdfs:comment>
<rdfs:label xml:lang="en">Pressure_AtmosphereProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#PrintBed_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PrintBed_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:comment xml:lang="en">Properties of the print plate/print bed.</rdfs:comment>
<rdfs:label xml:lang="en">PrintBed_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#PrintHead_PrinterComponent -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PrintHead_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Component_Printer"/>
<rdfs:label xml:lang="en">PrintHead_PrinterComponent</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#PrintHead_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PrintHead_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#PrintObject_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PrintObject_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">Limitations the print objects belongs to.</rdfs:comment>
<rdfs:label xml:lang="en">PrintObject_PrinterProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#PrintSpeed_InProcess -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#PrintSpeed_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#InProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:label xml:lang="en">PrintSpeed_InProcess</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Printer_Technology -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Printer_Technology">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Technology_Category"/>
```

<rdfs:comment **xml:lang**="en">Hardware ressources of the printer.</rdfs:comment>
<rdfs:label **xml:lang**="de">Printer_Technology</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Process_Category* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Process_Category">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Category"/>
<rdfs:comment **xml:lang**="en">Encompasses all intangible processes, data and information that is generated, consumed, transformed or influenced by any phase of the digital fabrication process. Business processes are part of this grouping.</rdfs:comment>
<rdfs:label **xml:lang**="en">Process_Category</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Property* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Property">
<owl:equivalentClass>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.w3.org/2002/07/owl#Thing"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasName"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/AM#Category"/>
</owl:Restriction>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasUnit"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/AM#Unit"/>
</owl:Restriction>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/AM#Value"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:equivalentClass>
<rdfs:comment **xml:lang**="en">The class of properties in general.</rdfs:comment>
<rdfs:label **xml:lang**="en">Property</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Property_Material* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Property_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:comment **xml:lang**="en">Properties of the available material.</rdfs:comment>
<rdfs:label **xml:lang**="en">Property_Material</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Property_Printer* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Property_Printer">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Printer_Technology"/>
<rdfs:comment **xml:lang**="en">Properties of the printer which does not directly depends on a hardware component</rdfs:comment>
<rdfs:label **xml:lang**="en">Property_Printer</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Radius_BuildEnvelope* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Radius_BuildEnvelope">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildEnvelope_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The radius of the build envelope, for polar coordinate based systems.</rdfs:comment>
<rdfs:label **xml:lang**="en">Radius_BuildEnvelope</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Range_Value* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Range_Value">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Value"/>
<rdfs:comment **xml:lang**="en">A range of values when there is no exact value available.</rdfs:comment>
<rdfs:label **xml:lang**="en">Range_Value</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#RelativeDensity_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#RelativeDensity_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Density_PropertyMaterial"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#RequiredProperties* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#RequiredProperties">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property"/>
<rdfs:comment **xml:lang**="en">Indicator if the property is required.</rdfs:comment>
<rdfs:label **xml:lang**="de">RequiredProperties</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ResolutionX_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ResolutionX_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Resolution_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">Description of the accuracy achievable by the machine in printing the X axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">ResolutionX_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ResolutionY_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ResolutionY_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Resolution_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">Description of the accuracy achievable by the machine in printing the Y axis</rdfs:comment>
<rdfs:label **xml:lang**="en">ResolutionY_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ResolutionZ_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ResolutionZ_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Resolution_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">Description of the accuracy achievable by the machine in printing the Z axis.</rdfs:comment>
<rdfs:label **xml:lang**="en">ResolutionZ_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Resolution_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Resolution_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Description of the accuracy achievable by the machine in printing.</rdfs:comment>
<rdfs:label **xml:lang**="en">Resolution_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ScanningSpeedRange_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ScanningSpeedRange_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:comment **xml:lang**="en">The speed that the laser beam can scan across the build surface.</rdfs:comment>
<rdfs:label **xml:lang**="en">ScanningSpeedRange_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Series_ModelPrinterType* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Series_ModelPrinterType">

<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Model_PrinterType"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The manufactureres assigned series.</rdfs:comment>
<rdfs:label **xml:lang**="en">Series_ModelPrinterType</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Shore_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Shore_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Hardness_PropertyMaterial"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ShrinkageBuild_Material* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ShrinkageBuild_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Indicator that states if there is systematic shrinkage of the object during the printing process.</rdfs:comment>
<rdfs:label **xml:lang**="en">ShrinkageBuild_Material</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Signature_FirmwareCategory* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Signature_FirmwareCategory">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Firmware_Category"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#SofteningTemperatures_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#SofteningTemperatures_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Software_Category* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Software_Category">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Category"/>
<rdfs:comment **xml:lang**="en">Encompasses all software and IT components that are involved in the model creation phase, the object fabrication phase or that are used for the control and management of digital fabrication equipment.</rdfs:comment>
<rdfs:label **xml:lang**="en">Software_Category</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#SolidificationPoint_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#SolidificationPoint_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#SpecificHeatCapacity_PropertyMaterial* -->

```
<owl:Class rdf:about="http://www.semanticweb.org/AM#SpecificHeatCapacity_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Temperature_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#SpeedExtrusionRange_PrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#SpeedExtrusionRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The speed that the print head can be moved while extruding (min to max).</rdfs:comment>
<rdfs:label xml:lang="en">SpeedExtrusionRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#SpeedMovementRange_PrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#SpeedMovementRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The speed that the print head can be moved without any extrusion (min to max).</rdfs:comment>
<rdfs:label xml:lang="en">SpeedMovementRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Speed_PrintBedProperty -->
```

<owl:Class rdf:about="http://www.semanticweb.org/AM#Speed_PrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintBed_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the speed that the print bed can be moved (min to max).</rdfs:comment>
<rdfs:label **xml:lang**="en">Speed_PrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#SupportStructure_PrintSpeed* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#SupportStructure_PrintSpeed">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintSpeed_InProcess"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#SupportStructure_PrinterProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#SupportStructure_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Describes if the object to be printed requires a support structure or if it can be printed without.</rdfs:comment>
<rdfs:label **xml:lang**="en">SupportStructure_PrinterProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#SupportedProperties* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#SupportedProperties">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property"/>
<rdfs:comment **xml:lang**="en">Indicator if the property is supported by the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">SupportedProperties</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#SurfaceTexture_Material* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#SurfaceTexture_Material">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Material_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>

```
</owl:Class>

<!-- http://www.semanticweb.org/AM#Technology_Category -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Technology_Category">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Category"/>
<rdfs:comment xml:lang="en">Encompasses all hardware and machine equipment that are used for the object fabrication, as well as pre- and
        post-processing.</rdfs:comment>
<rdfs:label xml:lang="en">Technology_Category</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#TemperatureNozzleRange_PrintHeadProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#TemperatureNozzleRange_PrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintHead_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasNozzle"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#Nozzle_HeadTypePrinterComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The temperature a extruder can achieve (min to max).</rdfs:comment>
<rdfs:label xml:lang="en">TemperatureNozzleRange_PrintHeadProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#TemperatureRange_PrintBedProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#TemperatureRange_PrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintBed_PrinterProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasHeatingCartridge"/>
<owl:someValuesFrom rdf:resource="http://www.semanticweb.org/AM#HeaterCartridge_PrinterProperty"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment xml:lang="en">The temperature the print bed can be set to (min to max).</rdfs:comment>
<rdfs:label xml:lang="en">TemperatureRange_PrintBedProperty</rdfs:label>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Temperature_PropertyMaterial -->
```

```
<owl:Class rdf:about="http://www.semanticweb.org/AM#Temperature_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#TensileModulus_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#TensileModulus_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Tensile_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#TensileStrength_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#TensileStrength_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Tensile_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#Tensile_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Tensile_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ThermalConductivity_PropertyMaterial -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ThermalConductivity_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Temperature_PropertyMaterial"/>
</owl:Class>

<!-- http://www.semanticweb.org/AM#ThirdPartyCompatible_PrinterProperty -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ThirdPartyCompatible_PrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isBoolean"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#boolean"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
```

<rdfs:comment **xml:lang**="en">Indicator for the (allowed) use of compatible third party material.</rdfs:comment>
<rdfs:label **xml:lang**="en">ThirdPartyCompatible_PrinterProperty</rdfs:label>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#Toxicity_PropertyMaterial* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#Toxicity_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#Translucence_PropertyMaterial* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#Translucence_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#Type_CoordinateSystemPrinterProperty* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#Type_CoordinateSystemPrinterProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#CoordinateSystem_PrinterProperty"/>
<rdfs:comment>Cartesian, Polar, Spherical or other coordinate system that is used by the printer for movement and positioning.</rdfs:comment>
<rdfs:label>Type_CoordinateSystemPrinterProperty</rdfs:label>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#Type_Printer* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#Type_Printer">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Printer_Technology"/>
<rdfs:comment **xml:lang**="en">Properties about the pinters type.</rdfs:comment>
<rdfs:label **xml:lang**="de">Type_Printer</rdfs:label>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#UVLight_HeadTypePrinterComponent* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#UVLight_HeadTypePrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeadType_PrinterHeadComponent"/>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#UltrasonicTransducer_PrinterHeadComponent* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#UltrasonicTransducer_PrinterHeadComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#HeadType_PrinterHeadComponent"/>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#Unit* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#Unit">
<rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
<rdfs:comment **xml:lang**="en">The unit of the property.</rdfs:comment>
<rdfs:label **xml:lang**="en">Unit</rdfs:label>
</owl:Class>

<!−− *http://www.semanticweb.org/AM#VacuumPressure_InProcess* −−>

<owl:Class rdf:about="http://www.semanticweb.org/AM#VacuumPressure_InProcess">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#InProcess_Technology"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasBeam"/>
<owl:allValuesFrom rdf:resource="http://www.semanticweb.org/AM#ElectronBeam_PrinterHeadComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>

<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasBeam"/>
<owl:qualifiedCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1</owl:qualifiedCardinality>
<owl:onClass rdf:resource="http://www.semanticweb.org/AM#ElectronBeam_PrinterHeadComponent"/>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The pressure of the vacuum required for operation of the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">VacuumPressure_InProcess</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Value* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Value">
<rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDatatype"/>
<owl:someValuesFrom>
<rdfs:Datatype>
<owl:unionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#base64Binary"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#boolean"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#byte"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#dateTime"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#dateTimeStamp"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#decimal"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#double"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#float"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#integer"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#long"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#negativeInteger"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#nonNegativeInteger"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#nonPositiveInteger"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#positiveInteger"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#short"/>
<rdf:Description rdf:about="http://www.w3.org/2001/XMLSchema#string"/>
</owl:unionOf>
</rdfs:Datatype>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The class of values of properties.</rdfs:comment>
<rdfs:label **xml:lang**="en">Value</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#VatFillMechanism_PrinterComponent* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#VatFillMechanism_PrinterComponent">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Component_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isString"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Describes the mechanism that is used to fill the vat with resin.</rdfs:comment>
<rdfs:label **xml:lang**="en">VatFillMechanism_PrinterComponent</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Version_FirmwareCategory* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Version_FirmwareCategory">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Firmware_Category"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>

<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isInteger"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Firmware version indicator.</rdfs:comment>
<rdfs:label **xml:lang**="en">Version_FirmwareCategory</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Viscosity_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Viscosity_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Temperature_PropertyMaterial"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#VolumeResistivity_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#VolumeResistivity_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#WaterAbsorption_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#WaterAbsorption_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#WaveLength_LaserPrintHeadProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#WaveLength_LaserPrintHeadProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Laser_PrintHeadProperty"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">Wavelength of the laser unit in the 3D printer.</rdfs:comment>
<rdfs:label **xml:lang**="en">WaveLength_LaserPrintHeadProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Weight_MachineProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Weight_MachineProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#MachineProperty_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">

<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The machine dimension (Weight).</rdfs:comment>
<rdfs:label **xml:lang**="en">Weight_MachineProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#WidthRange_EmbossDetailMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#WidthRange_EmbossDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#EmbossDetail_Material"/>
<rdfs:comment **xml:lang**="en">Possible width range (from min to max) of embossed detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">WidthRange_EmbossDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#WidthRange_EngravedDetailMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#WidthRange_EngravedDetailMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#EngravedDetail_Material"/>
<rdfs:comment **xml:lang**="en">Possible width range (from min to max) of engraved detail on an object to be printed.</rdfs:comment>
<rdfs:label **xml:lang**="en">WidthRange_EngravedDetailMaterial</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Width_BuildEnvelope* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Width_BuildEnvelope">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildEnvelope_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The width of the build envelope.</rdfs:comment>
<rdfs:label **xml:lang**="en">Width_BuildEnvelope</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Width_BuildPlate* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Width_BuildPlate">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#BuildPlate_PrinterComponent"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The width of the build plate/print bed.</rdfs:comment>
<rdfs:label **xml:lang**="en">Width_BuildPlate</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Width_MachineProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Width_MachineProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#MachineProperty_Printer"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:comment **xml:lang**="en">The machine dimension (Width).</rdfs:comment>
<rdfs:label **xml:lang**="en">Width_MachineProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#Workstation_Technology* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#Workstation_Technology">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Technology_Category"/>
<rdfs:comment **xml:lang**="en">Workstation requirements the printer depends on.</rdfs:comment>
<rdfs:label **xml:lang**="en">Workstation_Technology</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#XRange_AccelerationPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#XRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Acceleration_PrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the acceleration of the print bed in the X axis (min to max).</rdfs:comment>
<rdfs:label **xml:lang**="en">XRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#XRange_PrintObjectProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#XRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintObject_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The size (along the X axis) of any object to be printed (min to max).</rdfs:comment>
<rdfs:label **xml:lang**="en">XRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#XRange_SpeedPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#XRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Speed_PrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the speed that the print bed can be moved in the X axis (min to
max).</rdfs:comment>
<rdfs:label **xml:lang**="en">XRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#YRange_AccelerationPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#YRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Acceleration_PrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the acceleration of the print bed in the Y axis (min to max).</rdfs:comment>
<rdfs:label **xml:lang**="en">YRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#YRange_PrintObjectProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#YRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintObject_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The size (along the Y axis) of any object to be printed (min to max).</rdfs:comment>
<rdfs:label **xml:lang**="en">YRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#YRange_SpeedPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#YRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Speed_PrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the speed that the print bed can be moved in the Y axis (min to
max).</rdfs:comment>
<rdfs:label **xml:lang**="en">YRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#YieldStrentgh_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#YieldStrentgh_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#YoungsModulus_PropertyMaterial* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#YoungsModulus_PropertyMaterial">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Property_Material"/>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#hasValue"/>
<owl:someValuesFrom>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.semanticweb.org/AM#Value"/>
<owl:Restriction>
<owl:onProperty rdf:resource="http://www.semanticweb.org/AM#isDouble"/>
<owl:someValuesFrom rdf:resource="http://www.w3.org/2001/XMLSchema#double"/>
</owl:Restriction>
</owl:intersectionOf>
</owl:Class>
</owl:someValuesFrom>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ZRange_AccelerationPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ZRange_AccelerationPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Acceleration_PrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of moveable print bed this denotes the acceleration of the print bed in the Z axis (min to max).</rdfs:comment>
<rdfs:label **xml:lang**="en">ZRange_AccelerationPrintBedProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ZRange_PrintObjectProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ZRange_PrintObjectProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#PrintObject_PrinterProperty"/>
<rdfs:comment **xml:lang**="en">The size (along the Z axis) of any object to be printed (min to max).</rdfs:comment>
<rdfs:label **xml:lang**="en">ZRange_PrintObjectProperty</rdfs:label>
</owl:Class>

<!-- *http://www.semanticweb.org/AM#ZRange_SpeedPrintBedProperty* -->

<owl:Class rdf:about="http://www.semanticweb.org/AM#ZRange_SpeedPrintBedProperty">
<rdfs:subClassOf rdf:resource="http://www.semanticweb.org/AM#Speed_PrintBedProperty"/>
<rdfs:comment **xml:lang**="en">In case of a moveable print bed this denotes the speed that the print bed can be moved in the Z axis (min to
max).</rdfs:comment>
<rdfs:label **xml:lang**="en">ZRange_SpeedPrintBedProperty</rdfs:label>
</owl:Class>

<!--
//
//
// General axioms
//
//
-->

<rdf:Description>
<rdf:type rdf:resource="http://www.w3.org/2002/07/owl#AllDisjointClasses"/>
<owl:members rdf:parseType="Collection">

<rdf:Description rdf:about="http://www.semanticweb.org/AM#OptionalProperties"/>
<rdf:Description rdf:about="http://www.semanticweb.org/AM#RequiredProperties"/>
<rdf:Description rdf:about="http://www.semanticweb.org/AM#SupportedProperties"/>
</owl:members>
</rdf:Description>
</rdf:RDF>

<!-- *Generated by the OWL API* (**version** *4.2.6.20160910-2108) https://github.com/owlcs/owlapi* -->

• Declaration

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

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