Aeronautical Information Exchange Model (AIXM)

Obstacle Model Proposal

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1 Introduction

The purpose of this document is to analyse the current requirements for obstacle data and to propose a new conceptual schema for obstacle information, which satisfies the requirements for international air navigation.

This proposal for a new obstacle conceptual schema is made in the context of AICM/AIXM version 5, in particular as described in the "AIXM 5 - Exchange Model goals, requirements and design" document (also known as the AIXM 5 "White Paper"). All aspects discussed in the White Paper, such as temporality, object identification, use of GML, etc. are applicable and are not re-discussed in the current document.

1.1 References

[1] Aeronautical Information Services. 12th Edition. Annex 15 to the Convention on International Civil Aviation. ICAO. July 2004.
[2] User Requirements for Terrain and Obstacle Data. RTCA DO276/EUROCAE ED-98.
[3] Interchange Standards For Terrain, Obstacle, And Aerodrome Mapping Data. RTCA DO-291/EUROCAE ED-119

2 Requirements analysis

The purpose of this section is to analyse the obstacle data publication requirements and to propose a design satisfying these requirements.

2.1 Sources

2.1.1 ICAO Annex 15 – Aeronautical Information Services

Amendment 33 to ICAO Annex 15 has introduced new provisions for obstacle data publication. These are largely based on the work of RTCA/EUROCAE, as reflected in the document DO-276/ED-98 – User Requirements for Terrain and Obstacle Data. The new requirements have extended the already existing ICAO Standards and Recommended Practices for obstacle data publication in national AIP.

ICAO Annex 15 requirements for obstacle data publication are mainly listed in Appendix 1 (Content of Aeronautical Information Publications) and in Chapter 10 - Electronic Terrain and Obstacle Data.

2.1.2 ICAO ANNEX 4 – Aeronautical Charts

The Annex contains requirements for obstacle publication on charts. Most are the same as in Annex 15. There exist some additional requirements, such as the recommendation to indicate the reference obstacle associated with the clearance heights/altitudes of instrument approach procedure.

2.1.3 ICAO ANNEX 14 – Aerodromes

The Annex contains requirements for obstacle assessment, control and reporting. Most of the requirements for obstacle data publication are already included in Annex 15. In particular, there exist detailed requirements with regard to the marking and lighting of obstacles.

2.1.4 RTCA/EUROCAE – DO-276/ED-98 – User Requirements for Terrain and Obstacle Data

This document defines a set of minimal user (data integrators and system designers) requirements with regard to obstacle data publication. Although most of the requirements have been reflected in the ICAO Amendment 33 to Annex 15, the RTCA/EUROCAE document provides useful background information and detailed explanation for these requirements.

2.1.5 AICM version 4.5

AICM 4.5 was also considered as a source for requirements, for two reasons:

- it reflects how data has been published in the State AIPs before the introduction of the new Annex 15 requirements (Amendment 33)
- in order to facilitate backwards compatibility

2.1.6 ACCB – change proposals to version 4.5

To date, there exist only one open change proposal recorded with the AIXM Change Control Board, which is related to the obstacle model: AIXM00000125 “Obstacle markers”. This change proposal has been considered in this analysis.

2.1.7 IATA Standard Format

The format used by IATA in order to supply their users with aeronautical data includes two sections related to obstacle information:

- Section ARPOBS - Airport Obstacles
- Section RWYOBS - Runway Obstacles

The particularity of this format is that it includes information that could be deduced through calculation, such as "distance from ARP", "Magnetic bearing from ARP", "Height above airport elevation", etc. These have not been retained as requirements.

2.1.8 ICAO DOC 8126 - AIS Manual - NOTAM Selection Criteria

The goal of the new conceptual schema is to include all the elements necessary for modelling not only the static data but also the dynamic information. The NOTAM selection criteria (NSC) provide the list of the most likely temporary conditions that can occur in relation with an obstacle. These are grouped under the NSC codes with 'OB' (Obstacle), 'OL' (Obstacle lights) as second and third letter.

The only condition that requires a specific attribute, not already covered by the static data requirements, is related to the status of the feature:

- for obstacle – may be under construction or completed
- for obstacle lights – may be under construction, completed, or unserviceable.

2.2 Requirements

2.2.1 Obstacle - Definition

Source	ICAO Annex 15, Chapter 2 - Definitions
Description	The obstacle feature is defined as "***all fixed (whether temporary or permanent) and mobile objects, or parts thereof, that are located on an area intended for the surface movement of aircraft or that extend above a defined surface intended to protect aircraft in flight***".
Comments	This definition does not exclude "natural obstacles", such as trees or natural highpoints, for example. Chapter 10 of Annex 15 contains the following sentence: "*Obstacle data shall comprise the digital representation of the vertical and horizontal extent of man-made objects*." However, ICAO Annex 4 contains references to trees and relief features that may be considered as obstacles. Therefore, it may be concluded that obstacles are not limited to man-made objects. The following note will be added to the definition: "*Obstacles include both natural and man-made features that have vertical significance in relation to adjacent and surrounding features*". This requirement is already reflected in AICM 4.5.

2.2.2 Obstacle identifier

Source	ICAO Annex 15, Appendix 1, ENR 5.4; ICAO Annex 15, Appendix 1, AD 2.10; ICAO Annex 15, Appendix 8, table A8-4; IATA Standard Format
Description	Each obstacle feature must have an identifier
Comments	ENR 5.4 and AD 2.10 requirements indicate that each obstacle shall have identification or designation. In table A8-4, the identifier is listed as a mandatory attribute, in the context of an obstacle database. Therefore, this attribute will be modelled as a mandatory one in AICM. AIXM 5 will allow (through xlink:href) the use of both natural identifying properties and artificial identifiers. Therefore, whether this identifier is worldwide unique or not, it does not have an immediate impact on the model. However, ideally, this should be a global

	unique identifier, published in the national AIP.

2.2.3 Obstacle designator (name)

Source	ICAO Annex 15, Appendix 1, ENR 5.4; ICAO Annex 15, Appendix 1, AD 2.10
Description	Each obstacle feature may have a textual designator (name)

Comments

According to the AIP Sample included in the ICAO AIS Manual, the “designator” is a name\location associated with the obstacle. This interpretation is supported by the data available in many national AIP.

AIP Specimen — ENR 5.4-1 — 10 JUN 2004

ENR 5.4 Air navigation obstacles - en-route

1 (elevation/height 100m AGL or more)

Designation	Type of obstacle	Coordinates	ELEV/HGT GND (M)	OBST LGT Type/Colour
1	2	3	4	5
Justine	Mast	510136N 0311932W	277/163	OBST/R
Rainby	Chimney	553208N 0310225W	178/136	OBST/R
Kipol	Antenna mast	462021N 0250000W	505/454	Hazard light/ FLG W
Woodbank	Bridge tower	425015N 0364952W	170/110	Illuminated (flood light)

This attribute is not listed in table A8-4 of Annex 15. As the purpose of AIXM is to also support AIP publication processes, this attribute should be included in the model (optional).

This requirement is already satisfied in AICM 4.5 (TXT_NAME attribute).

2.2.4 Obstacle type

Source	ICAO Annex 15, Appendix 1, ENR 5.4; ICAO Annex 15, Appendix 1, AD 2.10; ICAO Annex 15, Appendix 8, table A8-4; IATA Standard Format
Description	Each obstacle feature may have a type

Comments

ICAO Annexes do not include any standardised list of obstacle types. RTCA/EUROCAE – DO-276/ED-98 provides a coded list of 39 obstacle types (plus one value for ‘other’). This list was used in this model as a basis and it has been extended with additional types from other relevant standards, such as the NGA Feature and Attribute Code Catalogue (FACC).

Annex 4 contains symbology for a number of cartographic features that appear in the RTCA/EUROCAE list of obstacle types.

According to Annex 4, 16.9.3.2 “when considered of importance to visual flight, prominent transmission lines and permanent cable car installations, which are obstacles, shall be shown”. The term ‘Cable car’ has the same meaning as the American English term ’cable railway’.

There are several operational reasons that justify including the obstacle type in the model:

- knowing the type of the obstacle that you are looking for, facilitates its identification in visual flying conditions
- synthetic vision applications can display it more realistically
- it facilitates reconciliating data from different sources; if the type is the same and the position is close, then it is very likely the same obstacle
- it is an ICAO requirement to publish the obstacle type in the AIP.

It is recommended that this list is not implemented as a fixed enumeration in the AIXM XML schema. It should be a recommended code list only. Therefore, the value ‘other’ is not necessary and was not included in the list below.

	aerial cable	dredge / powershovel / drag line	refinery
	aerial cableway pylon	elevator	storage depot
	amusement park structure	fence	substation / transformer
	antenna	flare pipe	tank
	aqueduct	fortification	ship
	arch	grain bin / silo	ship storage
	blast furnace	grain elevator	ski jump
	bridge / overpass / viaduct	hopper	ski lift
	bridge superstructure	launch pad	ski pilon
	bridge tower	lighthouse	spire
	building	light vessel / lightship	stack
	cable car / railway	light support structure	stadium
	catalytic cracker	monument	tethered balloon
	catenary	navaid	tower (non communication)
	chimney / smokestack	nuclear reactor	telephone lines
	conveyor	natural highpoint	telephone pylons / poles
	cooling tower	off shore platform	tramway
	communication building	power plant	tree
	communication tower	power transmission line	vegetation
	crane	power transmission pylon	water tower
	control tower	pole	windmill
	dam / wier	processing / treatment plant	windmill farms
	display sign	rig / superstructure	wind motor
	dome		wall
	Another aspect is whether to use plain text for the type attribute, such as “crane”, “dome”, etc. or to use coded values such as “004”, “005”, etc.. Keeping in mind that this list of values is not implemented as an exhaustive enumeration, it is recommended that plain text is used. Codified values, from a particular standard, may be included as extensions. However, it is important that the meaning of 'crane', for example, is the same for all systems using this model. Otherwise, the value is exchanged but perhaps the meaning is lost / altered. This requirement is already satisfied in AICM 4.5 (attribute TXT_DESCR_TYPE), but without a predefined list of obstacle types.		

2.2.5 Obstacle horizontal geometry

Source	ICAO Annex 15, Appendix 1, ENR 5.4; ICAO Annex 15, Appendix 1, AD 2.10; ICAO Annex 15, Appendix 8, table A8-4;
Description	Each obstacle feature must have a horizontal extent described as point, line or polygon.
Comments	According to Annex 15 Appendix 1, it is required to publish the position of an obstacle as geographical coordinates in degrees, minutes, seconds and eventually tenths of seconds. On the other side, in an Obstacle data product build according to the Annex 15 – Chapter 10 requirements: “*Obstacle data elements are features that shall be represented in the database by points, lines or polygons.*” For the purpose of this model, it is considered that the requirements in Chapter 10 prevail over the simpler requirements in the Appendix 1 of Annex 15. Annex 15 also mentions the ‘horizontal extent’ for an obstacle of type point. According

	to RTCA/EUROCAE – DO-276/ED-98 "*the horizontal extent is the footprint of or the area subtended by the obstacle, e.g. area covered by mast guy wires, or weather balloon*". In ED-119 this was interpreted as "*the radius of circle around the centre of the feature including the body of the feature and associated structures such as guy wires*". Therefore an obstacle may also have a circle as horizontal projection. The question is whether this requires a distinction between "prism like" obstacles and "cone like" obstacles. This distinction was not retained as a requirement, just the possibility to describe the horizontal shape as circle (as a particular case of polygon). In the Annex 15 Table A.8-4, the 'geometry type' is listed as a mandatory attribute for each obstacle. The geometry type (point/line/polygon) is likely to be an explicit part of the position encoding. For example, in GML, a specific element will be used for each type of geometry. Therefore, it is not considered necessary to include a dedicated attribute in the model to specify the geometry type. This requirement is partially satisfied in AICM 4.5 (GEO_LAT and GEO_LONG attributes; not possible to describe obstacles that are projected as lines or polygons).

2.2.6 Obstacle horizontal geometry reference system

Source	ICAO Annex 15, 3.7.1; ICAO Annex 15, Appendix 8, table A8-4;
Description	Each obstacle feature must have a specified horizontal reference system (datum).
Comments	Although the Annex 15 requires that "*published aeronautical geographical coordinates (indicating latitude and longitude) shall be expressed in terms of the WGS-84 geodetic reference datum*", the obstacle data published world-wide does not yet comply with this requirement. Therefore, for this model, it is still necessary to recognise the use of other datum. This requirement is already satisfied in AICM 4.5 (CODE_DATUM attribute).

2.2.7 Obstacle horizontal geometry data quality

Source	ICAO Annex 15, Appendix 8, table A8-4;
Description	Each obstacle feature must have the following data quality attributes for the horizontal geometry: accuracy, confidence level, resolution.
Comments	These data quality elements may be specified either for an obstacle feature instance or for an obstacle data set. The conceptual schema included in this document does not model the data set properties. In addition, it is obvious that this set of attributes is applicable to any other surveyed position that might appear in the other concept areas of the AICM 5 model (for example, the position of an aerodrome reference point). The need for the 'confidence level' attribute is debateable. The Annex 15 imposes the value of 95% confidence level when specifying data accuracy requirements: "*The order of accuracy for aeronautical data, based upon a 95 per cent confidence level, shall be as specified in Annex 11, Chapter 2, and Annex 14, Volumes I and II, Chapter 2.*" It is very likely that in a practical implementation this attribute will be used only when the confidence level is different from 95%. This requirement is partially satisfied in AICM 4.5 (the VAL_GEO_ACCURACY attribute; the resolution is implicit, as all values are modelled as formatted strings of characters).

2.2.8 Obstacle elevation

Source	ICAO Annex 15, Appendix 1, ENR 5.4; ICAO Annex 15, Appendix 1, AD 2.10; ICAO Annex 15, Appendix 8, table A8-4; IATA Standard Format
Description	Each obstacle feature must have an elevation value, measured at the top of the obstacle, from the Mean Sea Level (MSL).
Comments	For obstacles that have a horizontal projection of type line or polygon, is it required to

	enable the provision of a distinct elevation value at each line or the polygon vertex? For example, in the case of certain bridges supported by cables or in the case of transmission lines, the elevation may change significantly along the horizontal path. This requirement could not be identified either in Annex 15 or in the RTCA-EUROCAE documents. The typical approach in the aeronautical data domain is to use a 2.5D vertical model, by which a volume is represented as a horizontal boundary, complemented by attributes that define the vertical extent. These considerations would favour a single elevation value for the whole obstacle. On the other side, it is obvious that obstacles of type wire would be badly represented by a single elevation value for the whole obstacle. In order to solve this issue, the concept of obstacle part has been considered further down. Each part must have a single elevation value (the maximum overall the part). In GML, the use of gml:pos elements with x,y,z values is not restricted by this model. However, the geometrical meaning of such 3D positions should comply with the GML rules, for example the planar rule for 3D polygons. It should be noted that such gml:pos z values would be either ellipsoidal heights or would be expressed using a compound coordinate reference system, between x,y expressed as ellipsoidal positions and a geoidal height. This requirement is already satisfied in AICM 4.5 (attribute VAL_ELEV).

2.2.9 Obstacle elevation reference system

Source	ICAO Annex 15, 3.7.2;
Description	Each obstacle feature must have a specified elevation reference system (datum).
Comments	According to Annex 15, the Earth Gravitational Model — 1996 (EGM-96) shall be used as the global gravity model for international air navigation. In addition, regional, national or local geoid models containing high resolution (short wavelength) gravity field data shall be developed and used where necessary to meet the accuracy requirements specified by ICAO. In AICM 4.5, this requirement was taken into consideration through the inclusion in the models of a free text field (TXT_VER_DATUM). In the AIXM 5 version, it is recommended that an exhaustive list of vertical reference datums used around the world is included, in the form of an enumeration that also contains ‘other’. If ‘other’ is used, details should be provided in a dedicated elevationDatumRemarks. This concept shall be applied consistently in all other areas of the model.

2.2.10 Obstacle vertical extent

Source	ICAO Annex 15, Appendix 1, ENR 5.4; ICAO Annex 15, Appendix 1, AD 2.10; ICAO Annex 4, 11.10.2.2; IATA Standard Format
Description	Each obstacle feature may have a vertical extent, defined as the physical extent of the obstacle, between the bottom and the top of the obstacle.
Comments	Modelling the vertical extent rather than the height, enables the unambiguous description of obstacles that float in the air, such as wires or tethered balloons. According to Annex 4, Instrument Approach Charts should indicate the height of the each obstacle above the aerodrome reference point or the above the runway threshold, if the threshold elevation is more than 2 m (7 ft) below the aerodrome elevation). This value may be calculated and it is specific for each chart. Therefore, it has not been considered necessary to allow other references for the obstacle height. Combining the vertical extent information with the top elevation and a digital terrain model, in the case of obstacles floating in the air, enables the decution of the eventual free space between the bottom of the obstacle and the surface of the Earth. This requirement is already satisfied in AICM 4.5 (attribute VAL_HGT).

2.2.11 Obstacle vertical data quality

Source	ICAO Annex 15, Appendix 8, table A8-4;
Description	Each obstacle feature may have the following data quality attributes for the vertical geometry: accuracy, confidence level, resolution.
Comments	These data quality elements may be specified either for an obstacle feature instance or for an obstacle data set. The conceptual schema included in this document does not model the data set properties. The Annex 15 imposes the value of 95% confidence level when specifying data accuracy requirements: "*The order of accuracy for aeronautical data, based upon a 95 per cent confidence level, shall be as specified in Annex 11, Chapter 2, and Annex 14, Volumes I and II, Chapter 2.*" On the other side, in table A8-2, it is indicated that, for obstacle data, the required confidence level is only 90%. This requirement is partially satisfied in AICM 4.5 (the VAL_ELEV_ACCURACY attribute; the resolution is implicit, as all values are modelled as formatted strings of characters).

2.2.12 Obstacle geoid undulation

Source	ICAO Annex 15. AICM 4.5.
Description	Each obstacle feature may have a value for geoid undulation.
Comments	The VAL_GEOID_UNDULATION attribute has been consistently added in AICM in all entities that had a vertical distance property. However, Annex 15 requires this value to be recorded only for a specified number of locations, which does not include obstacles locations. For the sake of model uniformity and backwards compatibility, this attribute should be kept in the model.

2.2.13 Obstacle lighting

Source	ICAO Annex 15, Appendix 1, ENR 5.4; ICAO Annex 15, Appendix 1, AD 2.10
Description	Each obstacle feature may have lighting. Each light may have a horizontal position, an elevation, a colour, intensity and a type (flood or strobe).
Comments	Depending on the type of obstacle, some of the attributes might be left empty. For example, for an obstacle of type point, the horizontal position may be left empty as it is assumed to be the same as for the obstacle itself. However, there could exist several lights, situated at different elevations. There should also exist the possibility to complement this structured description of the lighting with free text remarks. This requirement is partially satisfied in AICM 4.5 (attribute TXT_DESCR_LGT). In the new model, the free text description would get a secondary role, only as a complement of the structured description (position, elevation, colour, type) of each light. The SURFACE_LGT_GROUP entity from AICM 4.5 should be generalised and re-used for this purpose: create an abstract class LightElement, from which both ObstacleLight element and SurfaceLightGroup are derived.

2.2.14 Obstacle marking (painting) - pattern and colour

Source	ICAO Annex 15, Appendix 1, ENR 5.4; ICAO Annex 15, Appendix 1, AD 2.10; ICAO Annex 14, Vol 1, Chapter 6. Visual aids for denoting obstacles
Description	Each obstacle feature may have marking.
Comments	Annex 14 contains requirements with regard to the marking of an obstacle. The marking types indicated in the Annex may be used as a code list:

	o painted - single colour o painted - chequered pattern o painted - horizontal bands o painted - vertical bands o flag with chequered pattern o markers (for cables, wires, etc.) However, it is recommended that this code list is not hardcoded in the AIXM XML Schema (not a fixed enumeration). In general, marking is done with two strongly contrasting colours, such as white/orange or white red. The two colours may be changed in order to ensure the best contrast with the environment of the obstacle. This could be modelled with two additional optional attributes: o first colour o second colour

2.2.15 Obstacle associated with MKR

Source	AIXM Change Control Board [AIXM00000125 - Obstacle markers]
Description	Each obstacle feature may be associated with a MKR navaid
Comments	The site of an obstacle that has significance for approach, landing or departure procedures may be marked by a MKR navaid. Examples may be found in AIP Ukraine (UKCC Donetsk aerodrome to mark a critical obstacle (pit refuse heap after coal mining).

2.2.16 Controlling Obstacle for Instrument Approach Procedure

Source	ICAO Annex 4, 11.10.2.3
Description	Each obstacle feature may be determining the obstacle clearance altitude/height of one or more procedures.
Comments	According to Annex 4, If one or more obstacles are the determining factor of an obstacle clearance altitude/height, those obstacles should be identified.

2.2.17 Obstacle data temporal characteristics

Source	ICAO Annex 15, Appendix 8, table A8-4;
Description	Each obstacle feature must have, as a minimum, start and end of validity date and time.
Comments	The general temporality model of AIXM 5 shall be applied.

2.2.18 Obstacle effectivity

Source	ICAO Annex 15, Appendix 8, table A8-4;
Description	Each obstacle feature may be effective according to a specified timetable.
Comments	The general timetable/timesheet concept shall be applied.

2.2.19 Obstacle status

Source	ICAO DOC 8126 – NOTAM Selection Criteria
Description	Each obstacle feature may have an operational status
Comments	The list of values include: “in construction”, “completed”.

2.2.20 Obstacle lighting status

Source	ICAO DOC 8126 – NOTAM Selection Criteria
Description	Each obstacle feature light may have an operational status.
Comments	The list of values include: “in construction”, “operational”, “unavailable”.

2.2.21 Obstacle lighting effectivity

Source	ICAO DOC 8126 – NOTAM Selection Criteria
Description	Each obstacle feature light may be effective according to a specified timetable.
Comments	The general timetable/timesheet concept shall be applied.

2.2.22 Data originator identifier

Source	ICAO Annex 15, Appendix 8, table A8-4;
Description	The originator of each obstacle feature instance and of each obstacle data set shall be explicitly recorded.
Comments	The requirement comes from the traceability requirement within DO-200A. Auditing the trail of the obstacle data is important. One question is whether it is necessary to provide full structured details – name and contact details (for example, provided by a relationship to Organization/Authority in AICM). A simple text string might not be appropriate. Another question is whether it is necessary to provide the full trail or just sufficient information for identifying the latest originator in the chain. Traceability requirements for obstacle data are not different in any way from the traceability requirements for navaid or runway data, as an example. There should be a consistent approach to this issue in AICM 5 with regard to all the features. Therefore, this requirement was left for being satisfied by the overall approach in AICM 5 for traceability, as part of the metadata concept.

2.2.23 Area of coverage for obstacle data set

Source	ICAO Annex 15, Appendix 8, table A8-4;
Description	Each obstacle data set may have an area of coverage
Comments	According to RTCA-EUROCAE documents, the area of coverage of a data set shall be described as free text, being intended for human interpretation. This requirement is applicable to an obstacle data set only. A similar requirement exists for any other aeronautical data set: list of airports, list of navaids, etc. Therefore, this requirement is left for being satisfied by the overall AICM 5 model and it is not dealt with in the obstacle conceptual schema presented in this document.

2.2.24 (Deprecated) group indicator

Source	AICM 4.5
Description	Each obstacle feature may have an indicator whether it consists of a group of similar obstacle items (for example, a group of trees, a group of poles, etc.)
Comments	This attribute already exists in AICM 4.5. In the new model, each component of a group of obstacles should be described individually. However, for backwards compatibility reason, this attribute should be kept in the model, but marked as ‘Deprecated’.

2.2.25 (Deprecated) Obstacle associated with aerodrome

Source	ICAO Annex 15, Appendix 1, AD 2.10; AICM 4.5; IATA Standard Format
Descriptio n	Each obstacle feature may be associated with an aerodrome. Additionally, obstacles situated in Area 3 may also be associated with a specified runway. Area 2 and 3 should become airspace types. A relationship should be established between Airspace and Aerodrome/Heliport.
Comments	Following Annex 15 AMDT 33, obstacles in AIP AD 2.10 must be presented separately per Area 2 and 3. In order to be able to make this separation, it is necessary to have the possibility to associate an obstacle with the airport instance and to indicate whether it is situated in either Area 2 or Area 3 (attribute of the association). An obstacle may be in Area 2 of one or more airports. An obstacle can be in Area 3 of a single airport (except for co-located airports). In order to support old style AIP, which do not indicate in which Area (2 or 3) the obstacle is located, the corresponding attribute should be optional. In order to support old style AIP, in which it was requested to indicate whether an obstacle affects approach, departure or circling operations, there should be an optional association with runway direction, with an attribute indicating the type of operations affected (Approach, Departure or Circling). This relationship already exists in AICM 4.5. It is considered that this spatial relationship may be deduced as result of a spatial query. This requires knowing the precise shape of the Area 2 or 3 involved – to be retained as a requirement for the Airspace concept area.

2.2.26 Obstacle made of parts

Source	ICAO Annex 15, Appendix 8, table A8-4;
Descriptio n	An obstacle may be made of parts. Each part must have a horizontal projection of type point/line/polygon and one value for the (maximum) vertical elevation and extent.
Comments	Most real-world obstacles have complex 3D geometries. For example, a bridge may have towers, cables, horizontal surfaces – polygons, etc. The decision (see 2.2.8) to model a single overall elevation value for each obstacle has triggered the need for modelling obstacle parts. It is expected that this facility will only be used for obstacles of type line, where the top elevation and/or vertical extent of each section is significantly different form those of the neighbouring sections.

2.3 Not retained as requirements

The purpose of this section is to document other possible issues related to obstacle data, which have not been retained as formal requirements.

2.3.1 Annex 15 – Table A.8-4"Elevation reference"

ICAO Annex 15, Appendix 8, table A8-4 lists 'elevation reference' as mandatory attribute for an obstacle. This attribute is not the vertical reference system (such as EGM-96, for example) – this being modelled by the "vertical reference system" attribute.

The elevation reference seems to be an attribute applicable only to terrain data, in which case it would indicate the point of the grid (centre, edge, etc.) where the elevation of each cell is provided. It is likely that this is an error in the Annex 15 and was therefore not retained as a requirement.

2.3.2 Data integrity as attribute of the obstacle

ICAO Annex 15, Appendix 8, table A8-4 lists 'integrity' as mandatory attribute for an obstacle.

Data integrity is a characteristic of a data storage or data transfer process. For example, a data set may have a level of 10^{-5} integrity at the moment when the data set instance was ready to be transferred by the data originator. If the same data set is transmitted to several users, the integrity with which this data is received may be different for each user, depending on the specific transmission channel. Through data transfer, the integrity might be downgraded to 10^{-4} for certain users. Therefore, it does not make much sense to put an integrity value inside the file, as it does not reflect the end-of-data-transfer situation, which depends on the data transfer process.

The possibility to indicate the integrity of the data for each individual obstacle feature instance was not considered appropriate as requirement. However, it may be required by some users that the integrity ensured at a specific point in the process is recorded as a property of the value or of the data set. This aspect will be dealt with as part of the general model for AIXM metadata.

2.3.3 Moving obstacles

There exist obstacles that are moving in a certain area or along a given trajectory. Examples of such obstacles include:

- a meteo balloon climbing on a vertical trajectory
- a large ship that crosses the departure or arrival area of a runway

If the position of the obstacle along the trajectory is predictable, then it might be interesting to include in the model the possibility to provide the exact position according to a timetable. However, no requirement in this sense has been identified, either in the RTCA/EUROCAE documents or in the ICAO Annex 15. Moving obstacles (such as a crane) can be modelled by providing the geometry of the maximum area in which the obstacle may be situated.

2.3.4 Obstacles with variable geometry

Similarly, there may exist obstacles that change shape/volume, such as a mobile bridge. No requirement in this sense has been identified either in Annex 15 or in the RTCA/EUROCAE documents. Obstacles than change their geometry can be modelled by providing the geometry of the maximum volume in which the obstacle may be situated. Eventually, obstacles, which have 2-3 clearly distinct shapes that are activated according to precise timetables, can be modelled as individual obstacles. This procedure could be applied for example for a mobile bridge, which would be modelled as two obstacles: closed bridge and open bridge.

2.3.5 Obstacle operations

ICAO Annex 15, Appendix 8, table A8-4 lists 'operations' as optional attribute for (mobile) obstacles. Operations are defined as

In the UML context, "operations" is equivalent to "methods" and indicates a function (not an attribute!) that can be performed by a class of features. An operation is not a relevant characteristic for data exchange.

Therefore, it has not been considered necessary to include an 'operations' attribute.

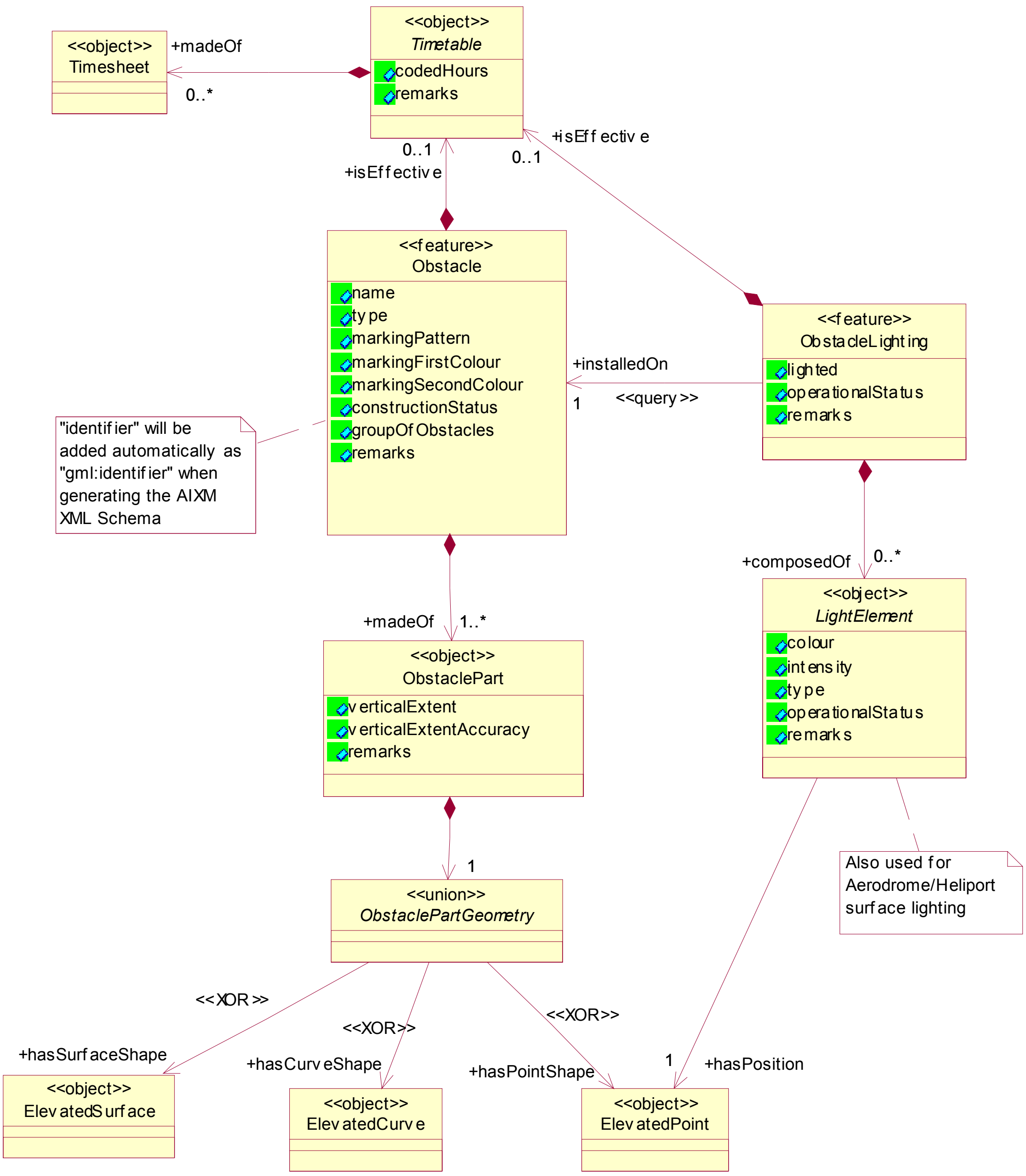
2.3.6 Obstacle associated with State/Territory

Following AMDT 33 to Annex 15, the AIP ENR 5.4 table should contain the obstacles in Area 1 (the whole State/Territory). This spatial relationship may be deduced as result of a spatial query and it was therefore not retained as a requirement for the Obstacle model. This relationship did not exist in AICM 4.5, therefore it is not necessary either for backward compatibility.

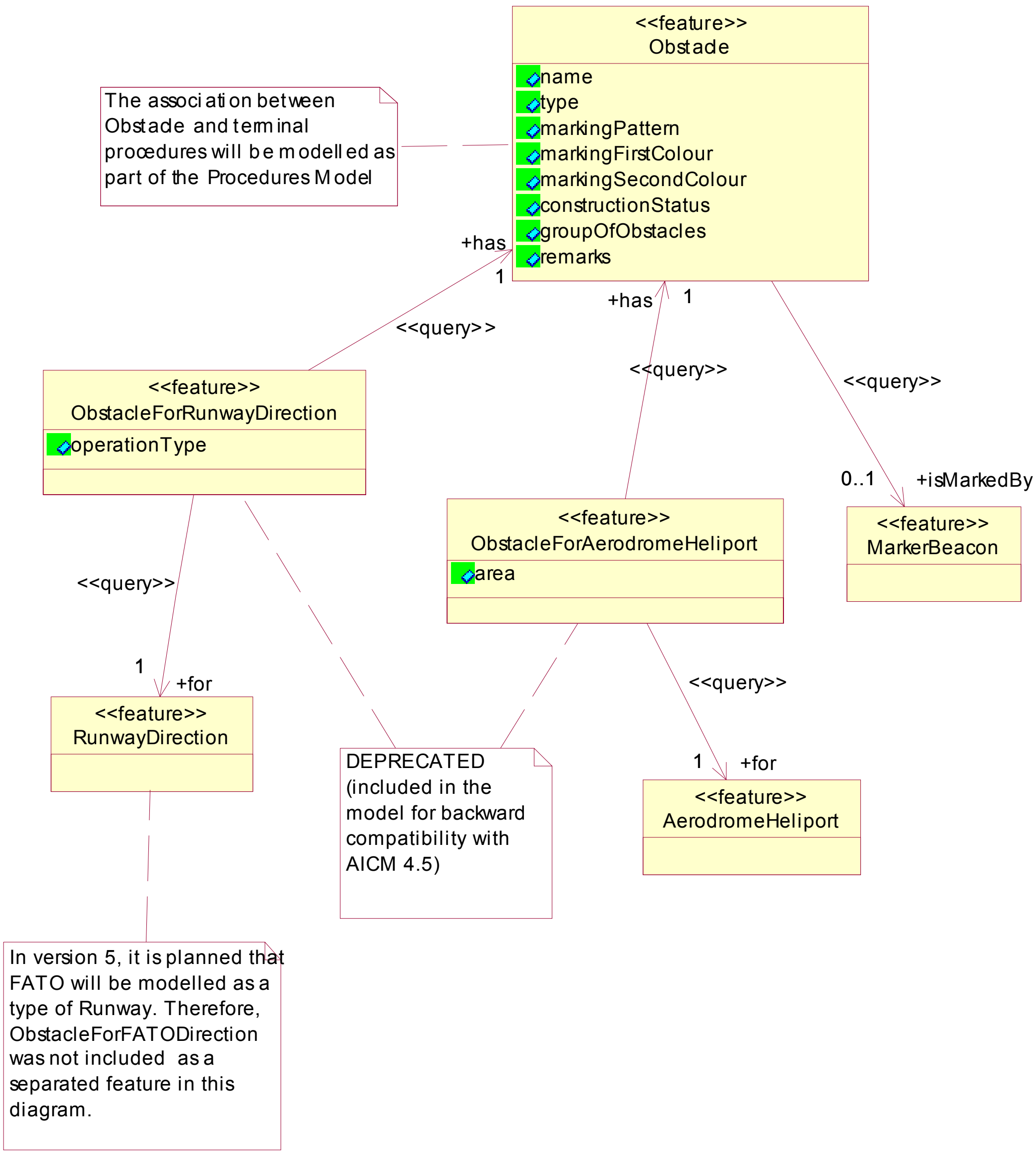
3 Conceptual schema

The UML class diagrams included in this section document the conceptual schema for obstacle information, which was developed based on the requirements listed in section 2.2. This is an extract from the global AICM 5 conceptual schema.

3.1 Obstacle class



3.2 Obstacle Associations



4 Data Encoding

Obstacle data can encoded according to the AIXM 5 XML Schema, which is based on GML and is designed according to the rules detailed in the “AIXM 5 - Exchange Model goals, requirements and design” and the “AIXM 5 Profile of GML” documents.

The purpose of this chapter is to introduce some of the schema elements and to provide examples of obstacle data encodings.

4.1 XML Schema

The schema is defined in 3 main modules.

4.1.1 AIXM-AbstractGML-ObjectTypes.xsd

This schema module defines the high level XML types and elements, which are based on GML and provide the foundation for the definition of the specific AIXM features and objects. The most important ones are listed below:

- the **aixm:AbstractObjectType**, which is the base type for AIXM complex types that are not features or do not have geometries. For example, TimeTable, Fuel, etc.. It derives from gml:AbstractGMLType, so that it can participate within many GML constructs if and as required. Retains only the optional gml:id attribute.
- the **aixm:AbstractAIXMFeatureType**, which is the base for all AIXM complex types that are features, such as VOR, Aerodrome/Heliport, Obstacle, etc. It derives, through an intermediate complex type, from gml:DynamicFeatureType, as most if not all AIXM features are expected to be have some temporal properties modeled using the timeslice model.
- the **aixm:AIXMTimeSliceType**, which is the base for all AIXM “timeslices”. It derives, through an intermediate complex type, from gml:AbstractTimeSliceType and it adds properties that are specific to AIXM, such as the “interpretation” element (baseline, temporary delta, permanent delta, etc.)
- the **aixm:PointType**, which extends the gml:PointType with specific properties such as horizontal accuracy and which is used in AIXM for all features that have a point position, such as navaids, aerodrome reference point, etc.
- the **aixm:CurveType** and **aixm:SurfaceType**, which extend the gml:CurveType and the gml:SurfaceType respectively, in similar way to the extension of the gml:PointType.

4.1.2 AIXM-DataTypes.xsd

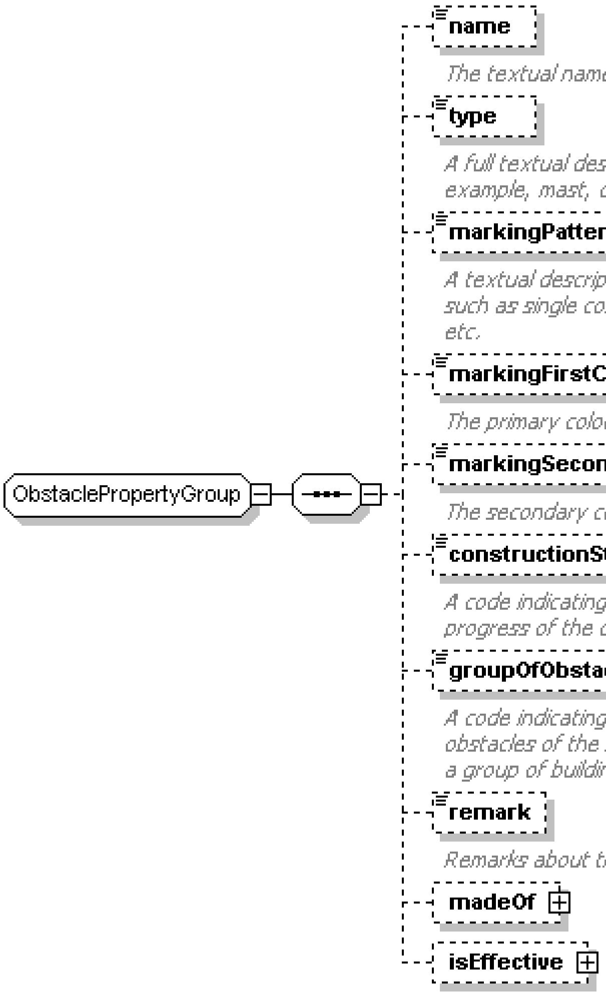
This schema module defines domains of values and enumerations, in the form of simple and complex XSD types. It is largely based on the similarly named schema module of AIXM 4.5. One important difference is that most domains of type “value” are defined as complex types, which include an unit-of-measurement (uom) attribute. In AIXM 5, the unit of measurement is no longer a separated object attribute, as it was in AIXM 4.5.

4.1.3 AIXM-GML-ObjectTypes.xsd

This is the largest schema module and it contains the definitions of all objects and features that may be encoded using the AIXM 5 schema. For the obstacle part of the schema, it defines mainly:

4.1.3.1 The ObstaclePropertyGroup

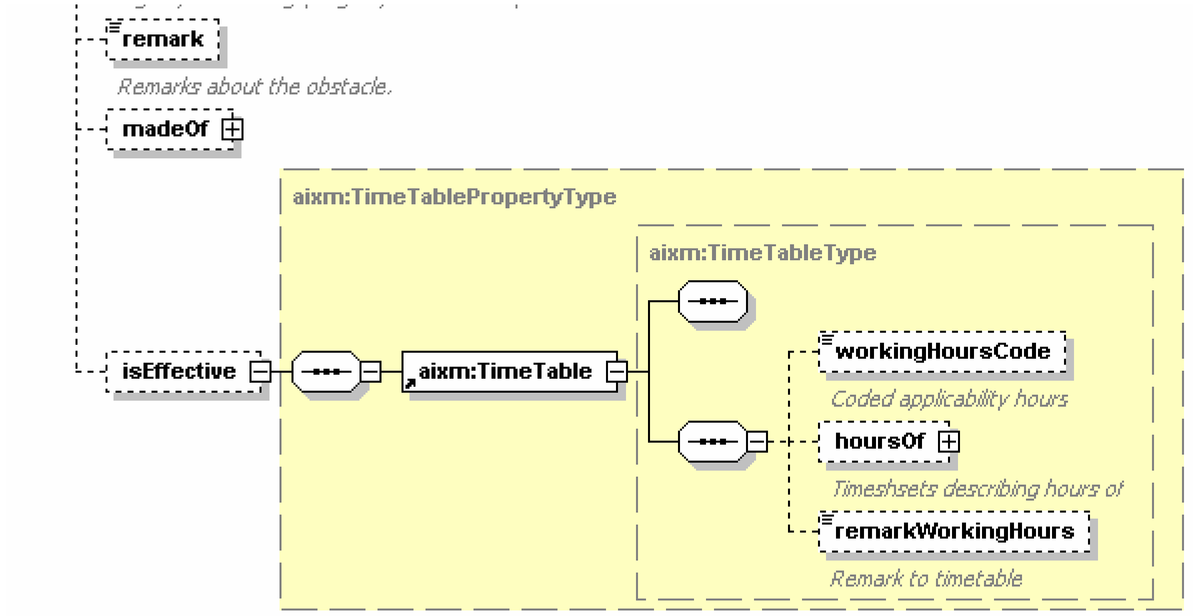
This Group contains the definition of all properties of the Obstacle feature, as derived from the Obstacle UML conceptual schema.



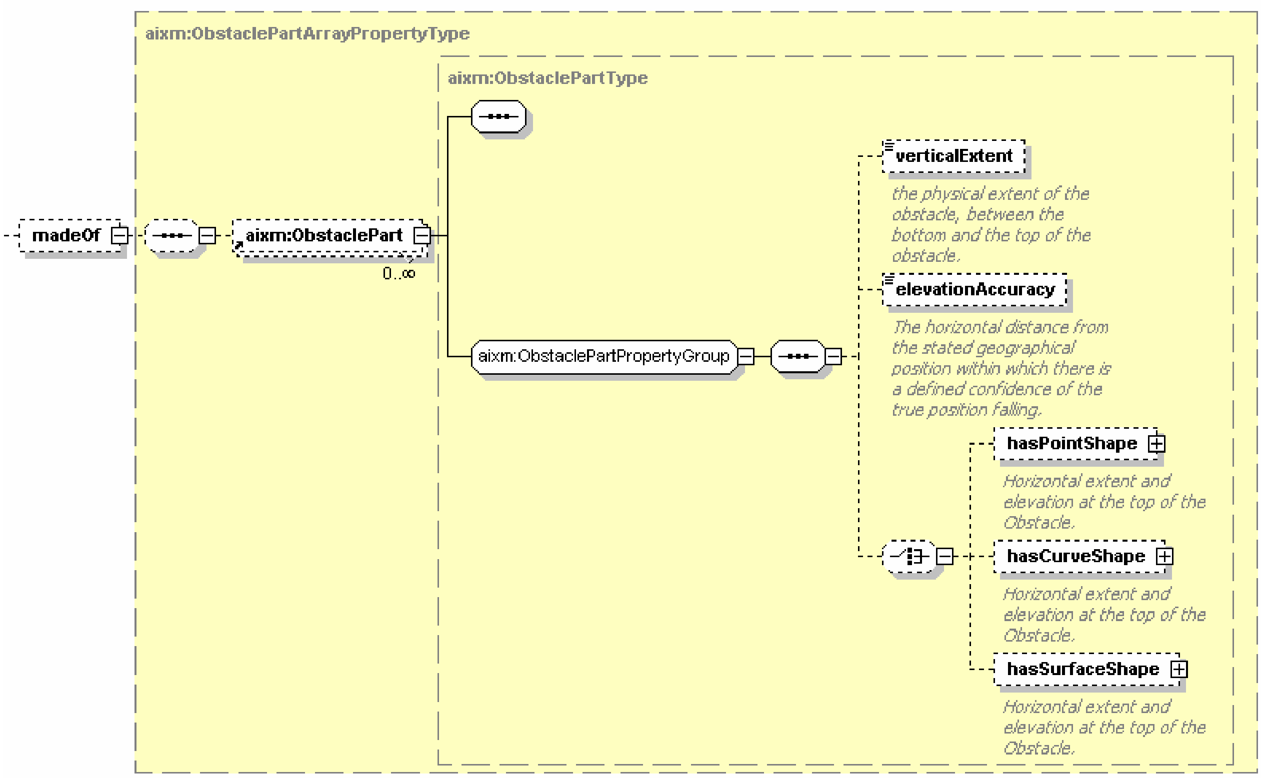
Due to the use of GML, the schema must comply with the so-called "object/property" model. This is visible in the way that complex feature properties are defined. For example, the complex TimeTable element is not directly defined as a property of the Obstacle. The name of the Obstacle property is "isEffective" (from the name of the UML association between the Obstacle <<feature>> and the TimeTable <<object>>), which is then declared of type TimeTablePropertyType. The last one is simply a reference to the TimeTable element.

By convention, in a "temporary delta" timeslice, only the properties that are changed as compared to the baseline shall be included. Therefore, all properties are defined as optional in the XML Schema.

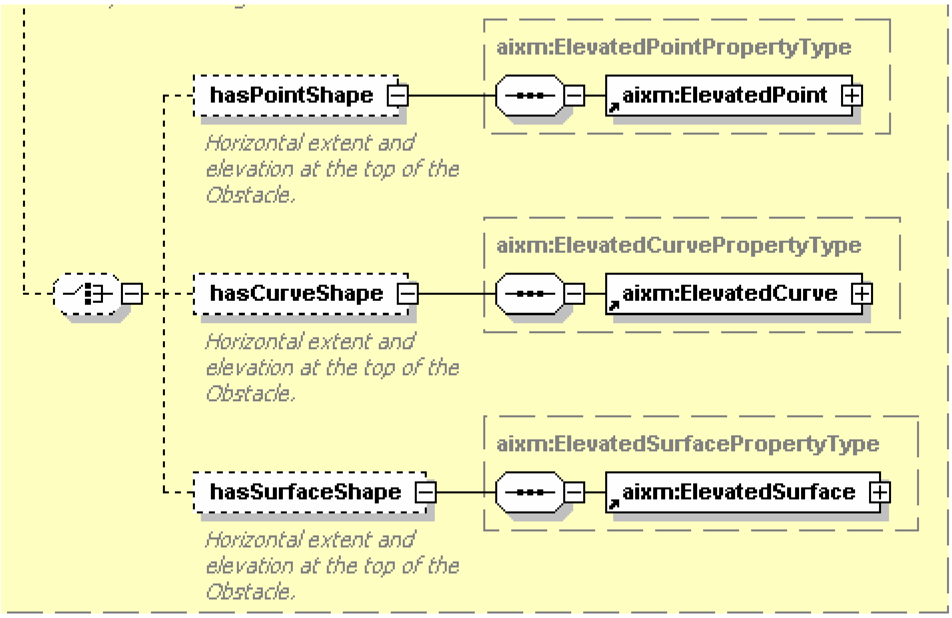
Each feature may have properties that implement either attributes or associations from the conceptual model. By convention, in the definition of every feature, the properties that implement UML class attributes are listed first, in the same order as in the conceptual model. The properties that implement UML class associations are listed at the end of the feature definition and have as names the role of the class in the association.



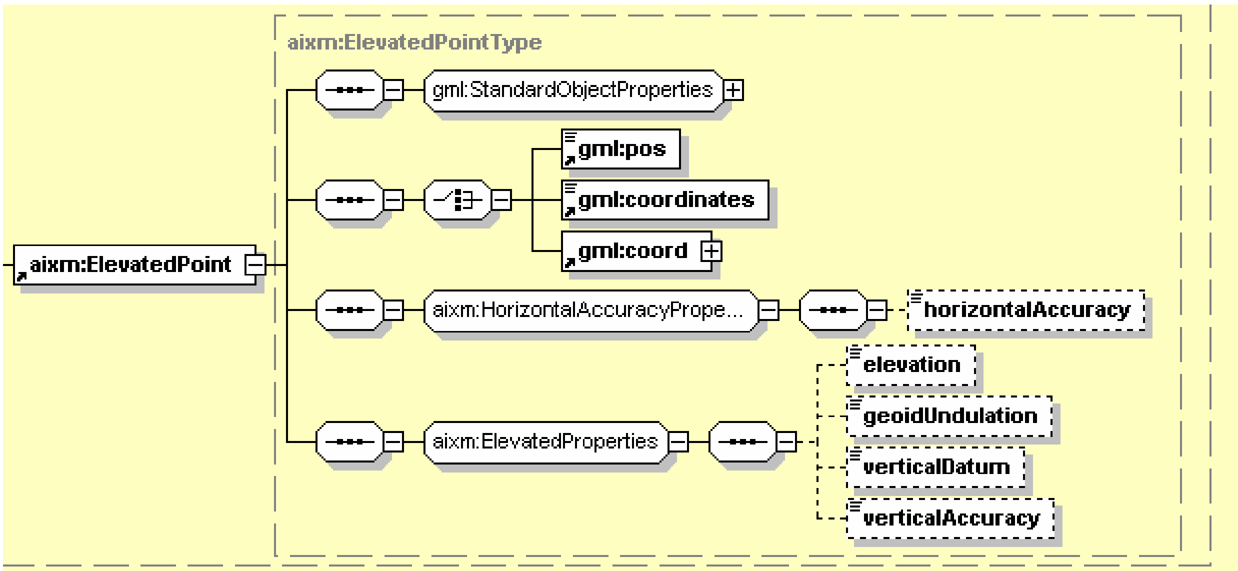
The shape of the obstacle is defined using a similar technique, as a choice between a horizontal projection of type point, curve (line) or surface (polygon), an elevation at the top and a vertical extent.



The three options (point/curve/surface) are declared using the same object/property pattern, as shown in the diagram below.



The details of the aixm:ElevatedPoint are shown in the diagram below.



4.2 XML Examples

This chapter contains a number of obstacle encoding examples

4.2.1 "Antenna" type obstacle

The first example demonstrates the encoding of an obstacle with point-type geometry. This Obstacle element example is not part of a particular message. In this example, the encoding contains the definition of a single timeslice of type "baseline", valid from 01 Jan 1985.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<Obstacle xmlns="http://www.aixm.aero" xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.aixm.aero AIXM-GML-ObjectTypes.xsd" gml:id="ID000000">
	<identifier codeSpace="http://www.aixm.aero/Amswell">EA001</identifier>
	<gml:validTime>
		<gml:TimePeriod>
			<gml:beginPosition>1985-01-01T00:00:00</gml:beginPosition>
			<gml:endPosition indeterminatePosition="unknown"/>
		</gml:TimePeriod>
	</gml:validTime>
	<timeSlice>
		<ObstacleTimeSlice gml:id="ID000002">
			<gml:validTime>
				<gml:TimePeriod>
					<gml:beginPosition>1985-01-01T00:00:00</gml:beginPosition>
					<gml:endPosition indeterminatePosition="unknown"/>
				</gml:TimePeriod>
			</gml:validTime>
			<interpretation>BASELINE</interpretation>
			<name>Donlon</name>
			<type>antenna</type>
			<markingPattern>painted - vertical bands</markingPattern>
			<markingFirstColour>RED</markingFirstColour>
			<markingSecondColour>WHI</markingSecondColour>
			<constructionStatus>COMPLETED</constructionStatus>
			<groupOfObstacles>N</groupOfObstacles>
			<remark>A fictitious obstacle</remark>
			<madeOf>
				<ObstaclePart gml:id="ID000004">
					<verticalExtent uom="FT">104</verticalExtent>
					<elevationAccuracy uom="FT">5</elevationAccuracy>
					<hasPointShape>
						<ElevatedPoint srsDimension="2" srsName="WGS84" gml:id="ID000005">
							<gml:pos>52.352718 -31.852205</gml:pos>
							<horizontalAccuracy uom="FT">10</horizontalAccuracy>
							<elevation uom="FT">255</elevation>
							<geoidUndulation uom="FT">-25</geoidUndulation>
							<verticalDatum>EGM-96</verticalDatum>
							<verticalAccuracy uom="FT">5</verticalAccuracy>
						</ElevatedPoint>
					</hasPointShape>
				</ObstaclePart>
			</madeOf>
			<isEffective>
				<TimeTable gml:id="ID000006">
					<workingHoursCode>H24</workingHoursCode>
				</TimeTable>
			</isEffective>
		</ObstacleTimeSlice>
	</timeSlice>
</Obstacle>
```

4.2.2 "Building" type obstacle

The second example demonstrates the encoding of an obstacle with a horizontal projection of type polygon (surface). Another important aspect of this example is that it includes two timeslices:

- the first timeslice provides a "baseline" which record obstacle characteristics after the finalization of the construction work.
- the second timeslice provides a temporary delta which indicates that the obstacle is "in construction" between 01 Jan 1985 and 01 Jan 1986.

The exterior shape of the obstacle is encoded using the gml:exterior … gml:LinearRing … gml:posList elements.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<Obstacle xmlns="http://www.aixm.aero" xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.aixm.aeroGML-ObjectTypes.xsd" gml:id="ID000000">
	<identifier codeSpace="http://www.aixm.aero/Atlantis">EA002</identifier>
	<gml:validTime>
		<gml:TimePeriod>
			<gml:beginPosition>1985-01-01T00:00:00</gml:beginPosition>
			<gml:endPosition indeterminatePosition="unknown"/>
		</gml:TimePeriod>
	</gml:validTime>
	<timeSlice>
		<ObstacleTimeSlice gml:id="ID000002">
			<gml:validTime>
				<gml:TimePeriod>
					<gml:beginPosition>1985-01-01T00:00:00</gml:beginPosition>
					<gml:endPosition indeterminatePosition="unknown"/>
				</gml:TimePeriod>
			</gml:validTime>
			<interpretation>BASELINE</interpretation>
			<name>Donlon Hospital</name>
			<type>building</type>
			<groupOfObstacles>N</groupOfObstacles>
			<remark>A fictitious polygonal obstacle</remark>
			<madeOf>
				<ObstaclePart gml:id="ID000004">
					<verticalExtent uom="FT">200</verticalExtent>
					<elevationAccuracy uom="FT">5</elevationAccuracy>
					<hasSurfaceShape>
						<ElevatedSurface>
							<gml:exterior>
								<gml:LinearRing>
									<gml:posList>52.350000 -31.830000 52.355000 -31.830000
52.355000 -31.835000 52.350000 -31.835000</gml:posList>
								</gml:LinearRing>
							</gml:exterior>
							<horizontalAccuracy uom="FT">5</horizontalAccuracy>
							<elevation uom="FT">250</elevation>
							<geoidUndulation uom="FT">-25</geoidUndulation>
							<verticalAccuracy uom="FT">5</verticalAccuracy>
						</ElevatedSurface>
					</hasSurfaceShape>
				</ObstaclePart>
			</madeOf>
			<isEffective>
				<TimeTable gml:id="ID000006">
					<workingHoursCode>H24</workingHoursCode>
				</TimeTable>
			</isEffective>
```

```
            </ObstacleTimeSlice>
            <ObstacleTimeSlice>
                <gml:validTime>
                    <gml:TimePeriod>
                        <gml:beginPosition>1985-01-01T00:00:00</gml:beginPosition>
                        <gml:endPosition>1986-01-01T00:00:00</gml:endPosition>
                    </gml:TimePeriod>
                </gml:validTime>
                <interpretation>TEMPDELTA</interpretation>
                <constructionStatus>IN_CONSTRUCTION</constructionStatus>
            </ObstacleTimeSlice>
        </timeSlice>
</Obstacle>
```

4.2.3 "Moving ship" type obstacle

This example shows another capability of the obstacle model, which is to encode the information about a ship moving along a given as an obstacle of type line, associated with a timetable. The trajectory of the ship is assumed to be an arc of circle defined by three points on the edge, followed by a straight line.

The timesheet structure is identical to that of the homonym AIXM 4.5 complex type.

```
<?xml version="1.0" encoding="UTF-8"?>
<Obstacle xmlns="http://www.aixm.aero" xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.aixm.aeroGML-ObjectTypes.xsd" gml:id="ID000000">
        <identifier codeSpace="http://www.aixm.aero/Atlantis">EA003</identifier>
        <gml:validTime>
            <gml:TimePeriod>
                <gml:beginPosition>1985-01-01T00:00:00</gml:beginPosition>
                <gml:endPosition indeterminatePosition="unknown"/>
            </gml:TimePeriod>
        </gml:validTime>
        <timeSlice>
            <ObstacleTimeSlice gml:id="ID000002">
                <gml:validTime>
                    <gml:TimePeriod>
                        <gml:beginPosition>1995-01-01T00:00:00</gml:beginPosition>
                        <gml:endPosition indeterminatePosition="unknown"/>
                    </gml:TimePeriod>
                </gml:validTime>
                <interpretation>BASELINE</interpretation>
                <name>Donlon Cruise Ship</name>
                <type>ship</type>
                <groupOfObstacles>N</groupOfObstacles>
                <remark>A fictitious cruise ship that arrives at port every monday between 9 AM and 10
AM</remark>
                <madeOf>
                    <ObstaclePart gml:id="ID000004">
                        <verticalExtent uom="FT">50</verticalExtent>
                        <elevationAccuracy uom="FT">10</elevationAccuracy>
                        <hasCurveShape>
                            <ElevatedCurve>
                                <gml:segments>
                                    <gml:Arc>
                                        <gml:pos>52.300000 -31.000000</gml:pos>
                                        <gml:pos>52.400000 -31.000000</gml:pos>
                                        <gml:pos>52.500000 -31.050000</gml:pos>
                                    </gml:Arc>
                                    <gml:LineStringSegment>
```

```
                        <gml:pos>52.500000 -31.050000</gml:pos>
                        <gml:pos>52.500000 -31.250000</gml:pos>
                    </gml:LineStringSegment>
                </gml:segments>
                <horizontalAccuracy uom="FT">10</horizontalAccuracy>
                <elevation uom="FT">50</elevation>
                <geoidUndulation uom="FT">-25</geoidUndulation>
                <verticalAccuracy uom="FT">10</verticalAccuracy>
            </ElevatedCurve>
        </hasCurveShape>
    </ObstaclePart>
</madeOf>
<isEffective>
    <TimeTable gml:id="ID000006">
        <workingHoursCode>TIMSH</workingHoursCode>
        <hoursOf>
            <Timesheet>
                <timeReference>UTC</timeReference>
                <effectiveDate>01-01</effectiveDate>
                <expirationDate>31-12</expirationDate>
                <day>MON</day>
                <effectiveTime>09:00:00</effectiveTime>
                <expirationTime>10:00:00</expirationTime>
            </Timesheet>
        </hoursOf>
    </TimeTable>
</isEffective>
</ObstacleTimeSlice>
</timeSlice>
</Obstacle>
```