Result of Research Project

SPECIFICATION

Submodel Predictive Maintenance

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Submodel Template of the

Asset Adminstration Shell

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2023-03-30	Version 0.2	Incorporation of results of 1st meeting of the working group
2023-04-28	Version 0.3	Update of UML-Diagram
2023-05-22	Version 0.4	Update of UML-Diagram, update of specifications and missing descriptions added.
2023-05-31	Version 0.5	Introduction of SMC ListPreAlets, and related properties, minor text modifications
2023-06-07	Version 0.6	- Property type of ConditionLevel->ValueRange changed to “Range”, - “RemainingUsfulLifeTimeSpan” renamed to “RemainingUsfulLifeDateTime” and definition chaned to Date/Time, - SMC “FailureModeDetectionInformation” added

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Foreword

The submodel Predictive Maintenance aims to provide standardized meta data and information from different sub-systems of highly automated production lines that are important for predictive maintenance solutions (PM solutions). With this, integration and interoperability of sub-systems of production lines into PM solutions is improved, and their data can be evaluated in a more targeted manner in the context of the PM application in order to reduce unplanned machine downtimes. Accordingly, the PM solutions can in turn play back maintenance-relevant information via the AAS, e.g. on predicted remaining life time or the probability of failure.

The submodel has been developed in the joint-project InterOpera by a working group of industrial and scientific specialists with different roles related to predictive maintenance. The members of the working group are listed in authors caption on page 2.

1 General

1.1 About this document

This document is a part of a specification series. Each part specifies the contents of a Submodel template for the Asset Administration Shell (AAS). The AAS is described in [1-3] and [6]. First exemplary Submodel contents were described in [4], while the actual format of this document was derived by the "Administration Shell in Practice" [5]. The format aims to be very concise, giving only minimal necessary information for applying a Submodel template, while leaving deeper descriptions and specification of concepts, structures and mapping to the respective documents [1-6].

The target group of the specification are developers and editors of technical documentation and manufacturer information, which are describing assets in smart manufacturing by means of the Asset Administration Shell (AAS) and therefore need to create a Submodel instance with a hierarchy of SubmodelElements. This document especially details on the question, which SubmodelElements with which semantic identification shall be used for this purpose.

1.2 Scope of the Submodel

This Submodel template aims at interoperable provision of information describing predictive maintenance topics in regard to the asset of the respective Asset Administration Shell. Central element is the provision of properties [7], ideally interoperable by the means of dictionaries such as ECLASS and IEC CDD (Common Data Dictionary). The purpose of this document is to make selected specifications of Submodels in such manner that information about assets can be exchanged in a meaningful way between partners in a value creation network. It targets sub-systems of production lines and predictive maintenance applications by defining standardized meta data.

The intended use-case is the provision of a standardized property structure for predictive maintenance (PM) processes, which enables to integrate sub-systems of automated production lines easier into predictive maintenance applications and thus enables PM solutions to provide improved information about remaining lifetime and potential component failures, in order to reduce machine downtimes in manufacturing processes.

This concept can serve as a basis for standardizing the respective Submodel. The conception is based on existing norms, studies of common practices at enterprises, directives and standards so that a far-reaching acceptance can be achieved.

Beside standardized Submodel this template also introduces standardized SubmodelElementCollections (SMC) in order to improve the interoperability while modelling aspects of predictive maintenance applications within other Submodels.

1.3 Relevant standards and sources of concepts for the Submodel template

According to [3], interoperable properties might be defined by standards, consortium specifications or manufacturer specifications. Useful standards providing sources of concepts are:

Table 1: List of examplary standards defining interoperable properties

DIN EN IEC 63270	Industrial automation equipment and systems – Predictive maintenance [8]
VDI 2872	Lean production systems – Lean enterprise system – Introduction and fundamentals [9]

So called property dictionaries are used identify information elements (see Terms and Definitions of [6]). Such property dictionaries include:

- ECLASS, see: https://www.eclasscontent.com/
- IEC CDD, see: https://cdd.iec.ch/cdd/iec61987/iec61987.nsf and https://cdd.iec.ch/cdd/iec62683/cdddev.nsf

In this document, properties are aimed to be described by ECLASS.

2 Information set for Submodel Predictive Maintenance

While defining submodels the following three aspects must be considered as suggested in [5]:

Use and economic relevance

The submodel Predictive Maintenance is designed for standardized provision of meta data and information from different sub-systems of highly automated production lines that are important for predictive maintenance solutions (PM solutions). This should make it easier to integrate sub-systems of production lines into PM solutions and their data can be evaluated in a more targeted manner in the context of the application, so that unplanned machine downtimes are reduced. Accordingly, the PM solutions can in turn play back maintenance-relevant information via the AAS, e.g. on predicted remaining life time or the probability of failure.

This addresses the economic interest of companies with highly automated manufacturing processes (e.g. injection molding) in avoiding unplanned machine downtimes and rejects. Likewise, manufacturers of production machines and systems as well as suppliers of sub-systems have an interest in recognizing possible component failures and their causes at an early stage.

Possible causes for unplanned plant downtimes are, for example:

- Wear and tear (e.g. of servomotors, increased friction/lubrication, joints, dirty fans which result in increased temperature of the servomotors, longer switching times, etc.)
- Machine component failures (servo motor, relay, converter, fan, etc.)
- Component failures in sub-systems, e.g. cooling (monitor temperatures, flow rate/leakage), handling (vacuum loss), reject switch (defective relay, mechanics), conveyor belt (motor, slippage, etc.)
- Tool defects (e.g. broken ejector pin)

Automated production lines usually consist of a large number of sub-systems (e.g. production machine, tool, handling, ...).

The monitoring of process parameters based on different sensors as part of condition monitoring, e.g. using the OPC UA standard, is common practice. There are also solutions for online quality forecasting and process monitoring, which can be used to identify process and quality drifts as well as rejects at an early stage.

For data-driven predictive maintenance applications (PM solutions), however, meta-information for the interpretation of the data recorded by individual sub-systems must be made available and included in order to recognize and identify causes. So far, these have not been provided and processed in a standardized way. Therefore, close coordination between the providers of predictive maintenance solutions and the suppliers of the machines and sub-systems is often necessary and the integration of sub-systems is associated with a correspondingly high level of effort.

A standardized semantic description of the data relevant to predictive maintenance and provision via asset administration shells (AAS for short) of machines and sub-systems thus enables easier integration as well as expanded, more comprehensive and new solutions for data-driven predictive maintenance applications in production plants.

In Figure 1 this general use case is depicted schematically.

This could, for example, support automated determination of the cause when a process drift or an accumulation of component failures is detected, which makes it possible to recommend an early replacement of the causative components via the predictive maintenance solution.

Manufacturers of production systems and/or predictive maintenance solutions can more easily integrate third-party subsystems into their solutions through appropriate standardization.

Furthermore, previously rigid maintenance intervals can be supplemented or replaced by dynamic needs-based intervals using appropriate PM solutions suitable for Industry 4.0.

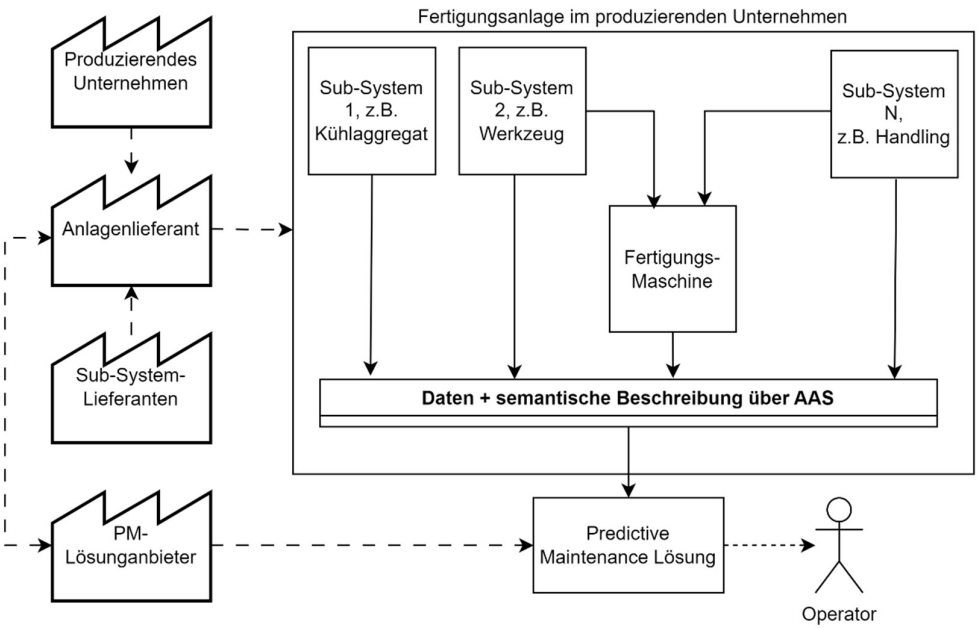

Figure 1: Schematic depiction of the general use case

The integration of sub-systems into the PM solution is simplified by providing semantic information of the sub-system in the AAS, without having to implement individual solutions for each sub-system. For the sub-system possible faults can be predefined semantically, and if a fault occurs corresponding information can be provided for the PM solution.

The predictive maintenance solution can return information about the predicted remaining life time as via the AAS to the sub-system, so that the maintenance team and or manufacturer of the sub-system can react at an early stage.

The PM system could also use the meta-information to assign process changes/drifts identified during condition monitoring to specific causes of wear. In addition, the PM system can display information for upcoming unplanned maintenance events for the sub-system, in order to make those events manageable and plannable during the running production.

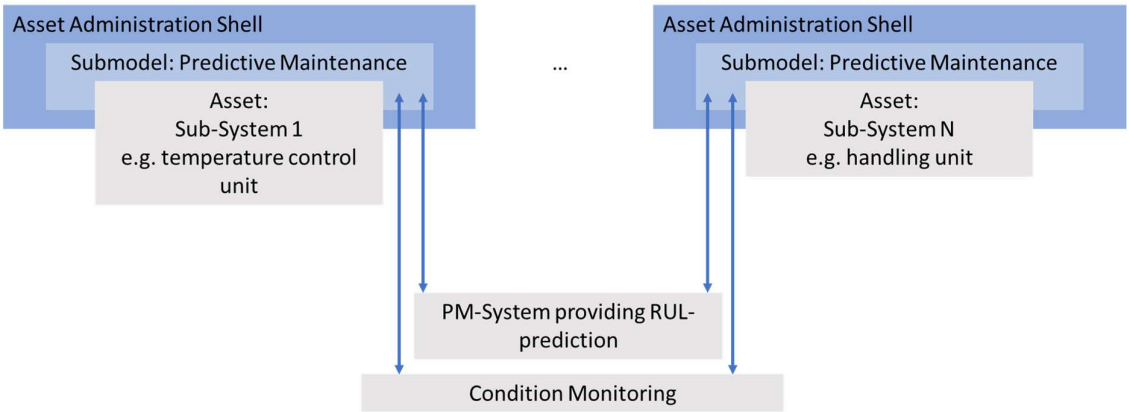

Figure 2: Schematic depiction of a setup consisting of several assets (sub-systems), a condition monitoring system and a predictive maintenance (PM) system

Functions and interactions

In a predictive maintenance solution, semantic descriptions for interpreting the data via the AAS from different sub-systems of the production line (e.g. injection molding machine, handling, temperature control unit, material dryer, etc.) are brought together and superordinated evaluated with the aim of early detection of wear or faults, e.g. by monitoring time series of condition indicators. Metadata of the sub-systems can be transmitted via the AAS, which is useful for identifying the cause of failures, as well as information about remaining useful life prediction.

A typical setup is shown schematically in Figure 2: The sub-systems AAS hold the information about their conditions, faults/failure modes and remaining useful life, whereas condition monitoring system(s), and PM-systems interact with these ASS to receive and provide data.

The definition of the AAS Submodel Predictive Maintenance is based on the standard DIN EN IEC 63270 Industrial automation equipment and systems – Predictive maintenance [8]. In this context predictive maintenance is a “form of preventive maintenance performed continuously or at intervals governed by observed conditions to monitor, diagnose or trend a structure, system or component’s condition indicators. Results indicate present and future functional ability or the nature of, and schedule for, planned maintenance”. According to this standard there are three main topics addressed by the submodel:

- Condition monitoring / Condition status assessment
- Fault diagnosis
- Remaining Useful Life (RUL) prediction

Maintenance management is not in the scope of the submodel PredictiveMaintenance because it is addressed by IDTA submodel Maintenance [10]. Maintenance actions / repair measures are considered in the submodel regarding their latest occurrences (Last maintenance relevant events). The main structure and topics are depicted in Figure 3.

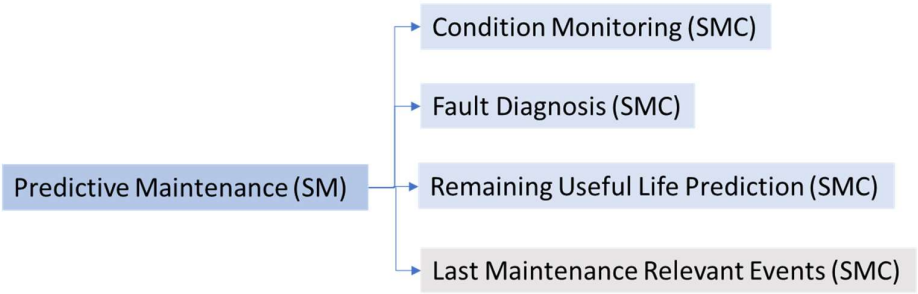

Figure 3: Main topics and structure of submodel Predictive Maintenance

Following main ideas and concepts have been implemented in the submodel Predictive Maintenance which are important to understand and use the submodel:

General concepts

A major topic when dealing with wear of components is that wear depends on the operation conditions. Therefore, time based properties described in the submodel predictive maintenance, e.g. remaining useful life, last maintenance event, etc. are not only represented by a time stamp, but foremost by the amount of time expressed in the wear relevant unit of the asset. This can be for example operation cycles (e.g. of an injection molding machine), distance (e.g. of a linear robot), operation time (e.g. of a cooling system), and others.

If there are time stamps (calender dates and time) defined in the submodel, it is important to consider that the time between all assets / AAS have to be synchronized in an appropriate way.

For the submodel Predictive Maintenance the main topics mentioned above are considered in separate SMC's (ConditionMonitoring, FaultDiagnosis, RemainingUsefulLifePrediction, LastMaintenanceRelevantEvents).

Please note that Fault Diagnosis and Remaining Useful Life Prediction are independent from each other: A fault might be detected without being considered in remaining useful life prediction.

SMCs which may have a multiplicity of more than one are organized in SMC's which have the prefix "List" followed by the name of the SMC which can multiplicity greater one (e.g. condition indicator 1, 2, 3,..).

Concepts regarding Condition Monitoring

For condition monitoring a list of condition indicators can be defined in the submodel. Each condition indicator has a time series which refers to the IDTA submodel TimeSeries [11].

The condition indicator might be based on physical sensor data (e.g. temperature, pressure measurement) or data calculated by a model (soft-sensor), e.g. quality prediction by a machine learning algorithm. For predictive maintenance applications it is common to derive condition indicators from data by using time, frequency, and time-frequency domain features [12]. In the

submodel the domain is defined as an enumerated list IndicatorDomain with the following possible labels:

- DomainTime
- DomainFrequency
- DomainMixed
- DomainOther

As it is not important for a predictive maintenance application whether the condition indicator is based on a sensor or algorithm, only the accuracy for the values of the condition indicator is considered. Please note that the accuracy here is defined as the accuracy as percentage with relation to the “measured” value not the “end of scale” value. However, for artificial intelligence systems, the submodel allows an optional classification for machine learning based condition indicators according to DIN SPEC 92001-3 Artificial Intelligence - Life Cycle Processes and Quality Requirements - Part 3: Explainability [13].

Each condition indicator has a list of one or more condition levels, which describe different conditions (e.g. nominal operation, warning range, alert range) based on value ranges of the condition indicator. Figure 4 shows an example.

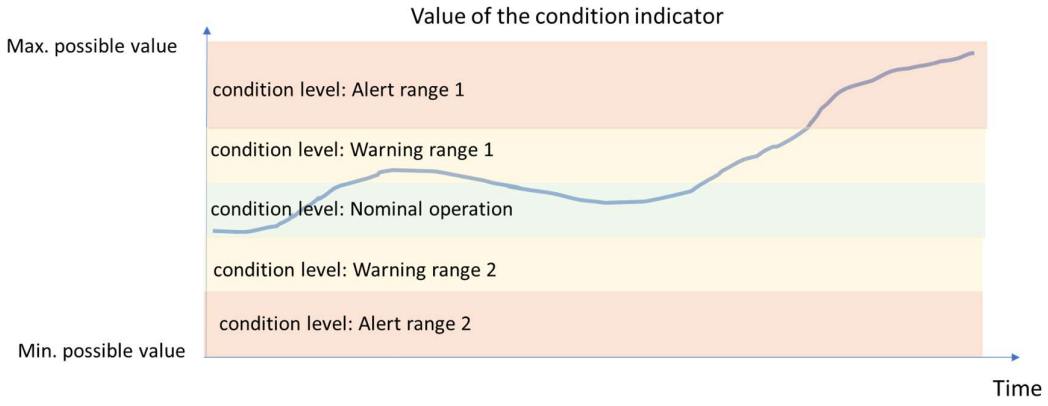

Figure 4: Concept of condition indicator time series and condition levels (please note: this is only an example, the number and contents of condition levels can be freely defined)

Concepts regarding Fault Diagnosis

The SMC FaultDiagnosis consists of a list of possible FailureModes and a SMC describing the decision based on the occurrence of a failure.

A manufacturer of a sub-system can pre-fill this list with possible failures that may occur, adding descriptions and failure codes. If a failure is detected during operation the optional SMC FailureModeDetectionInformation can be filled with information how the fault has been determined using the enumerated list property DeterminationType, which has the labels

- DeterminationByMeasurement
- DeterminationByModel
- DeterminationByHumanDecision

Also the confidence level according to DIN EN IEC 63270 is considered as an enumerated list property ConfidenceLevel, with the values:

- ConfidenceLevel1: “There is a REMOTE PROBABILITY of this failure mode diagnosis being accurate.”
- ConfidenceLevel2: “There is a LOW PROBABILITY of this failure mode diagnosis being accurate.”
- ConfidenceLevel3: “There is a MODERATE PROBABILITY of this failure mode diagnosis being accurate.”
- ConfidenceLevel4: “There is a HIGH PROBABILITY of this failure mode diagnosis being accurate”
- ConfidenceLevel5: “It is CERTAIN that this failure mode diagnosis will be accurate.

The decision based on a detected fault can have the labels:

- Continue without Change
- Continue with Adjusted Parameters
- Continue with Adjusted Operation Mode
- Stop

Here the definition provided by DIN EN IEC 63270 is enhanced by “continue with adjusted operation mode” which could be considered as a subform of “continue with adjusted parameters”.

Optionally, a list of adjusted parameters can be provided in SMC ListAdjustedParameters.

Concepts regarding Remaining Useful Life (RUL) Prediction

The remaining useful life (property RemainingUsefulLifeInOperation) is defined as a value in wear relevant unit representing a “point in time” when the useful life is predicted to end; not a “duration”. This is because this value might be updated not regularly or to unknown points in time by the model used for RUL prediction. This is accomplished by a confidence interval.

In addition a timestamp can be defined (property RemainingUsefulLifeDateTime), which describes at which date and time the useful life ends.

To understand how to interpret the calculated RUL it is also important to make information available on the boundary conditions for which the RUL prediction takes place (SMC ListRULBoundaryConditions. The boundary conditions are defined by value ranges for parameters which are used in the model for rule prediction and additional parameters.

The model used for RUL prediction can be described by model type as an enumerated list (property ModelType) with labels:

- ModelTypePhysical
- ModelTypeDataDriven
- ModelTypeHybrid

In addition a text description for the model can be provided.

Pre-alerts can be defined before reaching end of life using the SMC ListPreAlerts. A pre-alert is characterized by an event (AlertEvent), a message (PreAlertMessage) and a value (PreAlertValue) which defines the duration when the alert is trigger before reaching end of useful life, in wear relevant units.

Last but not least, an alert for exceeding the useful life is defined, characterized by an event, a message and a trigger of the property MaintenanceRequired.

Concepts regarding Last Maintenance Relevant Events

For describing events that are relevant for predictive maintenance three SMC's are defined to describe the last maintenance, repair and replacement event. Each of these consists of a value describing when the specific event occurred in wear relevant units (Last…EventValue) and a time stamp (Last…EventDateTime).

In addition information about the initial operation of the asset is provided by defining the calendar date (InitialOperationDate) and a (InitialOperationEventValue) defining the time of initial operation in the wear relevant unit, which is zero if the asset was new at the time of initial operation, but might be greater than zero for refurbished assets.

Use case example of Predictive Maintenance for a temperature control unit in an injection molding production line

In injection molding, mold temperature control plays a crucial role in the stability of the manufacturing process and part quality. The corresponding temperature control devices are independent sub-systems of the injection molding machine and are therefore not necessarily integrated into the machine monitoring system. The unnoticed failure of a temperature control unit can result in expensive consequential damage to the tool, hot runner and machine. This might occur e.g., if the temperature control unit fails in a blind shift and the hot runner temperature is not reduced, the mold heats up to several hundred degrees Celsius (up to 300°C). In the worst case, this results in a tool defect, combined with financial damage of a five to six-digit amount in Euro.

Possible causes for a critical decrease in the cooling capacity or a failure of the temperature control unit are, for example, dirt and deposits in the lines, which lead to blockages over time.

By integrating the temperature control unit in the condition monitoring of the entire system, a corresponding failure can be detected at an early stage. The water flow or the decisive cooling capacity can be determined via the temperature difference at the inlet to the outlet of the temperature control unit and via the corresponding pressure difference. When monitoring a condition indicator based on these values, a warning can be triggered if a the cooling capacity falls below a pre-set threshold. In addition, a data-driven model from historical data can be used to forecast the period or number of cycles until the threshold is reached (e.g. trend progression) and thus a Remaining Useful Life (RUL) can be calculated.

The staff can be warned beforehand about reaching the end of useful life by several pre-warning levels.

Property specification

See section 3 Submodel and Collections.

3 Submodel and Collections

3.1 Specification of the Submodel “Predictive Maintenance”

The figure below shows the UML-diagram defining the relevant properties which need to be set describes the details of the Submodel structure combined with examples.

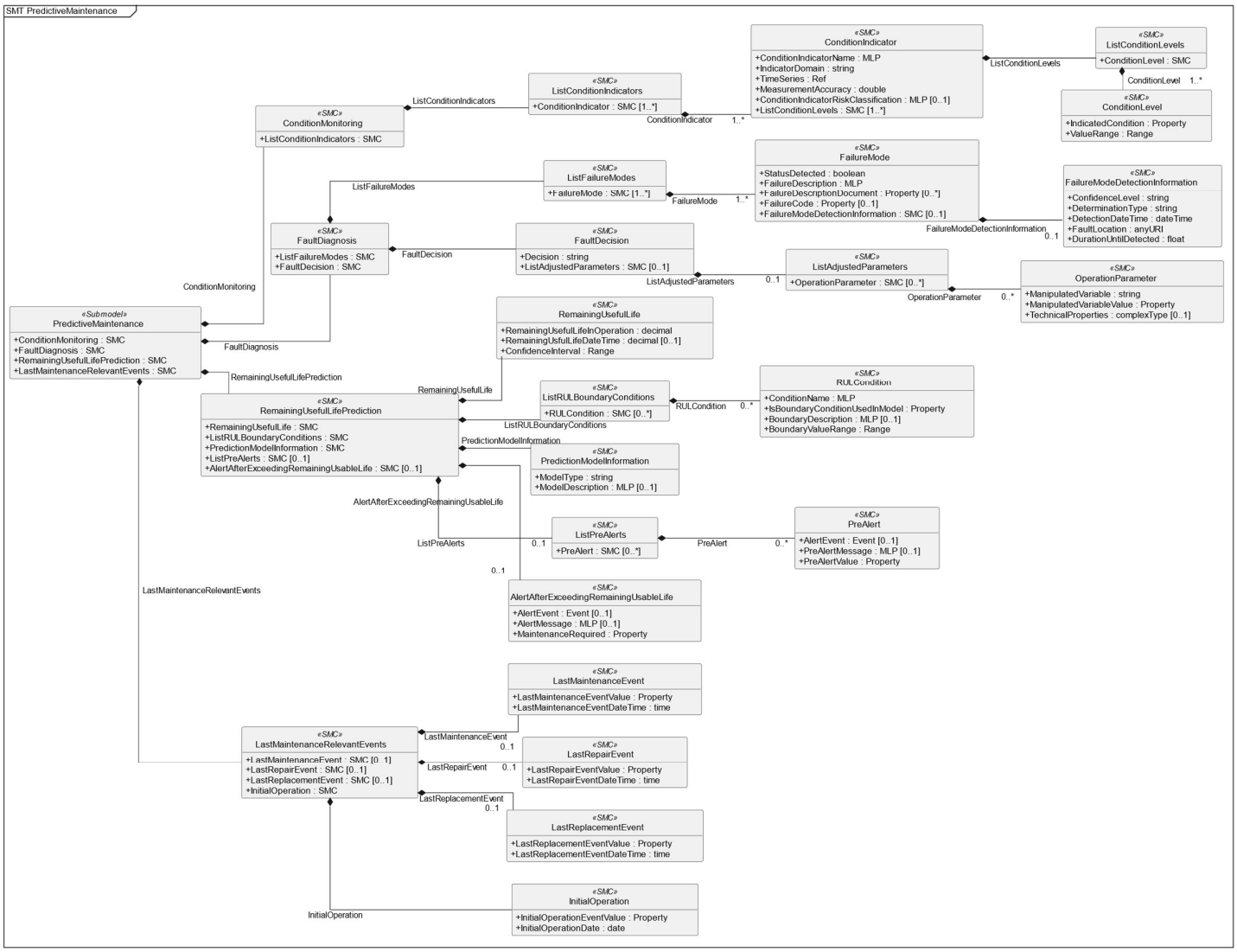

Figure 5: UML-Diagram for Submodel "Predictive Maintenance"

Table 2: Specification of Submodel “Predictive Maintenance"

idShort	*PredictiveMaintenance*		
Class	Submodel		
semanticId			
Parent			
Explanation	The Submodel Predictive Maintenance is the collection for various SubmodelElementCollections to provide information for predictive maintenance use cases. This comprises topics of condition monitoring, fault diagnosis, remaining useful life (RUL) prediction, and relevant maintenance events. It is intended to use this submodel in sub-systems of production lines to describe predictive maintenance relevant topics for the sub-system, as well as to use this submodel in predictive maintenance software applications@en. Das Teilmodell Predictive Maintenance stellt Informationen für Anwendungsfälle von Predictive Maintenance bereit. Dies umfasst die Bereiche Zustandsüberwachung, Fehlerdiagnose, Vorhersage der verbleibenden Nutzungsdauer (RUL) und relevante Wartungsereignisse. Dieses Teilmodell ist für Sub-Systeme von Produktionslinien vorgesehen, um Predictive Maintenance relevante Informationen für das Sub-System zu beschreiben sowie für Software-Anwendungen für vorausschauende Wartung@de.		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] ConditionMonitoring	[IRI] https://example.com/ids/cd/3045_9051_5032_6159 preferredName @en: Condition monitoring indicators and data preferredName @de: Indikatoren und Daten zur Zustandsüberwachung definition @en: A set of indicators and related data used for condition monitoring definition @de: Eine Reihe von Indikatoren und Daten, die zur Zustandsüberwachung verwendet werden description @en: Contains condition monitoring indicators and data description @de: Enthält Indikatoren und Daten zur Zustandsüberwachung	[-]	[1]
[SMC] FaultDiagnosis	[IRI] https://example.com/ids/cd/5380_2151_5032_2670 preferredName @en: Fault diagnosis information preferredName @de: Informationen zur Fehlerdiagnose	[-]	[1]

	definition @en: Contains data and indicators about fault diagnosis relevant for predictive maintenance definition @de: Enthält Daten und Indikatoren über die Fehlerdiagnose, die für vorausschauende Wartung relevant sind description @en: Contains data and indicators about fault diagnosis relevant for predictive maintenance description @de: Enthält Daten und Indikatoren über die Fehlerdiagnose, die für vorausschauende Wartung relevant sind		
[SMC] RemainingUsefulLifePrediction	[IRI] https://example.com/ids/cd/7513_3151_5032_3911 preferredName @en: Information on remaining useful life prediction preferredName @de: Informationen über die Prognose der Restlebensdauer definition @en: Information about remaining useful life (RUL) prediction in the context of predictive maintenance definition @de: Informationen über die Prognose der nutzbaren Restlebensdauer (RUL) im Kontext der vorausschauenden Wartung description @en: Information on prediction of remaining usable life of an asset description @de: Informationen über die Vorhersage der Restlebensdauer des Assets	[-]	[1]
[SMC] LastMaintenanceRelevantEvents	[IRI] https://example.com/ids/cd/6555_4151_5032_7244 preferredName @en: Last maintenance relevant events preferredName @de: Letzte wartungsrelevante Vörgange definition @en: Information about last maintenance relevant events: maintenance, repair, replacement, initial operation definition @de: Informationen zu den letzten Vorgängen, die wartunsgrelevant sind: Wartung, Reparatur, Ersatz, Erstinbetriebnahme description @en: Wear relevant information about last maintenance event description @de: Verschleißrelevante Informationen zu den letzten Wartungs- und Instandsetzungsmaßnahmen	[-]	[1]

3.2 Properties of the SMC ConditionMonitoring

Figure 5 shows the UML-diagram defining the relevant properties which need to be set. The following table describes the details of the SMC structure combined with examples.

Table 3: Specification of SMC "ConditionMonitoring"

idShort	*ConditionMonitoring*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/3045_9051_5032_6159		
isCaseOf	-		
AllowDuplicates	-		
Parent	Submodel PredictiveMaintenance		
Explanation	Contains condition monitoring indicators and data@en, Enthält Indikatoren und Daten zur Zustandsüberwachung@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	

[SMC] ListConditionIndicators	[IRI] https://example.com/ids/cd/4510_0151_5032_2078 preferredName @en: List of Indicators preferredName @de: Indikatorliste definition @en: An array which contains a variable list of indicators for condition monitoring definition @de: Ein Array das eine variable Anzahl von Indikatoren zur Zustandsüberwachung enthält description @en: List of condition indicators time series, e.g. values from sensors, models description @de: Liste von Zustandsindikator-Zeitreihen, z.B. Werte von Sensoren, Modellen	[-]	[1]

Table 4: Specification of SMC "ListConditionIndicators"

idShort	*ListConditionIndicators*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/4510_0151_5032_2078		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC ConditionMonitoring		
Explanation	List of condition indicators time series, e.g. values from sensors, models@en, Liste von Zustandsindikator-Zeitreihen, z.B. Werte von Sensoren, Modellen@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] ConditionIndicator	IRI] https://example.com/ids/cd/3301_0151_5032_6664 preferredName @en: Condition Indicator preferredName @de: Zustandsindikator definition @en: Description of an indicator used for condition monitoring, based on e.g. values from a sensor or model. Contains definitions of the indicator and a time series of indicator values definition @de: Beschreibung eines Indikators, der für die Zustandsüberwachung verwendet wird, basierend z.B. auf Sensoren oder Modellen. Enthält die Definition des Indikators und eine Zeitreihe der Indikatorwerte. description @en: Definition of a condition indicator, e.g. values from sensors, models, used for monitoring the condition of a sub system description @de: Definition eines Zustandsindikators, z.B. Werte von Sensoren, Modellen, der für die Überwachung eines Sub-Systems verwendet wird	[-]	[1..*]

Table 5: Specification of SMC "ConditionIndicator"

idShort	*ConditionIndicator*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/3301_0151_5032_6664		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC ListConditionIndicators		
Explanation	Condition indicators, e.g. values from sensors, models@en, Zustandsindikatoren, z.B. Werte von Sensoren, Modellen@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[MLP] ConditionIndicatorName	[IRI] https://example.com/ids/cd/6570_0180_5032_9837 preferredName @en: Condition indicator name preferredName @de: Zustandsindikatorbezeichnung definition @en: Name of the condition indicator definition @de: Bezeichnung des Zustandsindikators description @en: Name of a condition indicator which is used for monitoring the sub system description @de: Bezeichnung eines Zustandsindikators, der für die Überwachung des Sub-Systems verwendet wird.	[-] Example Name	[1]
[Property] IndicatorDomain	[IRI] https://example.com/ids/cd/3122_0151_5032_6408 preferredName @en: Indicator domain preferredName @de: Indikatordomäne definition @en: Physical domain in which an indicator for condition monitoring is calculated or measured, e.g. time, frequency, mixed definition @de: Physikalische Domäne, in der ein Indikators für die Zustandsüberwachung berechnet oder gemessen wird, z.B. Zeit, Frequenz, gemischt description @en: domain of the indicator: time, frequency, mixed, other description @de: Domäne des Indikators: Zeit, Frequenz, gemischt, andere	[string]	[1]
[Ref] TimeSeries	[IRI] https://admin-shell.io/sandbox/zvei/TimeSeriesData/1/0	[-]	[1]

	preferredName @en: - preferredName @de: - definition @en: - definition @de: - description @en: Contains time series data and references to time series data to discover and semantically describe them along the asset lifecycle. description @de: Enthält Zeitreihendaten und Referenzen auf Zeitreihendaten, um diese entlang des Asset Lebenszyklus aufzufinden und semantisch zu beschreiben.		
[Property] MeasurementAccuracy	[IRDI] 0173-1#02-BAB511#006 preferredName @en: - preferredName @de: - definition @en: - definition @de: - description @en: measurement accuracy description @de: Messgenauigkeit	[double]	[1]
[MLP] ConditionIndicatorRisk Classification	[IRI] https://example.com/ids/cd/2572_0180_5032_6476 preferredName @en: Risk classification description preferredName @de: Beschreibung der Risikoklassifikation definition @en: Description of risk classification of condition indicator in the context of measuring/prediction accuracy definition @de: Beschreibung der Risikoklassifikation eines Zustandsindikators im Zusammenhang mit der Mess-/Prognosegenauigkeit description @en: Risk classification of condition indicator with respect to Anlehnung an DIN SPEC 92001-3 Artificial Intelligence - Life Cycle Processes and Quality Requirements - Part 3: Explainability description @de: Risikoklassifikation eines Zustandsindikators in Anlehnung an DIN SPEC 92001-3 Titel Künstliche Intelligenz - Life Cycle Prozesse und Qualitätsanforderungen - Teil 3: Erklärbarkeit	[-]	[0..1]

[SMC] ListConditionLevels	[IRI] https://example.com/ids/cd/5313_0151_5032_8129 preferredName @en: Condition level list preferredName @de: Liste der Zustandsniveaus definition @en: Array of a variable list of different (critical) levels which describes the condition of an asset, e.g. alert levels, should always contain at least one uncritical (o.k.) and one critical (n.o.k) level definition @de: Array einer variablen Liste unterschiedlicher (kritischer) Zustände eines Assets, z.B. Alarmniveaus, sollte immer mindestens einen unkritischen (i.O.) und einen kritischen Zustand (n.i.O.) enthalten description @en: List of possible condition levels, e.g. warning or alert levels description @de: Liste der möglichen Zustandslevel wie Warn-/bzw. Alarmlevel	[-]	[1]

Table 6: Specification of SMC "ListConditionLevels"

idShort	*ListConditionLevels*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/5313_0151_5032_8129		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC ConditionIndicator		
Explanation	List of possible condition levels, e.g. warning or alert levels@en, Liste der möglichen Zustandslevel wie Warn-/bzw. Alarmlevel@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] ConditionLevel	[IRI] https://example.com/ids/cd/9414_0151_5032_9489 preferredName @en: Condition level preferredName @de: Zustandsniveau definition @en: level which describes the condition of an asset, e.g. warning or alert level, or uncritical (o.k.) definition @de: Zustandslevel eines Assets, z.B. Warnlevel, Alarmlevel oder unkritisch description @en: condition level, e.g. warning or alert level description @de: Zustandslevel wie Warn-/bzw. Alarmstufe	[-]	[1..*]

Table 7: Specification of SMC "ConditionLevel"

idShort	*ConditionLevel*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/9414_0151_5032_9489		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC ListConditionLevels		
Explanation	condition level, e.g. warning or alert level@en, Zustandslevel wie Warn-/bzw. Alarmstufe@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] IndicatedCondition	[IRDI] 0173-1#02-AAQ575#004 preferredName @en: Indicated condition preferredName @de: Angezeigter Zustand definition @en: state of an existing situation definition @de: Status der vorliegenden Situation description @en: Indicated condition description @de: Angezeigter Zustand	[-]	[1]
[Range] ValueRange	[IRDI] 0173-1#02-AAV991#001 preferredName @en: value range preferredName @de: Wertebereich definition @en: value range for the required input signal or measurement definition @de: Wertebereich für das benötigte Eingangssignal bzw. für die benötigte Messung description @en: value range description @de: Wertebereich	[-]	[1]

3.3 Properties of the SMC FaultDiagnosis

Table 8: Specification of SMC "FaultDiagnosis"

idShort	*FaultDiagnosis*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/5380_2151_5032_2670		
isCaseOf	-		
AllowDuplicates	-		
Parent	SubModel PredictiveMaintenance		
Explanation	Contains data and indicators about fault diagnosis relevant for predictive maintenance@en, Enthält Daten und Indikatoren über die Fehlerdiagnose, die für vorausschauende Wartung relevant sind@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] ListFailureModes	[IRI] https://example.com/ids/cd/5521_2151_5032_7852 preferredName @en: List of failure modes preferredName @de: Liste möglicher Ausfälle definition @en: Array of possible failures of the asset definition @de: Array mit möglichen Ausfallarten eines Assets description @en: List of failure modes that may occur in a sub-system description @de: Liste möglicher Ausfallarten, die in einem Sub-System auftreten können	[-]	[1]
[SMC] FaultDecision	[IRI] https://example.com/ids/cd/7315_2151_5032_9814 preferredName @en: Information on opration after a failure preferredName @de: Information über Weiterbetrieb nach einem Fehler definition @en: Enumerated category of fault decision whether to continue, continue with adjusted parameters, continue with adjusted mode of operation, or stop the process definition @de: Enumerierte Kategorie der Entscheidung nache einem Fehler, ob der Prozess ohne Anpassung, mit angepassten Parametern, in einem angepassten Betriebsmodus weiterbetrieben wird oder der Prozess gestoppt wird	[-]	[1]

	description @en: Classification of the decision to continue operation depending on the error that is detected. description @de: Klassifikation der Entscheidung zum Weiterbetrieb abhängig von der Ausfallart die detektiert wurde.		

Table 9: Specification of SMC "ListFailureModes"

idShort	*ListFailureModes*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/5521_2151_5032_7852		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC FaultDiagnosis		
Explanation			
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] FailureMode	[IRI] https://example.com/ids/cd/2561_2151_5032_8023 preferredName @en: Failure mode information preferredName @de: Information zur Art des Ausfalls definition @en: Information about failure mode definition @de: Informationen über eine Ausfallart description @en: Failure Mode according to DIN EN IEC 63270:2022-09 description @de: Ausfallart gemäß DIN EN IEC 63270:2022-09	[-]	[1..*]

Table 10: Specification of SMC "FailureMode"

idShort	*FailureMode*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/2561_2151_5032_8023		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC ListFailureModes		
Explanation	Failure Mode according to DIN EN IEC 63270:2022-09@en, Ausfallart gemäß DIN EN IEC 63270:2022-09@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] StatusDetected	IRI] https://example.com/ids/cd/2222_2151_5032_2694 preferredName @en: Detection status of a failure mode preferredName @de: Detektionsstatus einer Ausfallart definition @en: true: status of the failure mode is "detected", false: status of the failure mode is undetected definition @de: wahr: Status der Ausfallart its "detektiert", falsch: Status der Ausfallart its "nicht detektiert" description @en: Status of the failure mode: true: detected, false: not detected. In case of "true" SMC FailueModeDetectedInformation has to be provided description @de: Status der Ausfallart: true: aufgetreten, false: nicht aufgetreten. Im Fall "true" muss die SMC ailueModeDetectedInformation bereitgestellt werden	[boolean]	[1]
[MLP] FailureDescription	[IRI] https://example.com/ids/cd/3262_2151_5032_0899 preferredName @en: Failure mode description preferredName @de: Beschreibung der Ausfallart definition @en: Description of the failure mode definition @de: Beschreibung der Ausfallart description @en: Description of Failure Mode description @de: Beschreibung der Ausfallart	[-] Example Failure@en Beispiel Ausfallart@de	[1]
[Property]	[IRI] https://example.com/ids/cd/5034_3110_6032_0079	[-]	[0..*]

FailureDescriptionDocument	preferredName @en: Failure description document preferredName @de: Dokument zur Fehlerbeschreibung definition @en: Link to the file or website of the failure description document definition @de: Link zu zur Datei oder Webseite mit dem Dokument zur Fehlerbeschreibung description @en: Supportive document for describing the failure. This can be textual descriptions combined with pictures description @de: Unterstützendes Dokument zur Beschreibung des Fehlerbilds, z.B. textliche Beschreibung mit Bildern		
[Property] FailureCode	[IRI] https://example.com/ids/cd/6093_3110_6032_6663 preferredName @en: Failure code preferredName @de: Fehlercode definition @en: Code for a specific failure, e.g. alpha-numerical code definition @de: Code eines bestimmten Fehlers, z.B. ein alphanumerischer Code description @en: Alphanumerical code of a specific failure description @de: Alphanumerischer Code eines bestimmten Fehlers	[-] Example Failure@en Beispiel Ausfallart@de	[1]
[SMC] FailureModeDetectionInformation	[IRI] https://example.com/ids/cd/2153_2151_5032_0080 preferredName @en: Confidence level preferredName @de: Konfidenzniveau definition @en: Collection of information about the concrete detection of a specific failure mode, e.g. date/time, detection method definition @de: Sammlung von Informationen über die konkrete Detektion eines Fehlers, z.B. Datum/Uhrzeit, Detektionsmethode description @en: Provides information about the concrete detection of a specific failure mode description @de: Stellt Informationen über ein konkretes Ereignis einer Fehlerdetektion bereit	[string]	[0..1]

Table 11: Specification of SMC " FailureModeDetectionInformation "

idShort	*FailureModeDetectionInformation*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/5311_3170_6032_1244		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC FailureMode		
Explanation	Provides information about the concrete detection of a specific failure mode@en, Stellt Informationen über ein konkretes Ereignis einer Fehlerdetektion bereit@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] ConfidenceLevel	[IRI] https://example.com/ids/cd/2153_2151_5032_0080 preferredName @en: Confidence level preferredName @de: Konfidenzniveau definition @en: Enumerated list of confidence levels for fault diagnosis according to DIN EN IEC 63270:2022-09 (Level1-5) definition @de: Enumerierte Liste von Konfidenz Niveaus für die Diagnose einer Ausfallart gemäß DIN EN IEC 63270:2022-09 (Niveau 1-5) description @en: Confidence level according to DIN EN IEC 63270:2022-09 (Level1-5) description @de: Konfidenzintervall gemäß DIN EN IEC 63270:2022-09 (Niveau 1-5)	[string]	[1]
[Property] DeterminationType	[IRI] https://example.com/ids/cd/6522_9051_5032_1283 preferredName @en: Fault determination type preferredName @de: Fehlerdiagnosetyp definition @en: Fault determination type: by measurement, by model or by human decision definition @de: Typ der Fehlerdiagnose: durch Messung, durch ein Modell oder durch menschliche Entscheidung description @en: Fault determination by measurement, model or human desicion description @de: Fehlerbestimmung durch Messung, Modell oder menschliche Entscheidung	[string]	[1]

[Property] DetectionDateTime	[IRDI] 0173-1#02-ABF198#001 preferredName @en: time stamp (date and time) preferredName @de: Zeitstempel (Datum und Uhrzeit) definition @en: mark attributed to an instant by means of a specified timescale, expressed as a date and a time definition @de: Markierung, zugeordnet zu einem Moment mittles einer spezifischen Zeitskala, ausgedrückt als Datum und Uhrzeit description @en: date and time when the fault was detected (empty if not detected). Please note: In order to ensure interoperability it is important that the date/time on all assets using this information are synchronized description @de: Datum und Uhrzeit der Detektion des Fehlers (leer, wenn nicht detektiert). Bitte beachten: Um Interoperabilität gewährleisten zu können ist es wichtig, dass Datum und Uhrzeit für alle Assets, die diese Information verwenden synchronisiert sind.	[dateTime]	[1]
[Property] FaultLocation	[IRI] https://example.com/ids/cd/1524_2151_5032_8540 preferredName @en: Fault location preferredName @de: Fehlerort definition @en: Location of the fault provided as an IRI of the asset's administarion shell definition @de: Ort des Fehlers als IRI zur Verwaltungsschale des Assets description @en: Location of the fault (ID of AAS) description @de: Ort des Fehlers (ID der AAS)	[anyURI]	[1]
[Property] DurationUntilDetected	[IRI] https://example.com/ids/cd/3374_2171_4032_8973 preferredName @en: Operation time in wear relevant unit preferredName @de: Betriebszeit in verschleißrelevanter Einheit definition @en: Value of operation time in wear relevant unit, e.g. time, operation cycles, distance, etc. definition @de: Wert der Betriebszeit in der verschleißrelevanten Einheit, z.B. Zeit, Zyklen, Wegstrecke, etc.	[float]	[1]

	description @en: Duration until fault occurance, e.g. time, operation cycles, distance, etc. since last relevant maintenance event description @de: Dauer bis zum Auftreten des Fehlers, z.B. Zeit, Zyklen, Wegstrecke, etc., seit dem letzten relevanten Wartungsereignis		

Table 12: Specification of SMC "FaultDecision"

idShort	*FaultDecision*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/7315_2151_5032_9814		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC FaultDiagnosis		
Explanation	Classification of the decision to continue operation depending on the error that is detected@en. Klassifikation der Entscheidung zum Weiterbetrieb abhängig von der Ausfallart die detektiert wurde@de.		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] Decision	[IRI] https://example.com/ids/cd/7315_2151_5032_9814 preferredName @en: Information on operation after a failure preferredName @de: Information über Weiterbetrieb nach einem Fehler definition @en: Enumerated category of fault decision whether to continue, continue with adjusted parameters, continue with adjusted mode of operation, or stop the process definition @de: Enumerierte Kategorie der Entscheidung nach einem Fehler, ob der Prozess ohne Anpassung, mit angepassten Parametern, in einem angepassten Betriebsmodus weiterbetrieben wird oder der Prozess gestoppt wird description @en: Decision whether to continue, continue with adjusted parameters, continue with adjusted mode of operation, or stop the process description @de: Entscheidung, ob der Prozess ohne Anpassung, mit angepassten Parametern, in einem angepassten Betriebsmodus weiterbetrieben wird oder der Prozess gestoppt wird definition @de: wahr: Status der Ausfallart its "detektiert", falsch: Status der Ausfallart its "nicht detektiert"	[string]	[1]

	description @en: Status of the failure mode: true: detected, false: not detected description @de: Status der Ausfallart: true: aufgetreten, false: nicht aufgetreten		
[SMC] ListAdjustedParameters	[IRI] https://example.com/ids/cd/1550_3151_5032_4973 preferredName @en: List of adjusted parameters preferredName @de: Liste angepasster Parameter definition @en: Array of adjusted parameters definition @de: Array von angepassten Parametern description @en: List of adjusted process parameters in case of decision to continue process with adjusted parameters or with adjusted mode of operation description @de: Liste angepasster Parameter, bei Entscheidung für einen Weiterbetrieb mit angepassten Parametern oder mit angepasstem Betriebsmodus	[-]	[0..1]

Table 13: Specification of SMC "ListAdjustedParameters"

idShort	*ListAdjustedParameters*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/1550_3151_5032_4973		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC FaultDecision		
Explanation	List of adjusted process parameters in case of decision to continue process with adjusted parameters or with adjusted mode of operation@en, Liste angepasster Parameter, bei Entscheidung für einen Weiterbetrieb mit angepassten Parametern oder mit angepasstem Betriebsmodus@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
|SMC] OperationParameter	[IRI] https://example.com/ids/cd/9201_3151_5032_7207 preferredName @en: Description of an operation parameter preferredName @de: Beschreibung eines Betriebsparameters definition @en: Description of properties of an operation parameter definition @de: Beschreibung der Eigenchaften eines Betriebsparameters description @en: Definition of an operation parameter which has been adjusted in case of decision to continue process with adjusted parameters or with adjusted mode of operation description @de: Definition eines Betriebsparameters, der im Fall eines Weiterbetriebs mit angepassten Parametern oder mit angepasstem Betriebsmodus, angepasst wurde	[-]	[0..*]

Table 14: Specification of SMC "OperationParameter"

idShort	*OperationParameter*
Class	SubmodelElementCollection
semanticId	[IRI] https://example.com/ids/cd/9201_3151_5032_7207
isCaseOf	-
AllowDuplicates	-
Parent	SMC ListAdjustedParameters
Explanation	Definition of an operation parameter which has been adjusted in case of decision to continue process with adjusted parameters or with adjusted mode of operation@en

	Definition eines Betriebsparameters, der im Fall eines Weiterbetriebs mit angepassten Parametern oder mit angepasstem Betriebsmodus, angepasst wurde@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] ManipulatedVariable	[IRDI] 0173-1#02-ABC125#001 preferredName @en: manipulated variable preferredName @de: Stellgröße definition @en: output variable of the controlling system, which is also an input variable of the controlled system definition @de: Ausgangsgröße der Regeleinrichtung, die auch eine Eingangsgröße der Regelstrecke ist description @en: manipulated variable description @de: Stellgröße	[string]	[1]
[Property] ManipulatedVariable Value	[IRDI] 0173-1#02-ABF309#001 preferredName @en: setpoint preferredName @de: Sollwert definition @en: in a control loop, the target value the process value is intended to assume, expressed in the units of measure of the process value definition @de: in einem Regelkreis der Zielwert, den der Prozesswert annehmen soll, ausgedrückt in Einheiten des Prozesswertes description @en: new value of the manipulated variable (process parameter) description @de: neuer Wert der Stellgröße	[]	[1]
[Property] TechnicalProperties	[IRI] https://admin-shell.io/sandbox/SG2/TechnicalData/TechnicalProperties/1/1 preferredName @en: Technical and product properties preferredName @de: Technische und Produktmerkmale definition @en: Individual characteristics that describe the product and its technical properties definition @de: Einzelne Merkmale die das Produkt und die technischen Eigenschaften beschreiben description @en: Technical properties of the process parameter according to submodel TechnicalData description @de: Technische Eigenschaften des Prozessparameters gemäß dem Teilmodel TechnicalData	[complexType]	[0..1]

3.4 Properties of the SMC RemainingUsefulLife

Table 15: Specification of SMC "RemainingUsefulLifePrediction"

idShort	*RemainingUsefulLifePrediction*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/7513_3151_5032_3911		
isCaseOf	-		
AllowDuplicates	-		
Parent	SubModel PredictiveMaintenance		
Explanation	Information on prediction of remaining usable life of an asset@en, Informationen über die Vorhersage der Restlebensdauer des Assets@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] RemainingUsefulLife	[IRI] https://example.com/ids/cd/7553_3151_5032_7284 preferredName @en: Data on remaining useful life preferredName @de: Daten zur nutzbaren Restlebensdauer definition @en: Contains data on remaining useful life (RUL) in context of precitive maintenance like predicted duration of operation and time until end of useful life definition @de: Enthält Daten zur nutzbaren Restlebensdauer (RUL im Kontext der vorausschauenden Wartung, wie die prognostizierte Dauer und Zeit der Restnutzung description @en: Information on predicted remaining useful life description @de: Informationen zur prognostizierten Restlebensdauer	[-]	[1]
[SMC] ListRULBoundaryConditions	[IRI] https://example.com/ids/cd/8410_4151_5032_7713 preferredName @en: List of boundary conditions of remaining useful life prediction preferredName @de: Liste der Randbedingungen für die Prognose der nutzbaren Restlebensdauer definition @en: List of boundary conditions for which remaining useful life has been predicted definition @de: Liste der Randbedingungen unter denen die nutzbare Restlebensdauer prognositiziert wurde	[-]	[1]

	description @en: List of boundary conditions for with RUL prediction is carried out description @de: Liste der Randbedingungen unter der die RUL Prognose erstellt wurde		
[SMC] PredictionModelInformation	[IRI] https://example.com/ids/cd/8413_4151_5032_4159 preferredName @en: Prediction model information preferredName @de: Informationen zum Prognosemodell definition @en: Information about the model for RUL prediction relevant in the context of predictive maintenance definition @de: Informationen über das Modell zur Prognose der RUL im Kontext der vorausschauenden Wartung description @en: Information about the model used for prediction of remaining useful life: type of the model and textual description of the model description @de: Informationen über das zur Vorhersage der Restnutzungsdauer verwendete Modell: Art des Modells und textliche Beschreibung des Modells	[-]	[1]
[SMC] ListPreAlerts	[IRI] https://example.com/ids/cd/5570_8013_5032_8604 preferredName @en: Pre-alert list preferredName @de: Voralarmliste definition @en: List for defining pre-alerts which should be raised before remaining useful life is exceeded definition @de: Liste, um Voralarme zu definieren, die vor Erreichen der Restlebensdauer ausgelöst werden sollen description @en: List of pre-alerts before reaching end of useful life description @de: Liste von Vor-Alarmen bis zum Erreichen der Restlebensdauer	[-]	[0..1]
[SMC] AlertAfterExceedingRemaining UsableLife	[IRI] https://example.com/ids/cd/1234_4151_5032_4329 preferredName @en: Alert remaining useful life exceeded preferredName @de: Alarm nutzbare Restlebensdauer überschritten definition @en: Definition of an alert if remaining useful life is exceeded	[-]	[0..1]

	definition @de: Definition eines Alarms, wenn die nutzbare Restlebensdauer überschritten ist description @en: Definition of an alert in case of exceeding remaining useful life description @de: Definition eines Alarms im Fall der Überschreitung der Restlebensdauer		

Table 16: Specification of SMC " RemainingUsefulLife "

idShort	*RemainingUsefulLife*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/7553_3151_5032_7284		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC RemainingUsefulLifePrediction		
Explanation	Information on predicted remaining useful life@en Informationen zur prognostizierten Restlebensdauer@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] RemainingUsefulLifeInOperation	[IRI] https://example.com/ids/cd/3374_2171_4032_8973 preferredName @en: Operation time in wear relevant unit preferredName @de: Betriebszeit in verschleißrelevanter Einheit definition @en: Value of operation time in wear relevant unit, e.g. time, operation cycles, distance, etc. definition @de: Wert der Betriebszeit in der verschleißrelevanten Einheit, z.B. Zeit, Zyklen, Wegstrecke, etc. description @en: Absolute value of operation time, when remaining usable life in operation ends, e.g. as time, operation cycles, distance, etc. description @de: Absoluter Wert für die Betriebszeit, wenn die verbleibenden Nutzungsdauer endet, z.B. als Zeit, Zyklen, Wegstrecke, etc.	[decimal]	[1]
[Property] RemainingUsfulLifeDateTime	[IRDI] 0173-1#02-ABF198#001 preferredName @en: time stamp (date and time) preferredName @de: Zeitstempel (Datum und Uhrzeit)	[decimal]	[0..1]

	definition @en: mark attributed to an instant by means of a specified timescale, expressed as a date and a time definition @de: Markierung, zugeordnet zu einem Moment mittles einer spezifischen Zeitskala, ausgedrückt als Datum und Uhrzeit description @en: Date and time when remaining usful life will be expected to be exceeded description @de: Datum und Zeit zu der das Ende der verbleibenden Nutzungsdauer erwartet wird		
[Range] ConfidenceInterval	[IRI] https://example.com/ids/cd/0080_0191_4032_0282 preferredName @en: Confidence interval preferredName @de: Konfidenzintervall definition @en: confidence interval, measured in the unit of the predicted value definition @de: Konfidenzintervall in der Einheit des prognositizierten Wertes description @en: Confidence intervall for remaining usable life prediction description @de: Konfidenzintervall für die prognotizierte verbleibende Nutzungsdauer	[-]	[1]

Table 17: Specification of SMC " ListRULBoundaryConditions "

idShort	*ListRULBoundaryConditions*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/8410_4151_5032_7713		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC RemainingUsefulLifePrediction		
Explanation	List of boundary conditions for with RUL prediction is carried out@en Liste der Randbedingungen unter der die RUL Prognose erstellt wurde@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] RULCondition	[IRI] https://example.com/ids/cd/7430_4151_5032_6288 preferredName @en: Boundary condition for remaining useful life prediction preferredName @de: Randbedingung für die Prognose der nutzbaren Restlebensdauer	[-]	[1]

	definition @en: Boundary condition for which remaining useful life has been predicted definition @de: Randbedingung unter der die nutzbare Restlebensdauer prognostiziert wurde description @en: Description of a boundary condition for which remaining useful life has been predicted description @de: Beschreibung einer Randbedingung unter der die nutzbare Restlebensdauer prognostiziert wurde		

Table 18: Specification of SMC " RULCondition "

idShort	*RULCondition*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/7430_4151_5032_6288		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC ListRULBoundaryCondition		
Explanation	List of boundary conditions for with RUL prediction is carried out@en Liste der Randbedingungen unter der die RUL Prognose erstellt wurde@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[MLP] ConditionName	[IRI] https://example.com/ids/cd/8534_9091_4032_2070 preferredName @en: Boundary condition name preferredName @de: Bezeichnung der Randbedingung definition @en: Name of a boundary condition for which RUL predication is valid definition @de: Bezeichnung einer Nebenbedingung für die die Prognode der RUL gültig ist description @en: Name of the RUL condition description @de: Name der RUL Bedingung	[-] Example Name@en, Beispielname@de	[1]
[Property] IsBoundaryConditionUsedInModel	[IRI] https://example.com/ids/cd/7584_9091_4032_9183 preferredName @en: Condition is used in RUL model preferredName @de: Bedingung wird im RUL Modell verwendet	[-]	[1]

	definition @en: Is this boundary condition used in the modle for RUl prediction? true: yes, fale: no definition @de: Wird diese Randbedingung im Modell für die RUL Prognose verwendet? Wahr: ja, Falsch: nein description @en: Boolean value which indicates if condition is used in the RUL model description @de: Boolscher Wert, der angibt, ob die Bedingung im RUL Modell verwendet wird		
[MLP] BoundaryDescription	[IRI] https://example.com/ids/cd/1025_9091_4032_6674 preferredName @en: Description of the boundary of a RUL prediction condition preferredName @de: Beschreibung einer RUL Vorhersage-Randbedingung definition @en: Description of the boundary of a RUL prediction condition definition @de: Beschreibung einer RUL Vorhersage-Randbedingung description @en: Description of the boundary condition, e.g. utilization, operational stress: intensity, frequency, duration of use description @de: Beschreibung der RUL Bedingung, z.B. Auslastung der Anlage, Betriebsstress: Intensität, Frequenz, Dauer der Nutzung	[-] Description of the boundary@en, Beschreibung der Randbedingung@de	[0..1]
[MLP] BoundaryValueRange	[IRI] https://example.com/ids/cd/0085_9091_4032_5460 preferredName @en: RUL boundary condition value range preferredName @de: Wertebereich der RUL Prognose Randbedingung definition @en: Value range of a boundary condition for which RUL prediction has been calculated definition @de: Wertebereich einer Randbedingung für die die RUL Prognose erfolgte description @en: Value range of the RUL condition boundary description @de: Wertebereich der RUL Bedingung	[-]	[1]

Table 19: Specification of SMC " PredictionModelInformation "

idShort	*PredictionModelInformation*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/8413_4151_5032_4159		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC RemainingUsefulLifePrediction		
Explanation	Information about the model used for prediction of remaining useful life: type of the model and textual description of the model@en Informationen über das zur Vorhersage der Restnutzungsdauer verwendete Modell: Art des Modells und textliche Beschreibung des Modells@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] ModelType	[IRI] https://example.com/ids/cd/8171_0191_4032_2272 preferredName @en: Model type according to DIN EN IEC 63270 preferredName @de: Modelltyp gemäß DIN EN IEC 63270 definition @en: Model type as an enumerated value: physical based methods, data-driven methods, hybrid methods definition @de: Modelltyp als enumerierter Wert: physical based methods, data-driven methods, hybrid methods description @en: model type according to DIN IEC 63270: Physical model, data driven method, hybrid method description @de: Modell Typ gemäß DIN IEC 63270: Physikalisches Modell, Datengesteuertes Verfahren, Hybridverfahren	[string]	[1]
[MLP] ModelDescription	[IRI] https://example.com/ids/cd/2391_0191_4032_8895 preferredName @en: Model description preferredName @de: Modellbeschreibung definition @en: More detailed description of the model type used for RUL prediction (optional) definition @de: Detailliertere Beschreibung des Modelltyps, der für die RUL Prognose verwendet wird (optional)	[-] Example of a model description@en, Beispiel einer Modellbeschreibung@de	[0..1]

	description @en: description of the model description @de: Beschreibung des Modells		

Table 20: Specification of SMC " ListPreAlerts "

idShort	*ListPreAlerts*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/5570_8013_5032_8604		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC RemainingUsefulLifePrediction		
Explanation	List of pre-alerts before reaching end of useful life@en, Liste von Vor-Alarmen bis zum Erreichen der Restlebensdauer@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] PreAlert	[IRI] https://example.com/ids/cd/8171_0191_4032_2272 preferredName @en: Pre-alert list preferredName @de: Voralarmliste definition @en: List for defining pre-alerts which should be raised before remaining useful life is exceeded definition @de: Liste, um Voralarme zu definieren, die vor Erreichen der Restlebensdauer ausgelöst werden sollen description @en: List of pre-alerts before reaching end of useful life description @de: Liste von Vor-Alarmen bis zum Erreichen der Restlebensdauer	[-]	[0..*]

Table 21: Specification of SMC " PreAlert "

idShort	*PreAlert*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/1234_4151_5032_4329		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC ListPreAlerts		
Explanation	Definition of a pre-alert before exceeding remaining useful life@en, Definition eines Vor-Alarms bis zur Überschreitung der Restlebensdauer@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Event] AlertEvent	[IRI] https://example.com/ids/cd/1564_4151_5032_8777 preferredName @en: Alert event RUL exceeded preferredName @de: Alarmevent bei RUL Überschreitung definition @en: Alert event in case of exceeding remaining useful life definition @de: Alarmevent, wenn nutzbare Restlebensdauer überschritten ist description @en: Definition of an event raised in case of exceeding remaining useful life description @de: Definition eines Events der iniziiert wird, wenn die nutzbare Restlebensdauer überschritten ist	[string]	[1]
[MLP] PreAlertMessage	[IRI] https://example.com/ids/cd/2530_0191_4032_5317 preferredName @en: Remaining usable life alert message preferredName @de: Alarmnachricht für verbleibende Restnutzungsdauer definition @en: Message to be displayed when alarm regarding predicted remaining useful life is raised definition @de: Nachricht, die bei Auslösen eines Alarms bezüglich der vorhergesagten verbleibenden Restnutzungsdauer angezeigt wird description @en: Message to be displayed when predicted remaining useful life is exceeded description @de: Nachricht bei Überschreitung der vorhergesagten verbleibenden Nutzungsdauer angezeigt wird	[-]	[0..1]

[MLP] PreAlertValue	[IRI] https://example.com/ids/cd/0281_8013_5032_3117 preferredName @en: Pre-alert value preferredName @de: Voralarmwert definition @en: Pre-warning duration in wear relevant unit before remaining useful life is exceeded definition @de: Vorwarndauer in verschleißrelevanter Einheit vor Eintritt der Überschreitung verbleibenden Restnutzungsdauer description @en: Pre-warning duration in wear relevant unit before remaining useful life is exceeded description @de: Vorwarndauer in verschleißrelevanter Einheit vor Eintritt der Überschreitung verbleibenden Restnutzungsdauer	[-]	[0..1]

Table 22: Specification of SMC " AlertAfterExceedingRemainingUsableLife "

idShort	*AlertAfterExceedingRemainingUsableLife*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/1234_4151_5032_4329		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC ListPreAlerts		
Explanation	Definition of an alert in case of exceeding remaining useful life@en Definition eines Alarms im Fall der Überschreitung der Restlebensdauer@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Event] AlertEvent	[IRI] https://example.com/ids/cd/1564_4151_5032_8777 preferredName @en: Alert event RUL exceeded preferredName @de: Alarmevent bei RUL Überschreitung definition @en: Alert event in case of exceeding remaining useful life definition @de: Alarmevent, wenn die nutzbare Restlebensdauer überschritten ist description @en: Definition of an event raised in case of exceeding remaining useful life	[-]	[0..1]

	description @de: Definition eines Events der iniziiert wird, wenn die nutzbare Restlebensdauer überschritten ist		
[MLP] AlertMessage	[IRI] https://example.com/ids/cd/2530_0191_4032_5317 preferredName @en: Remaining usable life alert message preferredName @de: Alarmnachricht für verbleibende Restnutzungsdauer definition @en: Message to be displayed when alarm regarding predicted remaining useful life is raised definition @de: Nachricht, die bei Auslösen eines Alarms bezüglich der vorhergesagten verbleibenden Restnutzungsdauer angezeigt wird description @en: Message to be displayed when alert regarding predicted remaining useful life is raised description @de: Nachricht die bei Erreichen eines Alarms im Zusammenhang mit verbleibenden Restnutzungsdauer angezeigt wird	[-] Predicted remaining usable life exceeded@en, Vorhergesagte verbleibenden Nutzungsdauer überschritten@de	[0..1]
[Property] MaintenanceRequired	[IRDI] 0173-1#02-AAW598#001 preferredName @en: Maintenance required preferredName @de: Wartung erforderlich definition @en: Maintenance required definition @de: Wartung erforderlich description @en: Maintenance required description @de: Wartung erforderlich	[-] Nutzungsdauer überschritten@de	[0..1]

3.5 Properties of the SMC LastMaintenanceRelevantEvents

Table 23: Specification of SMC "LastMaintenanceRelevantEvents"

idShort	*LastMaintenanceRelevantEvents*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/6555_4151_5032_7244		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC RemainingUsefulLifePrediction		
Explanation	Wear relevant information about last maintenance event@en, wear relevant information about last maintenance event@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC] LastMaintenanceEvent	[IRI] https://example.com/ids/cd/8310_5151_5032_0120 preferredName @en: Last maintenance event preferredName @de: Letzter Wartungsvorgang definition @en: Wear relevant information about last maintenance event definition @de: Verschleißrelevante Informationen zur letzten Wartung description @en: Wear relevant information about last maintenance event description @de: Verschleißrelevante Informationen über die letzte Wartung	[-]	[0..1]
[SMC] LastRepairEvent	[IRI] https://example.com/ids/cd/5240_5151_5032_9135 preferredName @en: Last repair event preferredName @de: Letzte Reparatur definition @en: Wear relevant information about last repair event definition @de: Verschleißrelevante Informationen zur letzten Reparatur description @en: Wear relevant information about last repair event description @de: Verschleißrelevante Informationen über die letzte Reparatur	[-]	[0..1]
[SMC] LastReplacementEvent	[IRI] https://example.com/ids/cd/0170_5151_5032_5824	[-]	[0..1]

	preferredName @en: Last replacement event preferredName @de: Letzte Ersetzung definition @en: Wear relevant information about last replacement event definition @de: Verschleißrelevante Informationen zur letzten Ersetzung description @en: Wear relevant information about last replacement event description @de: Verschleißrelevante Informationen über die letzte Ersetzung		
[SMC] InitialOperation	[IRI] https://example.com/ids/cd/4090_5151_5032_4671 preferredName @en: Information on initial operation preferredName @de: Informationen zur Erstinbetriebnahme definition @en: Wear relevant information about inital operation definition @de: Verschleißrelevante Informationen über die Erstinbetriebnahme description @en: Information about date of initial operation description @de: Informationen über den Inbetriebnahmezeitpunkt	[-]	[1]

Table 24: Specification of SMC "LastMaintenanceEvent"

idShort	*LastMaintenanceEvent*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/8310_5151_5032_0120		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC RemainingUsefulLifePrediction		
Explanation	Wear relevant information about last maintenance event@en, Verschleißrelevante Informationen über die letzte Wartung@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] LastMaintenanceEventValue	[IRI] https://example.com/ids/cd/3374_2171_4032_8973 preferredName @en: Operation time in wear relevant unit	[-]	[1]

	preferredName @de: Betriebszeit in verschleißrelevanter Einheit definition @en: Value of operation time in wear relevant unit, e.g. time, operation cycles, distance, etc. definition @de: Wert der Betriebszeit in der verschleißrelevanten Einheit, z.B. Zeit, Zyklen, Wegstrecke, etc. description @en: last maintenance event as a value in the wear relevant unit, e.g. time, operation cycles, distance, etc. description @de: letzte Wartung in verschleißrelevanter Einheit, z.B. Zeit, Zyklen, Wegstrecke, etc.		
[Property] LastMaintenanceEventDateTime	[IRDI] 0173-1#02-ABF198#001 preferredName @en: time stamp (date and time) preferredName @de: Zeitstempel (Datum und Uhrzeit) definition @en: mark attributed to an instant by means of a specified timescale, expressed as a date and a time definition @de: Markierung, zugeordnet zu einem Moment mittels einer spezifischen Zeitskala, ausgedrückt als Datum und Uhrzeit description @en: time stamp (date and time) of last maintenance description @de: Zeitstempel (Datum und Uhrzeit) der letzten Wartung	[time]	[1]

Table 25: Specification of SMC "LastRepairEvent"

idShort	*LastRepairEvent*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/5240_5151_5032_9135		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC RemainingUsefulLifePrediction		
Explanation	Wear relevant information about last repair event@en, Verschleißrelevante Informationen über die letzte Reparatur@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] LastRepairEventValue	[IRI] https://example.com/ids/cd/3374_2171_4032_8973 preferredName @en: Operation time in wear relevant unit preferredName @de: Betriebszeit in verschleißrelevanter Einheit definition @en: Value of operation time in wear relevant unit, e.g. time, operation cycles, distance, etc. definition @de: Wert der Betriebszeit in der verschleißrelevanten Einheit, z.B. Zeit, Zyklen, Wegstrecke, etc. description @en: last repair event as a value in the wear relevant unit, e.g. time, operation cycles, distance, etc. description @de: letzte Reparatur in verschleißrelevanter Einheit, z.B. Zeit, Zyklen, Wegstrecke, etc.	[-]	[1]
[Property] LastRepairEventDateTime	[IRDI] 0173-1#02-ABF198#001 preferredName @en: time stamp (date and time) preferredName @de: Zeitstempel (Datum und Uhrzeit) definition @en: mark attributed to an instant by means of a specified timescale, expressed as a date and a time definition @de: Markierung, zugeordnet zu einem Moment mittles einer spezifischen Zeitskala, ausgedrückt als Datum und Uhrzeit description @en: time stamp (date and time) of last maintenance description @de: Zeitstempel (Datum und Uhrzeit) der letzten Wartung	[time]	[1]

Table 26: Specification of SMC " LastReplacementEvent "

idShort	*LastReplacementEvent*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/0170_5151_5032_5824		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC RemainingUsefulLifePrediction		
Explanation	Wear relevant information about last replacement event@en, Verschleißrelevante Informationen über die letzte Ersetzung@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] LastReplacementEventValue	[IRI] https://example.com/ids/cd/3374_2171_4032_8973 preferredName @en: Operation time in wear relevant unit preferredName @de: Betriebszeit in verschleißrelevanter Einheit definition @en: Value of operation time in wear relevant unit, e.g. time, operation cycles, distance, etc. definition @de: Wert der Betriebszeit in der verschleißrelevanten Einheit, z.B. Zeit, Zyklen, Wegstrecke, etc. description @en: last replacement event as a value in the wear relevant unit, e.g. time, operation cycles, distance, etc. description @de: letzte Ersetzung in verschleißrelevanter Einheit, z.B. Zeit, Zyklen, Wegstrecke, etc.	[-]	[1]
[Property] LastReplacementEvent DateTime	[IRDI] 0173-1#02-ABF198#001 preferredName @en: time stamp (date and time) preferredName @de: Zeitstempel (Datum und Uhrzeit) definition @en: mark attributed to an instant by means of a specified timescale, expressed as a date and a time definition @de: Markierung, zugeordnet zu einem Moment mittles einer spezifischen Zeitskala, ausgedrückt als Datum und Uhrzeit description @en: time stamp (date and time) of last maintenance description @de: Zeitstempel (Datum und Uhrzeit) der letzten Wartung	[time]	[1]

Table 27: Specification of SMC "InitialOperation"

idShort	*InitialOperation*		
Class	SubmodelElementCollection		
semanticId	[IRI] https://example.com/ids/cd/4090_5151_5032_4671		
isCaseOf	-		
AllowDuplicates	-		
Parent	SMC RemainingUsefulLifePrediction		
Explanation	Information about date of initial operation@en, Informationen über den Inbetriebnahmezeitpunkt@de		
[SME type]	**semanticity = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] InitialOperationEventValue	[IRI] https://example.com/ids/cd/3374_2171_4032_8973 preferredName @en: Operation time in wear relevant unit preferredName @de: Betriebszeit in verschleißrelevanter Einheit definition @en: Value of operation time in wear relevant unit, e.g. time, operation cycles, distance, etc. definition @de: Wert der Betriebszeit in der verschleißrelevanten Einheit, z.B. Zeit, Zyklen, Wegstrecke, etc. description @en: value of wear relevant variable, e.g. time, operation cycles, distance, etc. at time of initial operation, in general zero description @de: Wert der verschleißrelevanten Größe, z.B. Zeit, Betriebszyklen, Distanz, etc. zum Zeitpunkt der Inbetriebnahme	[-]	[1]
[Property] InitialOperationDate	[IRDI] 0173-1#02-ABA683#001 preferredName @en: initial operation date preferredName @de: Datum der ersten Inbetriebnahme definition @en: date, when the machine was switched on the first time after it has left the manufacturer plant definition @de: Datum, an dem die Maschine das erste Mal eingeschaltet wurde, nachdem sie das Herstellerwerk verlassen hat description @en: initial operation date description @de: Datum der ersten Inbetriebnahme	[date]	[1]

4 Usage as SubmodelElementCollection

4.1 Properties of the Submodel “PredictiveMaintenance”

Due to the fact that PredictiveMainenance can be re-used in various contexts beside service issues, the specified SMC’s in section 3 can be used within other Submodels. In this way the parent Submodel can utilize standardized means of predictive maintenance (PM) use cases. The submodel can be used to provide PM relevant information on sub systems of a production line as well as provided by PM software applications.

Annex A: Explanations on used table formats

General
The used tables in this document try to outline information as concise as possible. They do not convey all information on Submodels and SubmodelElements. For this purpose, the definitive definitions are given by a separate file in form of an AASX file of the Submodel template and its elements.

Tables on Submodels and SubmodelElements
For clarity and brevity, a set of rules is used for the tables for describing Submodels and SubmodelElements.

- The tables follow in principle the same conventions as in [5].
- The table heads abbreviate 'cardinality' with 'card'.
- The tables often place two informations in different rows of the same table cell. In this case, the first information is marked out by sharp brackets [] form the second information. A special case are the semanticIds, which are marked out by the format: (type)(local)[idType]value.
- The types of SubmodelElements are abbreviated: SME

SME type Submodel	Element type
Property	Property
MLP	MultiLanguageProperty
Range	Range
File	File
Blob	Blob
Ref	ReferenceElement
Rel	RelationshipElement
SMC	SubmodelElementCollection

- If an idShort ends with '{00}', this indicates a suffix of the respective length (here: 2) of decimal digits, in order to make the idShort unique. A different idShort might be choosen, as long as it is unique in the parent’s context.
- The Keys of semanticId in the main section feature only idType and value, such as: [IRI]https://admin-shell.io/vdi/2770/1/0/DocumentId/Id. The attributes "type" and "local" (typically "ConceptDescription" and "(local)" or "GlobalReference" and (no-local)") need to be set accordingly; see [6].
- If a table does not contain a column with "parent" heading, all represented attributes share the same parent. This parent is denoted in the head of the table.
- Multi-language strings are represented by the text value, followed by '@'-character and the ISO 639 language code: example@de.
- The [valueType] is only given for Properties.

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