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Production Calendar

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SPECIFICATION

Submodel Template of the
Asset Administration Shell

Imprint

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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], [2], [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] to [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 defines a general interoperable representation of production calendars, detailing operating times within the industrial domain. It includes a template to retain one production calendar in the MIME-Type iCalendar (iCal), as specified in RFC 5545. The objective of this Submodel is to establish a single source of truth that facilitates the synchronization and utilization of production calendars across various applications.

For instance, this Submodel can be utilized by Manufacturing Execution Systems (MES) and Value Chain Simulations to exchange information such as shift schedules for individual production systems and workstations. Additionally, the Submodel could also be used to define the shift schedule in departments and companies if they are described through their own AAS. The production calendar Submodel in the higher business levels could be used to affect the production planning process in the single departments at lower levels. Thus, this Submodel allows the inheritance of one production calendar from another, enabling external applications to implement complex industrial use cases, like the aggregation of operating times of a works environment comprising multiple locations, departments, and machinery.

The definition of a production calendar using an AAS Submodel ensures that the production calendar is available in a standardized, machine-readable form. This allows different systems (MES, ERP, SCADA, etc.) to interpret and synchronize the same calendar data. Defining a production calendar as an AAS Submodel Template thus provides a standardized, automated and interoperable basis for calculating KPIs.

However, since the iCal format provides only abstract guidelines, it lacks sufficient standardization for industrial applications. Therefore, it is essential to first specify the necessary variables for accurately describing the content of the production calendar. These variables are defined in the Submodel itself and should be extended by the working group to assure the interoperability within the extended iCal format.

1.3 Not in Scope of the Submodel

1.3.1 Archiving a production calendar

When changes need to be done in one calendar, e.g. for a machine, the older version of the calendar is not stored in the same Submodel. This should be resolved by mechanisms of change management, e.g. with a new version of the Submodel or the AAS which contains the Submodel.

1.3.2 Store more than one production calendar

There is no use case which requires more than one production calendar for an asset. For example, a machine and a department can only have one production calendar respectively. The calendar for the department is the overall allowance for all dedicated machines and workstations. With the functionality, to

derive calendars, all subsidiary machines will inherit or adapt the calendar of the department. If one Submodel contains two production calendars a conflict situation arises.

1.4 Relevant standards for the Submodel template

- RFC 5545 - Internet Calendaring and Scheduling Core Object Specification [7]

1.5 Use cases, requirements and design decisions

1.5.1 Use Cases

1.5.1.1 Exchanging production calendar information between production applications

A Manufacturing Execution System (MES) and a value chain simulation can use the production calendar Submodel of the AAS to exchange information, such as the production calendar. Production calendars play a vital role in many business applications that address production-related challenges. They define the operational schedule of a plant, production line, or individual machine, specifying working periods, breaks, and downtime. In simulation and value stream management (VSM) applications, production calendars are crucial for accurately modelling production workflows. They enable simulations to reflect real-world constraints, such as shift lengths, worker availability, and machine operating hours, ensuring realistic analysis and optimization of production processes.

Production calendars are often created and managed within a specific application, such as an MES. Synchronizing these calendars across all applications that use them can be challenging, especially when updates are required. To address this, the MES can publish the production calendar to an AAS. Other applications that work with production calendars can then retrieve the most up-to-date production calendar data from the AAS and use it to fulfil their specific needs.

Using the AAS Submodel ensures seamless synchronization of production calendars across various applications, enhancing efficiency and accuracy in production planning and optimization.

1.5.1.2 Human resource planning

Effective human resource planning is essential to maintaining efficient, cost-effective, and timely manufacturing operations that meet business demands. The production calendar plays an important role in this process by providing a comprehensive overview of operational schedules and the availability of resources, enabling HR managers to allocate personnel optimally. This ensures efficient utilization of workforce resources, minimizes labor costs, and supports flexibility in adapting to fluctuations in production requirements.

With the introduction of the production calendar submodel not only for machines and workstations but also for employees, data exchange between these entities can be standardized. This facilitates greater automation in shift planning, making the process more dynamic and responsive to changing requirements. The synchronization of machine and employee availability becomes more straightforward and efficient. Furthermore, this integration allows seamless alignment with factory calendars.

The standardized format and exchange of information through corresponding administration shells ensure that human resource planning can better interact with other systems such as Manufacturing Execution Systems (MES) or Production Planning Systems (PPS). This enhances overall operational transparency and coordination across departments.

1.5.1.3 Production Schedule

Production planning aims to make manufacturing efficient, cost-effective, and timely to meet customer demands. It ensures optimal utilization of resources such as machines, personnel, and materials, minimizes costs, and reduces lead times. Production planning synchronizes all production steps to ensure smooth workflows and provides flexibility to quickly adapt to changes, such as fluctuations in demand or capacity.

To achieve this, a production planning system (PPS) requires not only production orders, material availability, and personnel availability but also the production calendar. The production calendar is essential for planning production processes as it defines the operating hours of machines, production lines, facilities, or the entire plant, specifying work hours, maintenance windows, breaks, and other relevant timeframes.

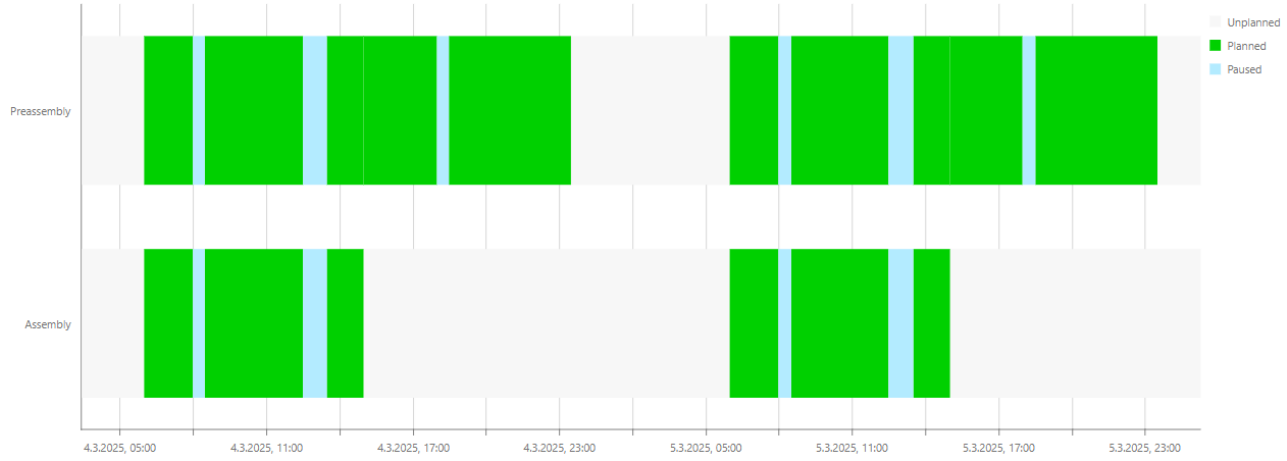

Figure 1: Gantt visualization and comparison of the different production calendars of two production lines

In production planning applications, such as scheduling and resource optimization systems, the production calendar plays a critical role in ensuring that the right resources are scheduled at the right time.

By providing the production calendar Submodel within the AAS, key calendar information can be made available not only for production planning but also for other systems, such as a MES.

The use of the AAS production calendar Submodel ensures that relevant calendar information can be utilized in real time across all applications. This enables precise planning and rescheduling of production processes based on the actual availability of machines, personnel, and other resources. In this way, the AAS Submodel supports dynamic and accurate production planning that aligns optimally with real-world operating conditions.

1.5.1.4 Base for KPI calculation

Beside of quality, production and operating data, the calculation of key performance indicators (KPI) requires working hours of machines, workstations as well as workers. The production calendar of a production machine, department or plant is essential for the calculation of KPIs, e.g. in accordance with VDMA 66412-1 or ISO 22400-2. The production calendar is the time reference for almost all KPIs in MES systems. It determines which times are considered productive, planned or unproductive, which in turn has a direct impact on the calculation of key performance indicators.

It defines the time basis for the calculation of many key performance indicators. Many KPIs in the MES environment, such as occupancy rate, degree of utilization, OEE (Overall Equipment Effectiveness) or availability, are based on time values. The production calendar defines which times may be used for the calculation (working times vs. downtimes) and ensures that, for example, only planned production times are considered for the KPIs. Without a correct reference from the production calendar, unplanned downtimes or breaks could be interpreted incorrectly.

It therefore forms the basis for the OEE, which is made up of availability, performance and quality. The production calendar defines when a machine should have been running (planned production time) in order to avoid distortions. Key figures such as employee productivity or machine utilization also depend on the planned production time. The calendar helps to realistically map productivity losses due to public holidays, maintenance times or shift models.

1.5.2 Requirements

The **iCalendar (iCal) format** is a standard for representing and exchanging calendar data across various systems and applications. Defined in **RFC 5545**, it allows the representation of events in a text-based, platform-independent manner. iCal files typically have the .ics extension and are widely used for synchronizing calendar information between different tools and platforms. For an example of the iCal format see Figure 2.

```
BEGIN:VCALENDAR
  VERSION:2.0
  PRODID:http://www.example.com/calendarapplication/
  METHOD:PUBLISH
  BEGIN:VEVENT
    UID:461092315540@example.com
    ORGANIZER;CN="Alice Balder, Example Inc.":MAILTO:alice@example.com
    LOCATION:Anywhere
    GEO:48.85299;2.36885
    SUMMARY:Short info
    DESCRIPTION:Description of appointment
    CLASS:PUBLIC
    DTSTART:20240910T220000Z
    DTEND:20240919T215900Z
    DTSTAMP:20240812T125900Z
    RRULE:FREQ=WEEKLY;BYDAY=TU,WE,FR;UNTIL=20280425T000000Z
  END:VEVENT
END:VCALENDAR
```

Figure 2: Basic iCal format

While the iCal format is highly versatile, its generic and abstract nature makes it insufficient to meet the specific requirements of certain industries. For example, sectors like manufacturing or production often require more detailed scheduling and resource management information than what iCal provides natively. As a result, additional context, such as breaks, production days, or maintenance periods, cannot be adequately captured using standard iCal properties.

1.5.2.1 Extending iCal with Custom Variables

The extensibility of iCal allows for the definition of **custom properties** to address its limitations and meet industry-specific requirements. These properties are prefixed with X-, denoting that they are non-standard extensions. By introducing custom variables, the iCal format can accommodate detailed data and semantics that are otherwise unavailable in the base specification.

To address the limitations of the iCal format for industry-specific use cases, the following custom properties are added using the X- prefix:

- **X-PRODUCTION-DAY** defines if the event offsets from the defined production day date. There are three allowed values for the variable:
  - A value of 1 indicates that the event belongs to the following production day.
  - A value of 0 indicates the event aligns with the defined production day.
  - A value of -1 indicates that the event belongs to the previous production day.

  For a better understanding Figure 4 gives an example for every type of X-PRODUCTION-DAY.
- **X-BREAK** specifies break intervals during an event. These are defined as periods, either with a start and end date or a start date and duration, such as X-BREAK:20240308T160000Z/PT3H (specifying a break starting at 16:00 UTC on March 8, 2024, lasting for 3 hours).
- **X-MAINTENANCE** defines maintenance intervals, following a similar structure to X-BREAK. For instance, X-MAINTENANCE:20240308T160000Z/PT3H represents a scheduled maintenance period.

Figure 3 presents an example of the iCal format with the extended variable for the breaks (X-BREAK). This iCal entry defines a recurring event that starts on September 10, 2024, at 20:00 UTC and ends on

September 11, 2024, at 05:00 UTC. The event follows a weekly recurrence pattern, occurring every Tuesday, Wednesday, and Friday until April 25, 2025. Additionally, it includes designated break periods from 22:30 to 23:00 UTC and from 02:30 to 03:00 UTC (next day). The break periods specified in the entry also follow the same weekly recurrence pattern, occurring every Tuesday, Wednesday, and Friday until April 25, 2025, just like the main event.

```
BEGIN:VCALENDAR
  VERSION:2.0
  PRODID:http://www.example.com/calendarapplication/
  METHOD:PUBLISH
  BEGIN:VEVENT
    UID:461092315540@example.com
    ORGANIZER;CN="Alice Balder, Example Inc.":MAILTO:alice@example.com
    LOCATION:Anywhere
    GEO:48.85299;2.36885
    SUMMARY:Short info
    DESCRIPTION:Description of appointment
    CLASS:PUBLIC
    DTSTART:20240910T200000Z
    DTEND:20240911T050000Z
    DTSTAMP:20240812T125900Z
    RRULE:FREQ=WEEKLY;BYDAY=TU,WE,FR;UNTIL=20250425T000000Z
    X-BREAK:20240910T223000Z-20240910T230000Z,20240911T023000Z-
20240911T030000Z
  END:VEVENT
END:VCALENDAR
```

Figure 3: iCal format with extensions

In Figure 4 three examples of a production calendar for one day are shown. The definition of X-PRODUCTION-DAY always refers to the end date and time of a current event (DTEND in iCal) and is set in relation to the defined production day. In the example the defined production day is Monday, and each shift is defined as an event like in Figure 3. The first example starts with a planned night shift event at calendar day Sunday. The shift ends at a critical point, 0 a.m., but it belongs to Monday (the following day), so the variable X-PRODUCTION-DAY is set to “1”. The second example has only two shifts which are at the same calendar day as the production day which leads to the value “0” for X-PRODUCTION-DAY. The last example is planned to end with a night shift event which starts at Monday and ends at calendar day Tuesday. In this case the value of X-PRODUCTION-DAY will be set to “-1” for the event because the event belongs to the previous production day, which is Monday.

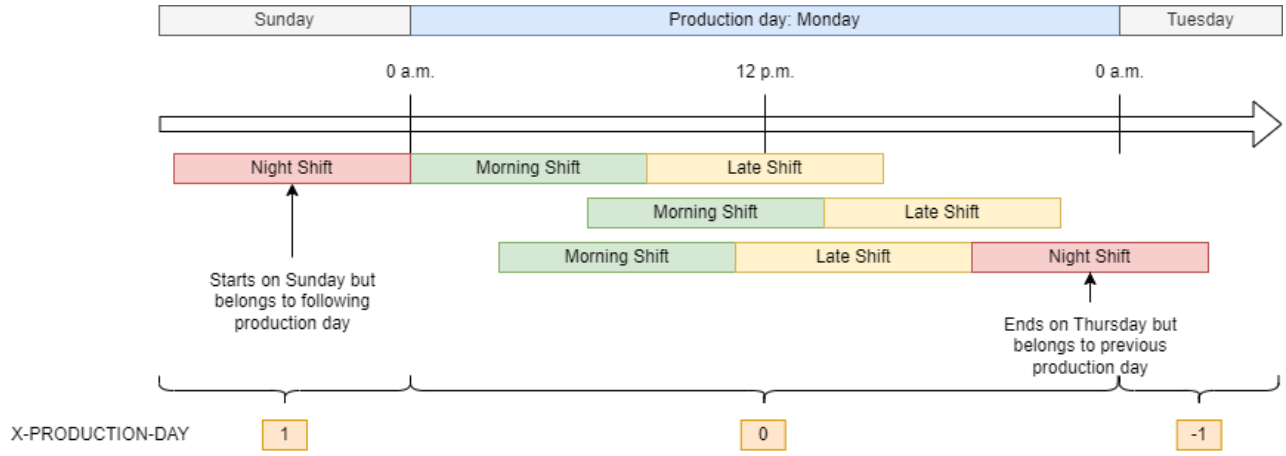

Figure 4: Example of shift plans for a defined production day

Due to different interpretations of Manufacturing Execution Systems in the planning of a production calendar the single events can be referred to different production days, like shown in the previous example. With the definition of the variable X-PRODUCTION-DAY and the three pre-defined values, interoperability should be guaranteed.

1.5.3 Design Decisions

1.5.3.1 Enabling inheritance of production calendars between different AAS

The Submodel offers in combination with the Submodel “Hierarchical Structures enabling Bills of Material” [8] the option of building hierarchies of production calendars according to a company structure with its locations, departments in the organizational layer as well as machines and workstations in the producing layer.

For this a reference element “inheritedFrom” is added to the Submodel. This reference can be used, if a subordinated AAS uses the same calendar as its superordinated AAS. See the example of “ProductionCalendar1” and “ProductionCalendar2” in Figure 5. Both Submodels in the AAS of “Machine1” and “WorkStation” are displayed with dashed lines to symbolize the absence of the calendar files. In case of “Machine2” a new calendar was created and stored in its AAS and therefore no reference is needed.

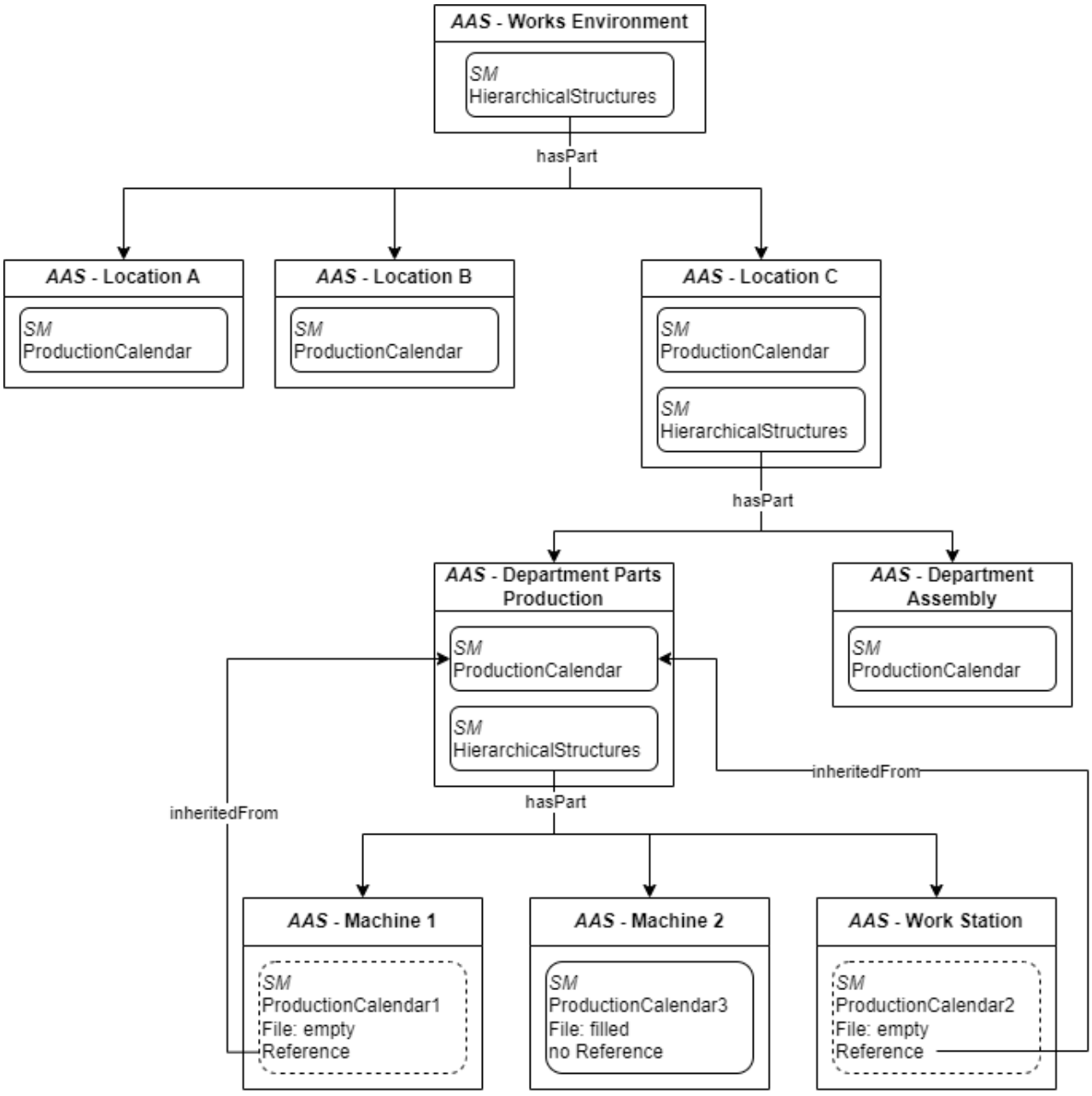

Figure 5: Inheritance of production calendars in a hierarchy of AAS

1.6 Further standardization and outlook

The first version of the Submodel enabling companies and their departments to store production calendars in an interoperable way. Currently the extended iCal format enables the semantic tagging of appointments with the topics “Production”, “Break” and “Maintenance”.

The structure of the Submodel allows further extensions of the iCal format with downward compatibility. Therefore, new variables can be added to the Submodel Element List “specificationExtensionVariables”, see section 2.3. If the new variable is used by more than one application, the specification and template of the Submodel version needs to be revised. If both the Submodel and the new variable are only intended for internal use, the Submodel can be extended by the respective company. In this case, however, interoperability cannot be guaranteed.

2 Submodel Production Calendar

2.1 Approach

In this section, the Submodel is defined to save a production calendar of e.g. a machine, workstation, department or production location etc. The Submodel is usable in Asset Administration Shells for type and instance.

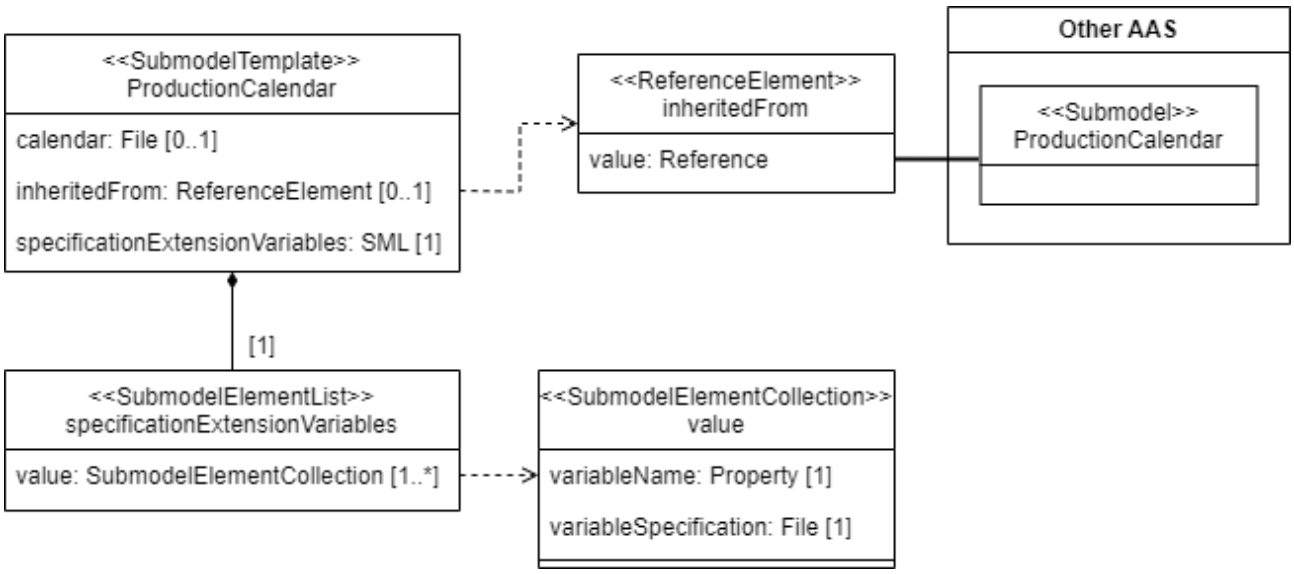

Figure 6: Submodel class diagram

2.2 Attributes of the Submodel

For the Submodel the following attributes have to be set, depending on the cardinality of every element.

Table 1: Attributes of the Submodel

idShort:	ProductionCalendar Note: A different idShort might be used, as long as it is unique in the AAS.		
Class:	Submodel (SM)		
semanticId:	[IRI] https://admin-shell.io/idta/SubmodelTemplate/ProductionCalendar/1/0		
Parent:	Asset Administration Shell, to which the production calendar shall be associated to.		
Explanation:	The Submodel allows the storage of one production calendar for e.g. a machine, work station, department, production location etc.		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[File] calendar	[IRI] https://admin-shell.io/idta/ProductionCalendar/calendar/1/0 Contains the iCalendar file with mimeType text/calendar. The format should comply to the standard RFC 5545.	n/a	0..1
[Ref] inheritedFrom	[IRI] https://admin-shell.io/idta/ProductionCalendar/inheritedFrom/1/0 Reference to a superordinate calendar from which this Submodel inherits.	n/a	0..1
[SML] specificationExtensionVariables	[IRI] https://admin-shell.io/idta/ProductionCalendar/specificationExtensionVariables/1/0 List of additional variables which extends the iCalendar file format.	n/a	1

2.3 SubmodelElements of specificationExtensionVariables

For the Submodel element list the following attributes must be set, depending on the cardinality of every element.

Table 2: Attributes of SML "specificationExtensionVariables"

idShort:	specificationExtensionVariables		
Class:	SubmodelElementList (SML)		
semanticId:	[IRI] https://admin-shell.io/idta/ProductionCalendar/specificationExtensionVariables/1/0		
Parent:	ProductionCalendar (SM)		
Explanation:	List of additional variables which extends the iCalendar file format.		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[SMC]	[IRI] https://admin-shell.io/idta/ProductionCalendar/specificationExtensionVariables/1/0 Groups the specification details for every variable extension. Note: The working group specified three mandatory variable extensions that are modelled in the AASX file of the Submodel template. The variables are - X_BREAK, - X_PRODUCTION_DAY and - X_MAINTENANCE.	n/a	1..*

2.4 SubmodelElements of SMC in specificationExtensionVariables

For the Submodel element collection the following attributes have to be set, depending on the cardinality of every element.

Table 3: Attributes of SMC in "specificationExtensionVariables"

idShort:	Note: An element in an SML does not have an idShort.		
Class:	SubmodelElementCollection (SMC)		
semanticId:	[IRI] https://admin-shell.io/idta/ProductionCalendar/specificationExtensionVariables/1/0		
Parent:	specificationExtensionVariables (SML)		
Explanation:	Groups the specification details for every variable extension.		
[SME type]	**semanticId = [idType]value**	**[valueType]**	**card.**
idShort	**Description@en**	**example**	
[Property] variableName	[IRI] https://admin-shell.io/idta/ProductionCalendar/variableName/1/0 Name of the variable which extends the iCal format. Note: The working group specified three mandatory variable extensions that are modelled in the AASX file of the Submodel template. The variables are - X_BREAK, - X_PRODUCTION_DAY and - X_MAINTENANCE.	X_BREAK or X_PRODUCTION_DAY or X_MAINTENANCE	1
[File] variableSpecification	[IRI] https://admin-shell.io/idta/ProductionCalendar/variableSpecification/1/0 Human readable description to specify the extension variable and its correct interpretation within an application. Note: An example is given in section 1.5.2.	n/a	1

Annex A. Explanations on used table formats

1. 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.

2. 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 information 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 type	SubmodelElement 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 chosen, 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@EN.
- The [valueType] is only given for Properties.

Annex B. iCal examples for modelling production schedules

1. General

This annex provides several examples of iCal-based production calendar definitions, demonstrating the use of custom extensions such as X-PRODUCTION-DAY and X-BREAK. The examples cover different scheduling scenarios, including multi-shift production days, weekday-only shifts, and exceptions for specific days. These definitions illustrate how iCal can be extended to model complex industrial production schedules.

2. 24-Hour production day with three shifts

The production calendar in Figure 7 models a continuous 24-hour production cycle with three distinct shifts—night, morning, and evening—recurring daily. The night shift starts at 22:00 UTC and ends at 06:00 UTC the following day. The morning shift follows from 06:00 to 14:00 UTC, and the evening shift runs from 14:00 to 22:00 UTC. The recurrence rule (RRULE:FREQ=DAILY) ensures that the cycle repeats every day without interruption. Figure 8 shows the corresponding iCal definition.

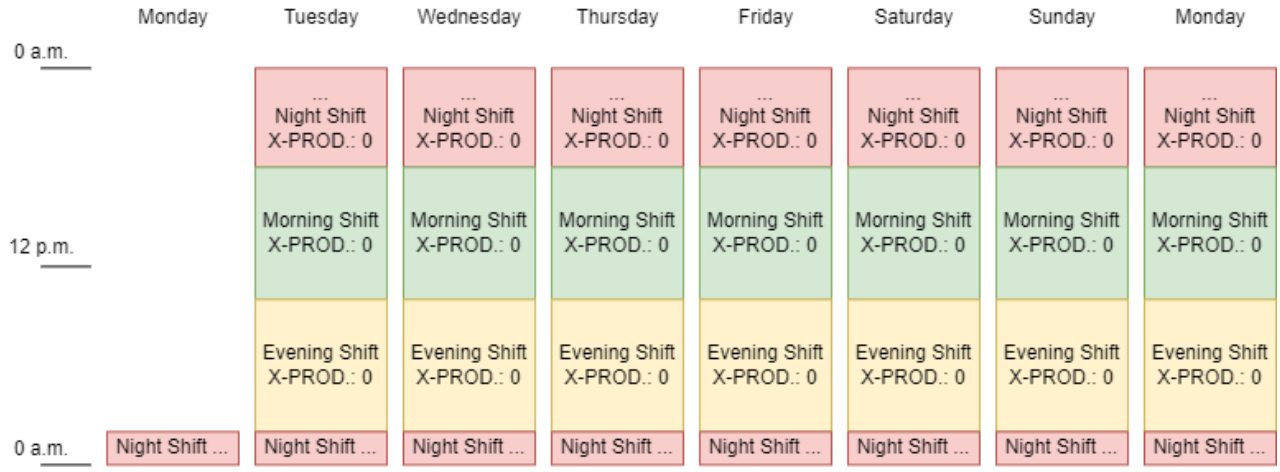

Figure 7: Production calendar for 24-hour production in three shifts

```
BEGIN:VCALENDAR
  VERSION:2.0
  PRODID:-//Example Inc//Production Calendar//EN
  METHOD:PUBLISH
  BEGIN:VEVENT
    UID:night_shift@example.com
    SUMMARY:Night Shift
    DTSTART:20250310T220000Z
    DTEND:20250311T060000Z
    RRULE:FREQ=DAILY
    X-PRODUCTION-DAY:0
  END:VEVENT
  BEGIN:VEVENT
    UID:morning_shift@example.com
    SUMMARY:Morning Shift
    DTSTART:20250311T060000Z
    DTEND:20250311T140000Z
    RRULE:FREQ=DAILY
    X-PRODUCTION-DAY:0
  END:VEVENT
  BEGIN:VEVENT
    UID:evening_shift@example.com
    SUMMARY:Evening Shift
    DTSTART:20250311T140000Z
    DTEND:20250311T220000Z
    RRULE:FREQ=DAILY
    X-PRODUCTION-DAY:0
  END:VEVENT
END:VCALENDAR
```

Figure 8: iCal for 24-hour production in three shifts

3. Morning shift, Monday to Friday, for three months

Figure 9 defines a morning shift running from 06:00 to 14:00 UTC every Monday to Friday for three months. A 30-minute break is scheduled daily at 10:00 UTC, and the shift follows a weekly recurrence pattern until June 09, 2025. Figure 10 shows the corresponding iCal definition.

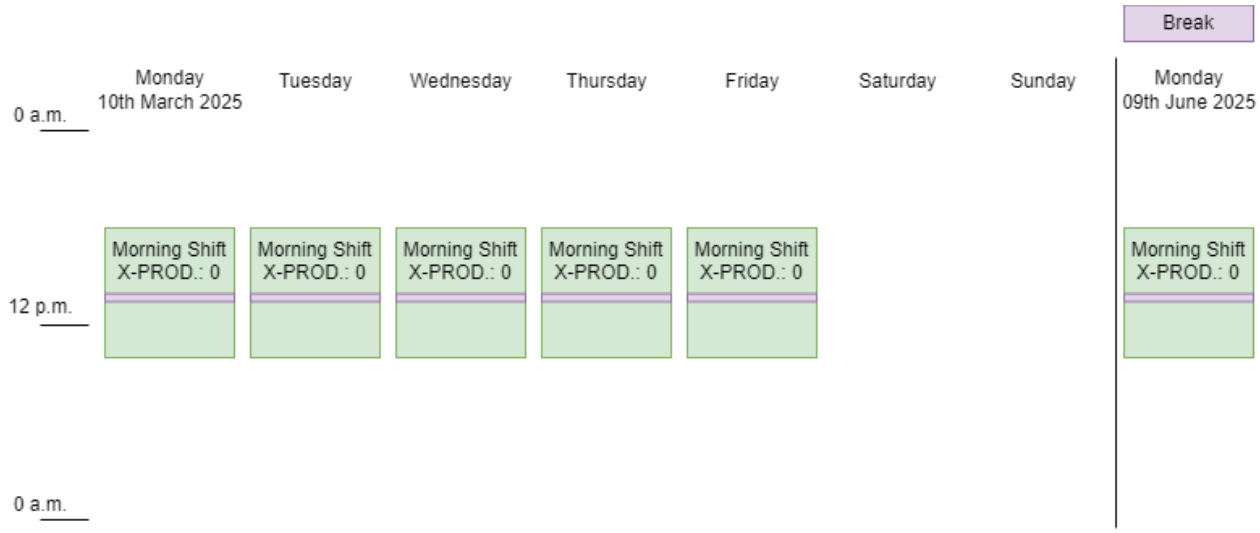

Figure 9: Production calendar for a three-month-long morning shift with breaks

```
BEGIN:VCALENDAR
  VERSION:2.0
  PRODID:-//Example Inc//Production Calendar//EN
  METHOD:PUBLISH
  BEGIN:VEVENT
    UID:morning_shift@example.com
    SUMMARY:Morning Shift
    DTSTART:20250310T060000Z
    DTEND:20250310T140000Z
    RRULE:FREQ=WEEKLY;BYDAY=MO,TU,WE,TH,FR;UNTIL=20250609T235959Z
    X-PRODUCTION-DAY:0
    X-BREAK:20250310T100000Z/PT30M
  END:VEVENT
END:VCALENDAR
```

Figure 10: iCal for a three-month-long morning shift with breaks

4. One-week shift cycle starting with a night shift

Figure 11 defines a one-week shift cycle, starting with a night shift on Sunday evening and ending with the evening shift on Friday. The schedule repeats from March 09, 2025, to March 16, 2025. X-PRODUCTION-DAY is set to 1 for the night shift, as the actual production day starts on the day after the night shift ends. Figure 12 shows the corresponding iCal definition.

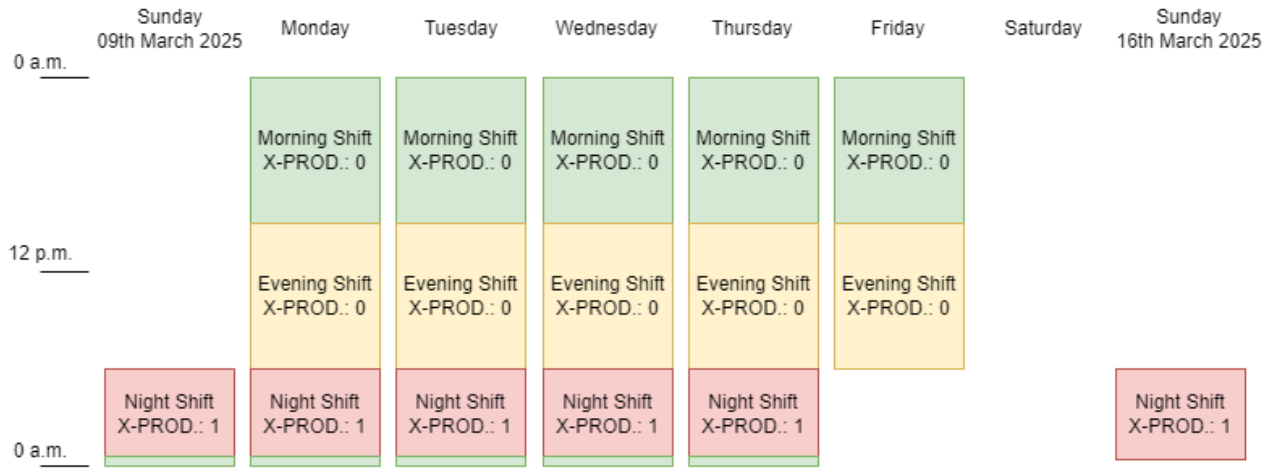

Figure 11: Production calendar for weekly production starting with night shift

```
BEGIN:VCALENDAR
  VERSION:2.0
  PRODID:-//Example Inc//Production Calendar//EN
  METHOD:PUBLISH
  BEGIN:VEVENT
    UID:night_shift@example.com
    SUMMARY:Night Shift
    DTSTART:20250309T180000Z
    DTEND:20250309T234500Z
    RRULE:FREQ=WEEKLY;BYDAY=SU,MO,TU,WE,TH;UNTIL=20250316T235959Z
    X-PRODUCTION-DAY:1
  END:VEVENT
  BEGIN:VEVENT
    UID:morning_shift@example.com
    SUMMARY:Morning Shift
    DTSTART:20250309T234500Z
    DTEND:20250310T090000Z
    RRULE:FREQ=WEEKLY;BYDAY=MO,TU,WE,TH,FR;UNTIL=20250316T235959Z
    X-PRODUCTION-DAY:0
  END:VEVENT
  BEGIN:VEVENT
    UID:evening_shift@example.com
    SUMMARY:Evening Shift
    DTSTART:20250310T090000Z
    DTEND:20250310T180000Z
    RRULE:FREQ=WEEKLY;BYDAY=MO,TU,WE,TH,FR;UNTIL=20250316T235959Z
    X-PRODUCTION-DAY:0
  END:VEVENT
END:VCALENDAR
```

Figure 12: iCal for weekly production starting with night shift

5. Weekly shift cycle with a Wednesday exception

Figure 13 defines a shift schedule that starts with a night shift on Sunday evening and ends with an evening shift on Friday. However, an exception is modelled for Wednesday, where only two shifts (morning and evening) are scheduled. The recurrence rule is set for weekly repetition. Figure 14 shows the corresponding iCal definition.

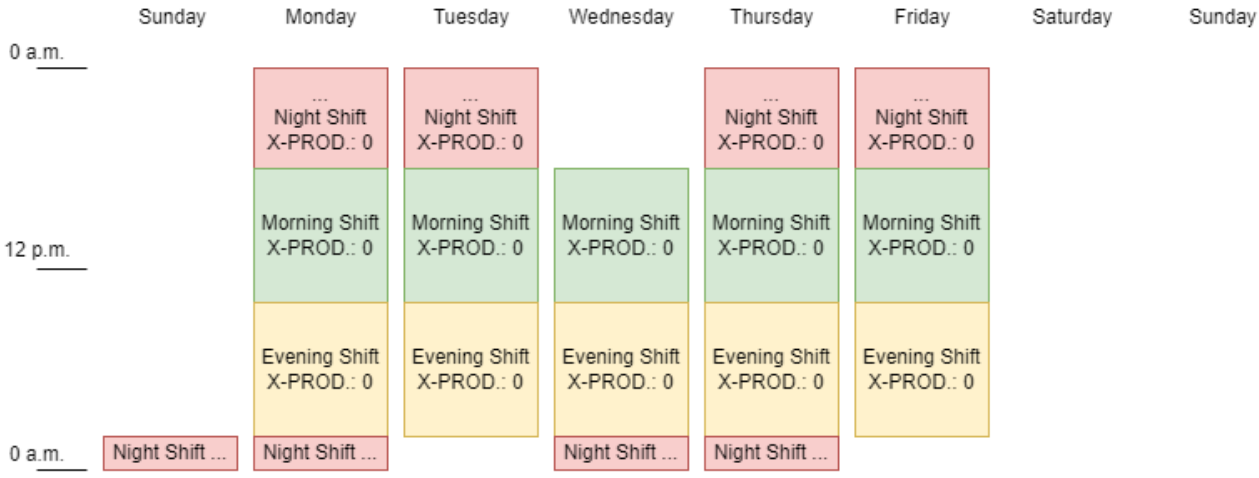

Figure 13: Production calendar for weekly production with Wednesday exception

```
BEGIN:VCALENDAR
  VERSION:2.0
  PRODID:-//Example Inc//Production Calendar//EN
  METHOD:PUBLISH
  BEGIN:VEVENT
    UID:night_shift@example.com
    SUMMARY:Night Shift
    DTSTART:20250309T220000Z
    DTEND:20250310T060000Z
    RRULE:FREQ=WEEKLY;BYDAY=SU,MO,WE,TH;UNTIL=20250316T215959Z
    X-PRODUCTION-DAY:0
  END:VEVENT
  BEGIN:VEVENT
    UID:morning_shift@example.com
    SUMMARY:Morning Shift
    DTSTART:20250310T060000Z
    DTEND:20250310T140000Z
    RRULE:FREQ=WEEKLY;BYDAY=MO,TU,WE,TH,FR;UNTIL=20250316T215959Z
    X-PRODUCTION-DAY:0
  END:VEVENT
  BEGIN:VEVENT
    UID:evening_shift@example.com
    SUMMARY:Evening Shift
    DTSTART:20250310T140000Z
    DTEND:20250310T220000Z
    RRULE:FREQ=WEEKLY;BYDAY=MO,TU,WE,TH,FR;UNTIL=20250316T215959Z
    X-PRODUCTION-DAY:0
  END:VEVENT
END:VCALENDAR
```

Figure 14: iCal for weekly production with Wednesday exception

6. Three shifts, Monday to Friday, night shift ends on next day

Figure 15 shows a production schedule for three shifts (morning, evening, and night) from Monday to Friday. The morning shift runs from 06:00 to 14:00 UTC, the evening shift from 14:00 to 22:00 UTC, and the night shift from 22:00 to 06:00 UTC the following day. The RRULE specifies that this schedule repeats, from March 09, 2025, to March 16, 2025. The X-PRODUCTION-DAY: -1 for the night shift indicates that the production day of the night shift belongs to the previous calendar day, as the shift spans overnight. Figure 16 shows the corresponding iCal definition.

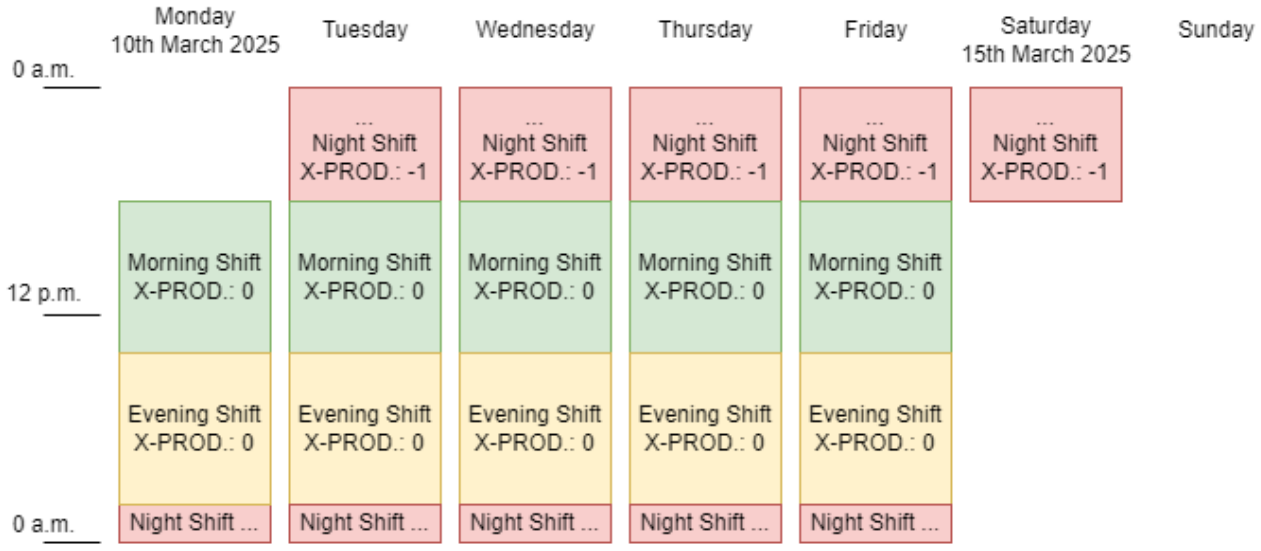

Figure 15: Production calendar for weekly production with adjusted production day

```
BEGIN:VCALENDAR
  VERSION:2.0
  PRODID:-//Example Inc//Production Calendar//EN
  METHOD:PUBLISH
  BEGIN:VEVENT
    UID:morning_shift@example.com
    SUMMARY:Morning Shift
    DTSTART:20250310T060000Z
    DTEND:20250310T140000Z
    RRULE:FREQ=WEEKLY;BYDAY=MO,TU,WE,TH,FR;UNTIL=20250315T235959Z
    X-PRODUCTION-DAY:0
  END:VEVENT
  BEGIN:VEVENT
    UID:evening_shift@example.com
    SUMMARY:Evening Shift
    DTSTART:20250310T140000Z
    DTEND:20250310T220000Z
    RRULE:FREQ=WEEKLY;BYDAY=MO,TU,WE,TH,FR;UNTIL=20250315T235959Z
    X-PRODUCTION-DAY:0
  END:VEVENT
  BEGIN:VEVENT
    UID:night_shift@example.com
    SUMMARY:Night Shift
    DTSTART:20250310T220000Z
    DTEND:20250311T060000Z
    RRULE:FREQ=WEEKLY;BYDAY=MO,TU,WE,TH,FR;UNTIL=20250315T235959Z
    X-PRODUCTION-DAY:-1
  END:VEVENT
END:VCALENDAR
```

Figure 16: iCal for weekly production with adjusted production day

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