

PD ISO/TS 19130-2:2014



BSI Standards Publication

Geographic information — Imagery sensor models for geopositioning

Part 2: SAR, InSAR, lidar and sonar

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee IST/36, Geographic information.

A list of organizations represented on this committee can be obtained on request to its secretary.

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© The British Standards Institution 2014. Published by BSI Standards Limited 2014

ISBN 978 0 580 76144 7

ICS 35.240.70

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 28 February 2014.

Amendments issued since publication

Date	Text affected
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Geographic information — Imagery sensor models for geopositioning —

Part 2: SAR, InSAR, lidar and sonar

*Information géographique — Modèles de capteurs d'images de
géopositionnement —*

Partie 2: SAR, InSAR, lidar et sonar





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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC ISO/TC 211, *Geographic information/Geomatics*.

ISO/TS 19130 consists of the following parts, under the general title *Geographic information — Imagery sensor models for geopositioning*:

- *Geographic information — Imagery sensor models for geopositioning*
- *Part 2: Geographic information — Imagery sensor models for geopositioning — Part 2: SAR, InSAR, lidar and sonar*

Introduction

The purpose of this Technical Specification is to specify the geolocation information that an imagery data provider shall supply in order for the user to be able to find the earth location of the data using a detailed physical sensor model for Synthetic Aperture Radar (SAR), Light Detection And Ranging (lidar) and Sound Navigation And Ranging (sonar). The intent is to standardize sensor descriptions and specify the minimum geolocation metadata requirements for data providers and geopositioning imagery systems. Observations in this document are the generic meaning of the word; observations are not in the meaning of ISO 19156 observations.

Vast amounts of data from imaging systems have been collected, processed and distributed by government mapping and remote sensing agencies and by commercial data vendors. In order for this data to be useful in extraction of geographic information, further processing of the data are needed. Geopositioning, which determines the ground coordinates of an object from image coordinates, is a fundamental processing step. Because of the diversity of sensor types and the lack of a common sensor model standard, data from different producers may contain different parametric information, lack parameters required to describe the sensor that produces the data, or lack ancillary information necessary for geopositioning and analysing the data. Often, a separate software package must be developed to deal with data from each individual sensor or data producer. Standard sensor models and geolocation metadata allow agencies or vendors to develop generalized software products that are applicable to data from multiple data producers or from multiple sensors. With such standards, different producers can describe the geolocation information of their data in the same way, thus promoting interoperability of data between application systems and facilitating data exchange.

Part 1 provided a location model and metadata relevant to all sensors. It also included metadata specific to whiskbroom, pushbroom, and frame sensors, and some metadata for Synthetic Aperture Radar (SAR) sensors. In addition, it provided metadata for functional fit geopositioning, whether the function was part of a correspondence model or a true replacement model. It also provided a schema for these metadata elements. Comments on Part 1 stated that metadata needed to be specified for additional sensors. The technology of such sensors has now become sufficiently mature that standardization is now possible. This Technical Specification extends the specification of the set of metadata elements required for geolocation by providing physical sensor models for Light Detection And Ranging (lidar) and Sound Navigation And Ranging (sonar), and it presents a more detailed set of elements for SAR. This Technical Specification also defines the metadata needed for the aerial triangulation of airborne and spaceborne images. This Technical Specification also provides a schema for all of these metadata elements.

Geographic information — Imagery sensor models for geopositioning —

Part 2: SAR, InSAR, lidar and sonar

1 Scope

This Technical Specification supports exploitation of remotely sensed images. It specifies the sensor models and metadata for geopositioning images remotely sensed by Synthetic Aperture Radar (SAR), Interferometric Synthetic Aperture Radar (InSAR), Light Detection And Ranging (lidar), and Sound Navigation And Ranging (sonar) sensors. The specification also defines the metadata needed for the aerial triangulation of airborne and spaceborne images.

This Technical Specification specifies the detailed information that shall be provided for a sensor description of SAR, InSAR, lidar and sonar sensors with the associated physical and geometric information necessary to rigorously construct a Physical Sensor Model. For the case where precise geoposition information is needed, this Technical Specification identifies the mathematical formulae for rigorously constructing Physical Sensor Models that relate two-dimensional image space to three-dimensional ground space and the calculation of the associated propagated error.

This Technical Specification does not specify either how users derive geoposition data or the format or content of the data the users generate.

2 Conformance

This Technical Specification specifies 5 conformance classes. There is one conformance class for each type of sensor. Any set of geopositioning information claiming conformance to this Technical Specification shall satisfy the requirements for at least one conformance class as specified in [Table 1](#). The requirements for each class are shown by the presence of an X in the boxes for all clauses in the application test suite (ATS) required for that class. If the requirement is conditional, the box contains a C. The conditions are defined in the corresponding UML models.

Table 1 — Conformance classes

		Section of this part of ISO 19130							
		A.1.1	A.1.2	A.1.3	A.2	A.3	A.4	A.5	A.6
Conformance Class	SAR	X	C		X				
	InSAR	X	C			X			
	Lidar	X	X	X			X		
	Sonar	X	X	X				X	
	Aerial triangulation	X	C						X

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TS 19103:2005, *Geographic information — Conceptual schema language*

ISO 19107:2003, *Geographic information — Spatial schema*

ISO 19108:2002, *Geographic information — Temporal schema*

ISO 19111:2007, *Geographic information — Spatial referencing by coordinates*

ISO 19115-1:2014, *Geographic information — Metadata — Part 1: Fundamentals*

ISO 19115-2:2009, *Geographic information — Metadata — Part 2: Extensions for imagery and gridded data*

ISO 19123:2005, *Geographic information — Schema for coverage geometry and functions*

ISO 19157:2013, *Geographic information — Data quality*

ISO/TS 19130:2010, *Geographic information — Imagery sensor models for geopositioning*

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

4.1

active sensor

sensor ([4.66](#)) that generates the energy that it uses to perform the sensing

4.2

active sonar

type of *active sensor* ([4.1](#)) that transmits sound waves into the water and receives the returned waves echoed from objects in the water

4.3

adjustable model parameters

model parameters that can be refined using available additional information, such as ground control points, to improve or enhance modeling corrections

[SOURCE: ISO/TS 19130:2010, 4.2]

4.4

ARP

aperture reference point

3D location of the centre of the synthetic aperture

Note 1 to entry: It is usually expressed in ECEF coordinates in metres.

[SOURCE: ISO/TS 19130:2010, 4.4]

4.5

area recording

instantaneously recording an image in a single *frame* ([4.22](#))

4.6

attitude

orientation of a body, described by the angles between the axes of that body's coordinate system and the axes of an external coordinate system

[SOURCE: ISO 19116:2004, 4.2]

4.7

attribute

named property of an entity

[SOURCE: ISO/IEC 2382-17:1999, 17.02.12]

4.8

azimuth resolution

<SAR> *resolution* (4.60) in the cross-range direction

Note 1 to entry: This is usually measured in terms of the impulse response of the SAR *sensor* (4.66) and processing system. It is a function of the size of the synthetic aperture, or alternatively the dwell time (e.g. larger aperture - > longer dwell time - > better resolution).

[SOURCE: ISO/TS 19130:2010, 4.7]

4.9

beam width

<SAR> useful angular width of the beam of electromagnetic energy

Note 1 to entry: For SAR, beam width is usually measured in radians and is the angular width between two points that have 1/2 of the power (3 dB below) of the centre of the beam. It is a property of the antenna. Power emitted outside of this angle is too little to provide a usable *return* (4.62).

Note 2 to entry: Angle, measured in a horizontal plane, between the directions on either side of the axis at which the *intensity* (4.37) of a beam of energy drops to a specified fraction of the value it has on the axis.

[SOURCE: ISO/TS 19130:2010, 4.8, modified — Notes 1 and 2 have been added.]

4.10

broadside

<SAR> direction orthogonal to the *velocity vector* (4.81) and parallel to the plane tangent to the Earth's ellipsoid at the nadir point of the *ARP* (4.4)

[SOURCE: ISO/TS 19130:2010, 4.9]

4.11

complex image

first-level product produced by processing SAR *Phase History Data* (4.48)

4.12

datum

parameter or set of parameters that define the position of the origin, the scale, and the orientation of a coordinate system

[SOURCE: ISO 19111:2007, 4.14]

4.13

depression angle

vertical angle from the platform horizontal plane to the *slant range direction* (4.56), usually measured at the *ARP* (4.4)

Note 1 to entry: Approximately the complement of the *look angle* (4.42).

4.14

Differential Global Navigational Satellite System

enhancement to Global Positioning System that uses GNSS and DGNSS to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions

4.15

Doppler angle

<SAR> angle between the *velocity vector* (4.81) and the *range vector* (4.58)

[SOURCE: ISO/TS 19130:2010, 4.19]

4.16

Doppler shift

wavelength change resulting from relative motion of source and detector

Note 1 to entry: In the SAR context, it is the frequency shift imposed on a radar signal due to relative motion between the *transmitter* (4.79) and the object being illuminated.

[SOURCE: ISO/TS 19130:2010, 4.20]

4.17

draught

vertical distance, at any section of a vessel from the surface of the water to the bottom of the keel

[SOURCE: IHO Hydrographic Dictionary, S-32, Fifth Edition]

4.18

easting

E

distance in a coordinate system, eastwards (positive) or westwards (negative) from a north-south reference line

[SOURCE: ISO 19111:2007, 4.16]

4.19

field of regard

total angular extent over which the *field of view (FOV)* (4.20) may be positioned

Note 1 to entry: The field of regard is the area that is potentially able to be viewed by a system at an instant in time. It is determined by the system's FOV and the *range* (4.54) of directions in which the system is able to point.

[SOURCE: Adapted from the Manual of Photogrammetry]

4.20

field of view

FOV

instantaneous region seen by a *sensor* (4.66), provided in angular measure

Note 1 to entry: In the airborne case, this would be *swath* (4.75) width for a linear array, ground footprint for an area array, and for a whiskbroom scanner it refers to the swath width.

[SOURCE: Manual of Photogrammetry]

4.21

first return

first reflected signal that is detected by a 3D imaging system, time of flight (TOF) type, for a given sampling position and a given emitted pulse

[SOURCE: Adapted from STM E2544]

4.22

frame

<lidar> data collected by the *receiver* (4.59) as a result of all *returns* (4.62) from a single emitted pulse

Note 1 to entry: A complete 3D data sample of the world produced by a *lidar* (4.40) taken at a certain time, place, and orientation. A single lidar frame is also referred to as a *range* (4.54) image.

[SOURCE: Adapted from NISTIR 7117]

4.23

geiger mode

photon counting mode for *lidar* (4.40) systems, where the detector is biased and becomes sensitive to individual photons

Note 1 to entry: These detectors exist in the form of arrays and are bonded with electronic circuitry. The electronic circuitry produces a measurement corresponding to the time at which the current was generated; resulting in a direct time-of-flight measurement. A lidar that employs this detector technology typically illuminates a large scene with a single pulse. The direct time-of-flight measurements are then combined with platform location/*attitude* (4.6) data along with pointing information to produce a three-dimensional product of the illuminated scene of interest. Additional processing is applied which removes existing noise present in the data to produce a visually exploitable data set.

[SOURCE: Adapted from Albota 2002]

4.24

geodetic coordinate system

coordinate system in which position is specified by geodetic latitude, geodetic longitude and (in the three-dimensional case) ellipsoidal height

[SOURCE: ISO 19111:2007, 4.18]

4.25

geodetic datum

datum (4.12) describing the relationship of a two- or three-dimensional coordinate system to the Earth

Note 1 to entry: In most cases, the geodetic datum includes an ellipsoid description (ISO/TS 19130:2010)

Note 2 to entry: The term and this Technical Specification may be applicable to some other celestial bodies.

[SOURCE: ISO 19111:2007, 4.24, modified — Notes 1 and 2 have been added.]

4.26

geographic coordinates

longitude, latitude and height of a ground or elevated point

Note 1 to entry: Geographic coordinates are related to a coordinate reference system or compound coordinate reference system. Depth equals negative height.

4.27

geographic information

information concerning phenomena implicitly or explicitly associated with a location relative to the Earth

[SOURCE: ISO 19101:2002, 4.16]

4.28

geolocating

geopositioning an object using a *Physical Sensor Model* (4.68) or a True Replacement Model

[SOURCE: ISO/TS 19130:2010, 4.34]

4.29

grazing angle

<SAR> vertical angle from the local surface tangent plane to the *slant range direction* (4.56)

Note 1 to entry: It is usually measured at the GRP and approximately the complement of the *incident angle* (4.35)

[SOURCE: ISO/TS 19130:2010, 4.39, modified — Note 1 to entry has been added.]

4.30

hydrophone

<sonar> component of the sonar system which receives the sound echo and converts it to an electric signal

4.31

heave

oscillatory rise and fall of a ship due to the entire hull being lifted by the force of the sea

[SOURCE: IHO Hydrographic Dictionary S-32, Fifth Edition]

4.32

hydrographic swath

<sonar> strip or lane on the ground scanned by a multi-beam sounder when the survey vessel proceeds along its course

[SOURCE: IHO Hydrographic Dictionary S-32, Fifth Edition]

4.33

image coordinates

coordinates with respect to a Cartesian coordinate system of an image

Note 1 to entry: The image coordinates can be in pixels or in a measure of length (linear measure).

4.34

image formation

<SAR> process by which an image is generated from collected *Phase History Data* (4.48) in a SAR system

[SOURCE: ISO/TS 19130:2010, 4.51]

4.35

incident angle

vertical angle between the line from the detected element to the *sensor* (4.66) and the local surface normal (tangent plane normal)

Note 1 to entry: It is approximately the complement of the *grazing angle* (4.29).

[SOURCE: ISO/TS 19130:2010, 4.57, modified — Note 1 to entry has been added.]

4.36

instantaneous field of view

instantaneous region seen by a single detector element, measured in angular space

[SOURCE: Manual of Photogrammetry]

4.37

intensity

power per unit solid angle from a point source into a particular direction

Note 1 to entry: Typically for *lidar* (4.40), sufficient calibration has not been done to calculate absolute intensity, so relative intensity is usually reported. In *linear mode* (4.41) systems, this value is typically provided as an integer, resulting from a mapping of the *return's* (4.62) signal power to an integer value via a lookup table.

4.38

last return

last reflected signal that is detected by a 3D imaging system, time-of-flight (TOF) type, for a given sampling position and a given emitted pulse

[SOURCE: Adapted from ASTM E2544]

4.39

layover

visual effect in SAR images of ambiguity among *returns* (4.62) from scatterers at different heights that fall into the same range-Doppler-time bin

Note 1 to entry: The effect makes buildings “lay over” onto the ground toward the *sensor* (4.66) *velocity vector* (4.81), akin to perspective views in projective imagery.

4.40

lidar

light detection and ranging

system consisting of 1) a photon source (frequently, but not necessarily, a laser), 2) a photon detection system, 3) a timing circuit, and 4) optics for both the source and the *receiver* (4.59) that uses emitted laser light to measure *ranges* (4.54) to and/or properties of solid objects, gases, or particulates in the atmosphere

Note 1 to entry: Time of flight (TOF) lidars use short laser pulses and precisely record the time each laser pulse was emitted and the time each reflected *return(s)* (4.62) is received in order to calculate the distance(s) to the scatterer(s) encountered by the emitted pulse. For *topographic lidar* (4.80), these time-of-flight measurements are then combined with precise platform location/*attitude* (4.6) data along with pointing data to produce a three-dimensional product of the illuminated scene of interest.

4.41

linear mode

lidar (4.40) system in which output photocurrent is proportional to the input optical incident *intensity* (4.37)

Note 1 to entry: A lidar system which employs this technology typically uses processing techniques to develop the time-of-flight measurements from the full waveform that is reflected from the targets in the illuminated scene of interest. These time-of-flight measurements are then combined with precise platform location/*attitude* (4.6) data along with pointing data to produce a three-dimensional product of the illuminated scene of interest.

[SOURCE: Adapted from Aull et al., 2002]

4.42

look angle

vertical angle from the *platform down direction* (4.50) to the *slant range direction* (4.56), usually measured at the *ARP* (4.4)

Note 1 to entry: It is approximately the complement of the *depression angle* (4.13).

4.43

mean sea level

MSL

average height of the surface of the sea at a tide station for all stages of the tide over a 19-year period, usually determined from hourly height readings measured from a fixed predetermined reference level

[SOURCE: IHO Hydrographic Dictionary S-32, Fifth Edition]

4.44

multibeam sonar

wide *swath* (4.75) echo sounder for use in seabed mapping and surveying using the multi-beam principle

Note 1 to entry: Depths are measured directly below and transverse to the ship’s track. The width of the swath is a function of the number of beams and their aperture.

[SOURCE: IHO Hydrographic Dictionary S-32, Fifth Edition]

4.45

multiple returns

multiple signals returned and detected for a given emitted pulse, such as when a laser beam hitting multiple objects separated in *range* (4.54) is split

[SOURCE: Adapted from ASTM E2544]

4.46

objective

optical element that receives light from the object and forms the first or primary image of an optical system

4.47

passive sonar

type of passive *sensor* (4.66) that only receives sound waves from external sources and does not transmit any sound waves

4.48

phase history data

PHD

video phase history data

raw radar *return* (4.62) signal information after demodulation

Note 1 to entry: Usually stored as a series of *range* (4.54) lines, each containing information from a specific *range bin* (4.55). PHD can be thought of as a table of five columns: In-phase signal, Quadrature signal, *Range* (4.54), *Doppler Angle* (4.15), and Time.

4.49

platform coordinate reference system

engineering coordinate reference system fixed to the collection platform within which positions on the collection platform are defined

[SOURCE: ISO/TS 19130:2010, 4.65]

4.50

platform down direction

downward normal to the platform horizontal plane

4.51

point cloud

collection of data points in 3D space

Note 1 to entry: The distance between points is generally non-uniform and hence all three coordinates (Cartesian or spherical) for each point must be specifically encoded.

4.52

projection centre

perspective centre

point located in three dimensions through which all rays between object points and image points appear to pass geometrically

Note 1 to entry: It is represented by the rear nodal point of the imaging lens system.

[SOURCE: ISO/TS 19130:2010, 4.62, modified — Note 1 to entry has been added.]

4.53

pulse repetition frequency

number of times the system (e.g. *lidar* [4.40]) emits pulses over a given time period, usually stated in kilohertz (kHz)

4.54

range

<SAR> distance between the antenna and a distant object, synonymous with slant range

4.55

range bin

<SAR> group of radar *returns* ([4.62](#)) that all have the same *range* ([4.54](#))

[SOURCE: ISO/TS 19130:2010, 4.69]

4.56

range direction

slant range direction

<SAR> direction of the *range vector* ([4.58](#))

Note 1 to entry: It is nominally the direction from a radar antenna to an object, represented by a vector from the ARP ([4.4](#)) to the GRP for SAR.

[SOURCE: ISO/TS 19130:2010, 4.70, modified — Note 1 to entry has been added.]

4.57

range resolution

spatial *resolution* ([4.60](#)) in the *range direction* ([4.56](#))

Note 1 to entry: For a SAR *sensor* ([4.66](#)), it is usually measured in terms of the impulse response of the sensor and processing system. It is a function of the bandwidth of the pulse.

[SOURCE: ISO/TS 19130:2010, 4.71]

4.58

range vector

vector from the antenna to a point in the scene

[SOURCE: ISO/TS 19130:2010, 4.72]

4.59

receiver

hardware used to detect and record signals

Note 1 to entry: In *lidar* ([4.40](#)) and sonar systems, the receiver detects and records reflected pulse *returns* ([4.62](#)).

4.60

resolution (of a sensor)

smallest difference between indications of a *sensor* ([4.66](#)) that can be meaningfully distinguished

[SOURCE: ISO/TS 19101-2:2008, 4.34]

4.61

resolution (of imagery)

smallest distance between two uniformly illuminated objects that can be separately resolved in an image

4.62

return

<lidar> sensed signal from an emitted laser pulse which has reflected off of an illuminated scene of interest

Note 1 to entry: There may be *multiple returns* ([4.45](#)) for a given emitted laser pulse.

4.63

scan

set of sequential *frames* ([4.22](#)) collected during a single full cycle of a mechanical scanner representing a cross-track excursion from one side of the *field of regard* ([4.19](#)) to the other and back again

4.64

scan mode

SAR mode in which the antenna beam is steered to illuminate a *swath* (4.75) of ground at various angles relative to flight path throughout the collection

Note 1 to entry: Steering the antenna also allows dwell time to be increased and provides the ability to collect strips at angles non-parallel to the flight direction and with better *resolution* (4.60) than Stripmap mode.

[SOURCE: ISO/TS 19130:2010, 4.77]

4.65

ScanSAR mode

special case of stripmap mode that uses an electronically steerable antenna to quickly change the *swath* (4.75) being imaged during collection to collect multiple parallel swaths in one pass

[SOURCE: ISO/TS 19130:2010, 4.78]

4.66

sensor

element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a quantity to be measured

[SOURCE: ISO/IEC GUIDE 99:2007, 3.8]

4.67

settlement

general lowering in level of a moving vessel, relative to what its level would be were it motionless, due to the regional depression of the surface of the water in which the ship moves

Note 1 to entry: Settlement is not an increase in displacement.

Note 2 to entry: Settlement is measured as an angular tilt about the centre of gravity of the vessel.

[SOURCE: IHO Hydrographic Dictionary S-32, Fifth Edition]

4.68

sensor model

<geopositioning> mathematical description of the relationship between the three-dimensional object space and the two-dimensional plane of the associated image produced by a *sensor* (4.66)

[SOURCE: ISO/TS 19130:2010, 4.80]

4.69

sidescan sonar

type of sonar that transmits sound energy from the sides of a towfish, creating a fanlike beam on either side that sweeps the seafloor, and continuously records *return* (4.62) signals, creating a “picture” of the seafloor and any other objects

Note 1 to entry: Sidescan sonar is used for imaging bottom features and targets in a wide variety of water depths.

Note 2 to entry: This includes synthetic aperture sidescan sonar.

4.70

single beam sonar

type of sonar that produces one narrow sonar beam directly beneath the *transducer* (4.78)/*receiver* (4.59) and receives a *return* (4.62) echo from the closest object

Note 1 to entry: Single beam sonar is commonly called a single beam echosounder (abbr: SBES).

4.71

sonar processing system

system that processes the sonar signals to determine the geopositions of objects sensed by sonar *sensors* (4.66)

4.72

Sound Navigation And Ranging

sonar

sensor (4.66) that uses sound navigation and ranging technology for sensing

4.73

squat

effect that causes a vessel moving through water to create an area of lowered pressure under its bottom that increases the effective *draught* (4.17) (i.e. lowers the vessel in the water)

Note 1 to entry: The effect is a result of Bernoulli's principle of fluid dynamics. The squat represents the increase in effective draught.

Note 2 to entry: For a ship underway, the change of level of the bow and stern from the still water condition in response to the elevation and depression of the water level about the hull resulting from the bow and stern wave systems.

[SOURCE: Implementation Specification — a Draught Information System for the St. Lawrence Seaway, 4.18, modified — Note 2 to entry has been added.]

4.74

stare

scanning mode consisting of a step stair pattern

Note 1 to entry: This applies to a HARLIE transceiver, based on a volume phase holographic optical element.

4.75

swath

<lidar> ground area from which *return* (4.62) data are collected during continuous airborne *lidar* (4.40) operation

Note 1 to entry: A typical mapping mission may consist of multiple adjacent swaths, with some overlap, and the operator will turn off the laser while the aircraft is oriented for the next swath. This term may also be referred to as a Pass.

4.76

sweep sonar

type of sonar that has several single beam *transducer* (4.78)/*receivers* (4.59) mounted on a boom, which is then operated parallel to the water's surface and orthogonal to the vessel's direction of travel

Note 1 to entry: Sweep sounding is commonly called multi-channel echosounding (MCES).

4.77

swipe

set of sequential *frames* (4.22) collected during a single half cycle of a mechanical scanner representing a cross-track excursion from one side of the *field of regard* (4.19) to the other

4.78

transducer

device that converts one type of energy to another

4.79

transmitter

component of sonar that converts an electrical impulse into a sound wave and sends the wave into the water

Note 1 to entry: Transmitter is also called projector in multibeam echosounding.

4.80

topographic lidar

lidar (4.40) system used to measure the topography of the ground surface

Note 1 to entry: Generally referring to an airborne lidar system.

4.81

velocity vector

<Radar> first derivative of the antenna's position vector

5 Symbols and abbreviations

5.1 Symbols

A	3D Affine transform matrix
a	image vector
B	radar pulse bandwidth
b	3D Affine translation vector
C	number of columns (samples) in the image
C_ℓ	correction for row-column to line-sample conversion.
C_s	correction for row-column to line-sample conversion
c	speed of light in a vacuum
c_s	speed of sound in the medium in which the sonar operates
<i>col</i>	column in the row-column coordinate system
D	physical radar antenna aperture
d_x	pixel width in CCS — not applicable to SAR
d_y	pixel height in CCS — not applicable to SAR
f	camera focal length
G₀	Ground Reference Point (GRP)
H	sensor altitude, m HAE; also platform Heading
H_{dg}	heading in reference to the local-vertical coordinate system, e.g. platform Heading
h	height (MSL) of the object the laser intersects, in kilometres.
h	object elevation, m HAE
h_{ae}	elevation relative to ellipsoid, e.g. sensor altitude, object elevation
I	In-phase (real) component of phase history data sample
i	index of frames
j	index of points

K	refraction constant, micro-radians
k	arbitrary constant
k_1	first order radial distortion coefficient
k_2	second order radial distortion coefficient
k_3	third order radial distortion coefficient
L	front nodal point of lens
ℓ	line in the line sample coordinate system
l	line number
l_0	location of GRP in line direction in image space
$\mathbf{M}_p$	generic 3D point (in ECEF)
$\mathbf{M}$	rotation matrix (various)
M_{ECEF}	rotation matrix from the ellipsoid-tangential reference frame to the ECEF reference frame
M_{ELL}	rotation matrix from the local vertical reference frame to the ellipsoid-tangential reference frame.
M_{GIM}	rotation matrix from the sensor reference frame to the gimbal reference frame (gimbal angles).
M_{PLA}	rotation matrix from the gimbal reference frame to the platform reference frame (boresight angles).
M_{SEN}	rotation matrix from scanner reference frame to sensor reference frame (scan angles).
M_{VER}	rotation matrix from the platform reference frame to the local vertical reference frame (INS observations).
$\mathbf{M}_\omega$	rotation about the x-axis (roll)
$\mathbf{M}_\varphi$	rotation about the y-axis (pitch)
$\mathbf{M}_\kappa$	rotation about the z-axis (yaw)
$\mathbf{M}_0$	the orientation matrix
mD	Down in the North East Down (NED) Coordinate System, cf. Figure C.4 . (“mZ” can also be used to represent down in the North East Down (NED) Coordinate System)
mE	East in the North East Down (NED) or North East Up Coordinate System, cf. Figure C.4 .
mN	North in the North East Down (NED) or North East Up Coordinate System, cf. Figure C.4 .
N	North in the North East Down (NED) or North East Up Coordinate System
P	pitch in reference to the local-vertical coordinate system

P_c	object point coordinate (ground space)
p_1, p_2	lens decentring coefficients
p_l, p_s	line and sample coordinates of a generic pixel in the image
Q_c	quadrature (imaginary) component of phase history data sample
Q	generic point in the image
Q_s	vector representing a generic point in the image in the slant plane
Q_0	vector representing GRP in the slant plane (ARP as origin)
$\overline{Q_0}$	vector from ARP to GRP (in ECEF)
R	range
R_G	ground range
R_S	slant range
R'	range from front nodal point (L) to the point on the ground (A)
r	radial distance on image from principal point to point of interest
r_A	azimuth resolution
r_{ECEF}	vector from the ECEF origin to the GNSS antenna phase-centre in the ECEF reference frame (GNSS observations)
r_{EP}	vector from the ECEF origin to the ground point in the ECEF reference frame.
r_{GIM}	vector from the sensor to the gimbal centre of rotation in the gimbal reference frame
r_{GPS}	vector from the GNSS antenna phase-centre to the INS in the platform reference frame
r_{GR}	ground range resolution
r_{INS}	vector from the INS to the gimbal centre of rotation in the platform reference frame.
r_R	range resolution
r_{SCA}	vector from the scanner to the ground point in the scanner reference frame (range).
r_{SR}	slant range resolution
row	row in the row-column coordinate system
S	antenna position vector (in ECEF)
$S(t)$	antenna position vector (in ECEF) as function of time
S_Y	antenna velocity vector (in ECEF)
$S_Y(t)$	antenna velocity vector (in ECEF) as function of time
S_0	Aperture Reference Point (ARP)

S_{Y0}	antenna velocity vector at the ARP (first derivative of ARP)
s	sample in the line-sample coordinate system; symbol has multiple meanings; meaning of the symbol defined in context .
s	adjustment for the range to account for distance from front nodal point to the lens; symbol has multiple meanings; meaning of the symbol defined in context .
s_0	location of GRP in sample direction in image space
T	period of signal
T	radar pulse width
t	time
t_r	round trip travel time
$\hat{U}_R$	unit vector in range direction in slant plane
$\hat{U}_A$	unit vector in azimuth direction in slant plane
X	X coordinates within Earth coordinate system
X_a	platform longitudinal axis
X,Y,Z	right-handed Cartesian ground coordinate system
X_a, Y_a, Z_a	Cartesian coordinates in Local Vertical Coordinate System
$X_L Y_L Z_L$	the position of the sensor front nodal point in ground coordinates
X_W, Y_W, Z_W	Cartesian coordinates in World Coordinate System
x'	image coordinate (x-component) adjusted for lens and atmospheric errors
$x_{GIM}, y_{GIM}, z_{GIM}$	Cartesian coordinates in Gimbal Coordinate System
X_0, Y_0	principal point offset in the x-y frame coordinate system
x_p, y_p, z_p	Cartesian coordinates in Platform Coordinate System
x_s, y_s, z_s	Cartesian coordinates in Sensor Coordinate System
$x_{sca}, y_{sca}, z_{sca}$	Cartesian Coordinates in Scanner Coordinate System
Y	Y coordinates within Earth coordinate system
Y_a	platform pitch axis
y	y coordinate in the x-y frame coordinate system
y'	image coordinate (y-component) adjusted for lens and atmospheric errors
Z	Z coordinates within Earth coordinate system
Z_a	platform yaw axis
z	various z coordinates, defined by subscripts

α	Doppler angle
α	the angle of the laser beam from vertical
α_0	Doppler angle of the GRP
α_L	local Doppler angle of a generic point
$a_1, b_1, c_1, a_2, b_2, c_2$	parameters for a six parameter transformation, in this case to account for array distortions.
$\dot{B}_{ij}$	coefficients of the unknown corrections to the sensor parameters
$\ddot{B}_{ij}$	coefficients of the unknown corrections to the ground coordinates
β	radar beamwidth
γ	grazing angle
Δd	angular displacement of the laser beam from the expected path
Δx_{atm}	atmospheric correction for image coordinates, x-component
Δy_{atm}	atmospheric correction for image coordinates, y-component
Δx_{dec}	lens decentring errors, x component
Δy_{dec}	lens decentring errors, y component
Δx_{lens}	total lens radial distortion and decentring distortion, x-component
Δy_{lens}	total lens radial distortion and decentring distortion, y-component
Δx_{radial}	radial lens distortions, x-component
Δy_{radial}	radial lens distortions, y-component
$\dot{\Delta}_i$	unknown corrections to the sensor parameters.
$\ddot{\Delta}_j$	unknown corrections to the ground coordinates.
θ	angular displacement of the range vector from the lens optical axis, x-component
E	easting
λ	geodetic longitude
v_{ij}	residuals of the frame coordinates.
Σ	covariance matrix
σ	covariance matrix element
Φ_{ps}	phase shift of signal
φ	geodetic latitude
φ_{eo}	rotation about the y-axis, pitch (equivalent to $\mathbf{M}_{\varphi}$)

φ	angular displacement of the range vector from the lens optical axis, y-component
ω	roll (in reference to the local-vertical coordinate system)

5.2 Abbreviated terms

ANSI	American National Standards Institute
APD	Avalanche Photo Diode (ASTM E2544-07a)
ARDC	Air Research Development and Command
ASTM	Formerly the American Society for Testing and Materials
CCD	Charge Coupled Device
CRS	Coordinate Reference System
CSM	Community Sensor Model
DEM	Digital Elevation Model
DGNSS	Differential Global Navigational Satellite System
ECEF	Earth Centred Earth Fixed
ENU	East North Up
EO	Earth Observation
FOR	Field of Regard
FOV	Field of View
FPA	Focal Plane Array
GmAPD	Geiger-mode Avalanche PhotoDiode
GNSS	Global Navigational Satellite System
GSD	Ground Sample Distance
HAE	Height Above Ellipsoid
IFOV	Instantaneous Field of View
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
InSAR,	Interferometric Synthetic Aperture Radar
IPR	ImPulse Response
IR	InfraRed
Ladar	Laser Detection and Ranging System. This term is used interchangeably with the term lidar. Historically, the term ladar grew out of the Radar community and is more often found in the literature to refer to tracking and topographic systems.
Lidar	Llght Detection and Ranging System

MBIO	Multi Beam Input-Output
MSL	Mean Sea Level
NED	North East Down
PHD	Phase History Data
PPS	Pulses Per Second
PRF	Pulse Repetition Frequency
RAR	Real Aperture Radar
Radar	RADio Detection And Ranging
SAR	Synthetic Aperture Radar
sonar	SOund Navigation And Ranging
TOF	Time of Flight

5.3 Notation

[Clauses 6, 7, 8, 9, 10](#), and [11](#) of this Technical Specification present a conceptual schema, specified in the Unified Modeling Language (UML), describing the characteristics of sensor models. Whereas ISO/TS 19103 describes the way in which UML is used in the ISO 19100 family of standards. It differs from standard UML only in the existence and interpretation of some special stereotypes, in particular, “CodeList” and “Union”. ISO/TS 19103 specifies the basic data types used in the UML model and the data dictionary in this Technical Specification.

[Annex B](#) contains a data dictionary for the UML diagrams in this schema.

ISO/TS 19103 requires that names of UML classes, with the exception of basic data type classes, include a prefix that identifies the standard and the UML package in which the class is defined. [Table 2](#) lists the prefixes used in this Technical Specification, the International Standard or Technical Specification in which each is defined and the package each identifies. UML classes defined in this Technical Specification belong to a package named Sensor Data Extension and have the prefix SE.

In this Technical Specification, classes taken from other geographic information standards are represented with a dotted outline.

Table 2 — UML class prefixes

Prefix	Standard	Package
CI	ISO 19115	Citation
CV	ISO 19123	Coverages
DQ	ISO 19157	Data quality
GM	ISO 19107	Geometry
MD	ISO 19115	Metadata
MI	ISO 19115-2	Metadata for Imagery
SC	ISO 19111	Spatial Coordinates
SD	ISO 19130	Sensor Data
SE	ISO 19130-2	Sensor Data Extensions
TM	ISO 19108	Temporal Schema

6 Sensor Model Extensions

6.1 Introduction

ISO/TS 19130 specifies the common and sensor-specific components of sensor models for precise geopositioning of imagery data. The specific sensors covered by ISO/TS 19130 are frame, whiskbroom, pushbroom, and SAR sensors. This Technical Specification covers InSAR, lidar, and sonar sensors, extends the SAR sensor model, and defines the sensor model for aerial triangulation. For sonar, the use of non ship based platforms is not covered in this Technical Specification. [Clause 6](#) specifies the extensions to the common sensor model classes defined in ISO/TS 19130. [Clauses 7, 8, 9, 10, and 11](#) specify sensor-specific extensions.

6.2 SE_SensorModel

SE_SensorModel is a specified subclass of SD_SensorModel that contains a description of sensor modeling methods and sensor manufacturer information to further specify the sensor and the modeling approach. The UML for this extension is shown in [Figure 1](#) and the data dictionary for this diagram is located in [Table B.1](#).

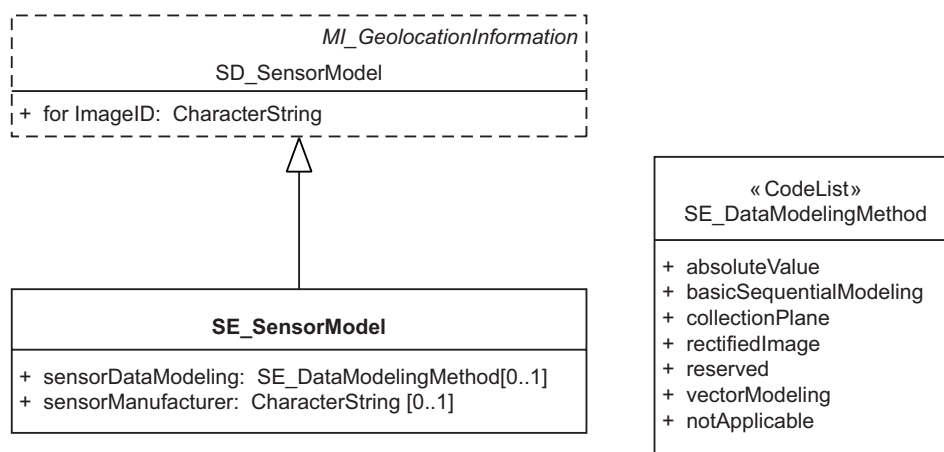


Figure 1 — Extension to the Sensor Model

6.3 SE_Dynamics

The class SD_Dynamics provides a set of elements for describing the rates at which elements of position and attitude change over time. SE_Dynamics is a subclass of SD_Dynamics that allows further specification of the uncertainties in motion and attitude of the sensor platform. The UML for this extension is shown in [Figure 2](#) and the data dictionary for this diagram is located in [Table B.2](#).

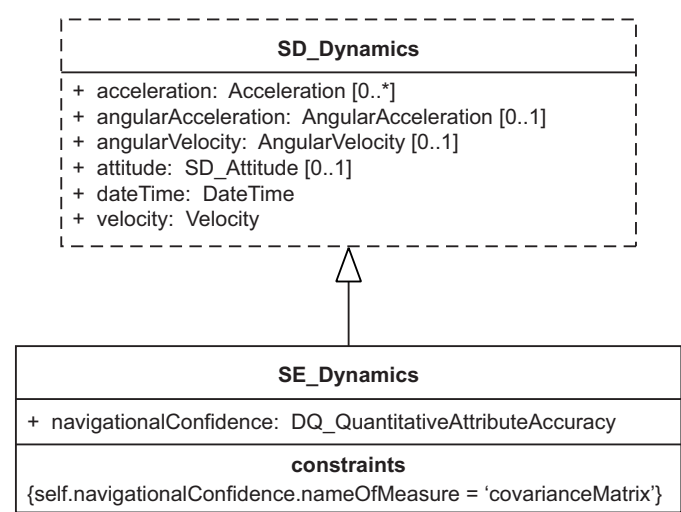


Figure 2 — SE_Dynamics

6.4 SE_PlatformDynamics

SE_PlatformDynamics is a subclass of SD_PlatformDynamics. It specifies additional parameters required to describe the dynamics of platforms for sonar and lidar sensors. The UML for this extension is shown in [Figure 3](#) and the data dictionary for this diagram is located in [Table B.3](#).

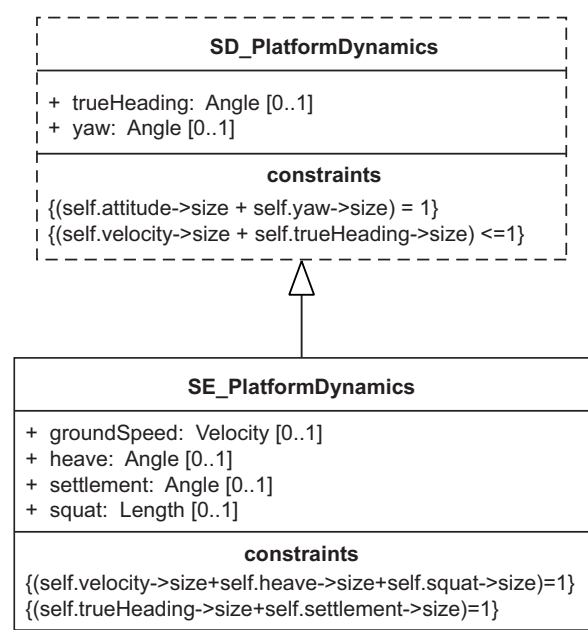


Figure 3 — Extensions to platform dynamics

7 Refinement of SAR physical sensor model

7.1 Introduction

Remote sensing systems using radar (radio detection and ranging) send radio signals towards an object and measure the intensity and phase of the reflected wave. The time difference between the sending of the signal and its return provide the distance to the object. Real Aperture Radar (RAR) images are along a line perpendicular to the flight track; they use the Doppler shift to filter out returns from points

ahead of or behind that line. The intensity of the reflectance allows different types of surfaces to be distinguished. In Synthetic Aperture Radar (SAR), the size of the antenna is synthetically enlarged by treating a series of returns from a much smaller physical antenna that is moving relative to the target as one long antenna (aperture). The distance the platform moves in synthesizing the antenna is known as the synthetic aperture. By synthesizing a large array, SAR can enjoy the benefits of improved angular resolution that come with large antennas without the technical and physical problems associated with them. SAR can sum the returns received from any given point over the time in which the physical antenna is moved along the length of the synthetic antenna. [Figure 4](#) shows the geometry of a SAR measurement.

Typically, SARs produce a two-dimensional (2-D) image. One dimension in the image is called range (or cross track) and is a measure of the “line-of-sight” distance from the radar to the target. Range measurement and resolution are achieved in synthetic aperture radar in the same manner as most other radars, from the time from transmission of a pulse to receipt of the echo. In the simplest SAR, range resolution is determined by the transmitted pulse width, i.e. narrow pulses yield fine range resolution. The other dimension is called azimuth (or along track) and is perpendicular to range. To obtain fine azimuth resolution, a large synthetic antenna is needed to focus the transmitted and received energy into a sharp beam. The sharpness of the beam defines the azimuth resolution. A side-looking radar is a SAR-system that records the object space (the ground) on one or both sides of the flight path or of the trajectory. The ground directly below the sensor is not recorded.

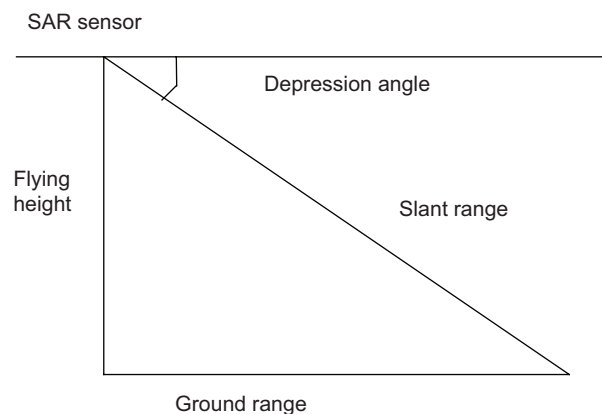


Figure 4 — Geometry of a SAR measurement

ISO/TS 19130:2010 specifies the fundamental metadata models needed for geolocating SAR images. In [7.2](#), this Technical Specification defines additional metadata for SAR geolocation. In [Annex C](#), it provides an updated informative description of how to use the sensor models defined in ISO/TS 19130:2010 and this Technical Specification for precise geopositioning of SAR images.

7.2 SE_SAROperation

SE_SAROperation is a subclass of SD_SAROperation. It provides further information on the data collection mode used in a SAR operation. [Figure 5](#) defines the extensions required to describe the operation of SAR. The data dictionary for this UML model is located in [Table B.4](#) and the code list [B.2.1.7](#).

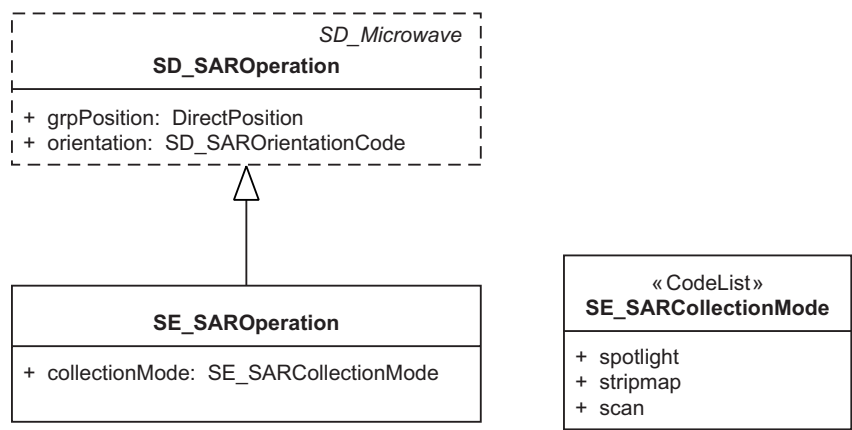


Figure 5 — SE_SAROperation

8 Interferometric SAR

8.1 Introduction

Interferometric SAR, or InSAR, is the application of interferometry to SAR images. An interferogram, the interferometric overlay of two SAR images, taking amplitude (intensity) and phase of both images into account, is produced. InSAR allows for a three-dimensional measurement of a surface and is especially useful for detecting minor surface deformation and mapping topography at millimetre or centimetre scales.

InSAR may be carried out in many ways. Single path interferometry is the interferometry of two SAR images taken from two antennas mounted on a common platform. Repeat-pass interferometry is the interferometry of two SAR images taken from two independent passes of a sensor over the same object. Repeat-pass interferometry of two sensors on two platforms flying almost at the same time and on the same orbit is called tandem interferometry. Differential interferometry is a special form of repeat-pass interferometry to detect local movements of the ground.

ScanSAR interferometry is a method to increase the possible width of the coverage below the flight path by focusing the system at points of interest. The swath is subdivided into several sub-swaths. After the beam has imaged a sub-swath with a certain number of pulses, its depression angle is rapidly steered to a different sub-swath. The result is a pattern of many small SAR image patches without complete coverage of the ground.

After the creation of an interferogram, the phase is ambiguous beyond the interval $[0, 2\pi]$. The ambiguities are removed by a process called phase unwrapping. One method of unwrapping the phases of an interferogram uses lines to connect positions with the same phase differences. A line of this type is called a cut.

8.2 InSAR geometry

The distance between the two imaging positions, either from single-pass dual-antennas or from single-antenna repeat passes, is the baseline of InSAR. In dual antenna InSAR, while the baseline vector can be at any orientation, it is often configured to either nearly perpendicular to the platform track, called cross-track InSAR ([Figure 6](#)), or nearly parallel to the platform track, called along-track InSAR ([Figure 7](#)). Cross-track InSAR is useful in mapping topography and topographic deformations, while along-track InSAR is useful in detecting radial movements such as ocean currents. In single-antenna repeat pass InSAR, the baseline vector is determined by the platform positions, which can be configured to cross-track or along-track geometry. It is also possible to command a platform to return to the exact same position and make another observation at the exact same geometry, in which case the phase difference recorded in the resultant interferogram image reflects, if the elementary scatters within each

imaging element are not changed, the movement of the target along the radial direction between the two observations. The amount of the displacement and the elapsed time between the two observations can be used to determine the velocity of the surface movement or deformation. Differential SAR Interferometry (DInSAR) is an application of InSAR for the detection of change in the geometry.

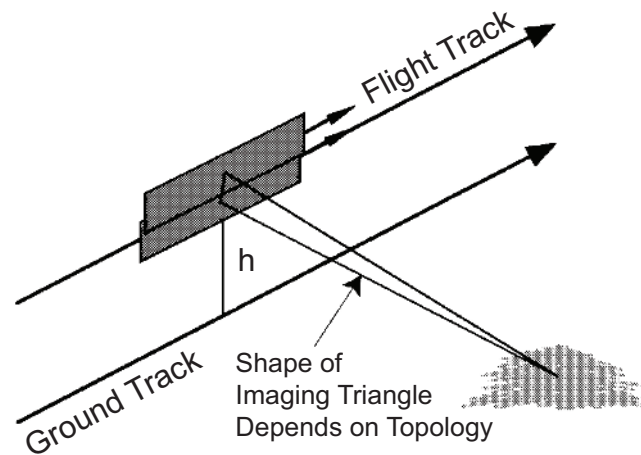


Figure 6 — Cross-track InSAR Configuration (from Rosen et al., 2000)

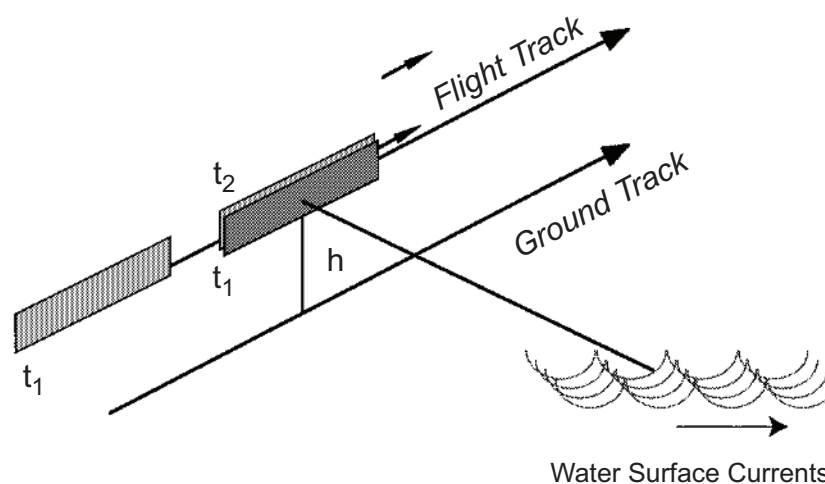


Figure 7 — Along-track InSAR Configuration (from Rosen et al., 2000)

[Figure 8](#) shows the various vectors in an InSAR geometry. The two antennas are positioned at A_1 and A_2 , separated by a baseline B . The target position is T . The location O is a reference position, such as the earth centre or nadir point. The vectors from O to the satellite, to the antenna positions, and to the target are $\vec{r}_1$, $\vec{r}_2$, and $\vec{r}_T$, respectively. The viewing vectors from the antennas to the target are $\vec{l}_1$ and $\vec{l}_2$.

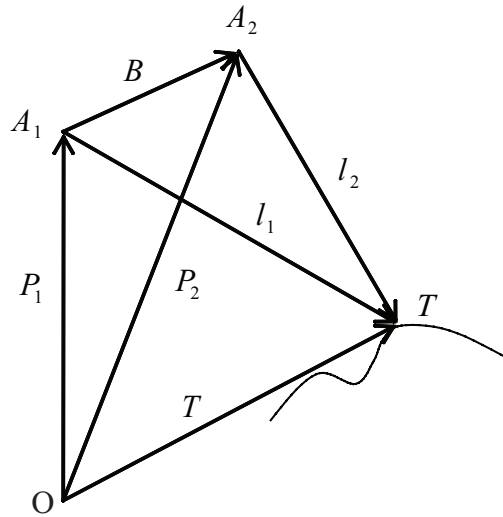


Figure 8 — InSAR Geometry

For cross-track interferometers, two modes of data collection are commonly used: single transmitter, or standard, mode, where one antenna transmits and both interferometric antennas receive, and dual transmitter, or “ping-pong”, mode, where each antenna alternatively transmits and receives its own echoes (Rosen et al., 2000). Single antenna repeat-pass InSAR operates inherently in ping-pong mode.

The following relationship between interferometric phase, ϕ , and baseline and viewing vectors can be derived (Rosen et al., 2000):

$$\begin{aligned}\bar{T} &= \bar{P}_1 + \bar{l}_1 = \bar{P}_1 + \rho_1 \hat{l}_1 \\ &= \bar{P}_2 + \bar{l}_2 = \bar{P}_2 + \rho_2 \hat{l}_2\end{aligned}\quad (1)$$

$$\bar{B} = \bar{P}_2 - \bar{P}_1 \quad (2)$$

$$\begin{aligned}\phi &= \frac{2\pi p}{\lambda} (\rho_2 - \rho_1) = \frac{2\pi p}{\lambda} (|\bar{l}_2| - |\bar{l}_1|) \\ &= \frac{2\pi p}{\lambda} \rho_1 \left[\left(1 - \frac{2\langle \hat{l}_1, \bar{B} \rangle}{\rho_1} + \left(\frac{B}{\rho_1} \right)^2 \right)^{1/2} - 1 \right]\end{aligned}\quad (3)$$

where $B = |\bar{B}|$ is the length of the baseline; ρ_1 and ρ_2 are ranges from the two antennas to the target; p equals 1 for standard mode and 2 for ping-pong mode.

8.3 Interferometric SAR operation

While surface reconstruction of InSAR is different from that of SAR, only a few additional parameters are required in the InSAR sensor model. These parameters include the geometrical relationships between the target and the positions of two antennas or the single repeat-pass antenna. In the two-antenna configuration, all parameters for the two antennas shall be exactly the same except that their positions in the platform are different. In the single antenna repeat pass configuration, the sensor parameters for the different observations shall be the same except that the observation times and positions in the multiple passes are different. [Figures 9](#) and [10](#) define the extensions required to describe the operation

of InSAR. The data dictionaries for this UML model are located in [Tables B.5](#) and [B.6](#) and the code lists in given in [B.2.1.11](#) and [B.2.1.12](#).

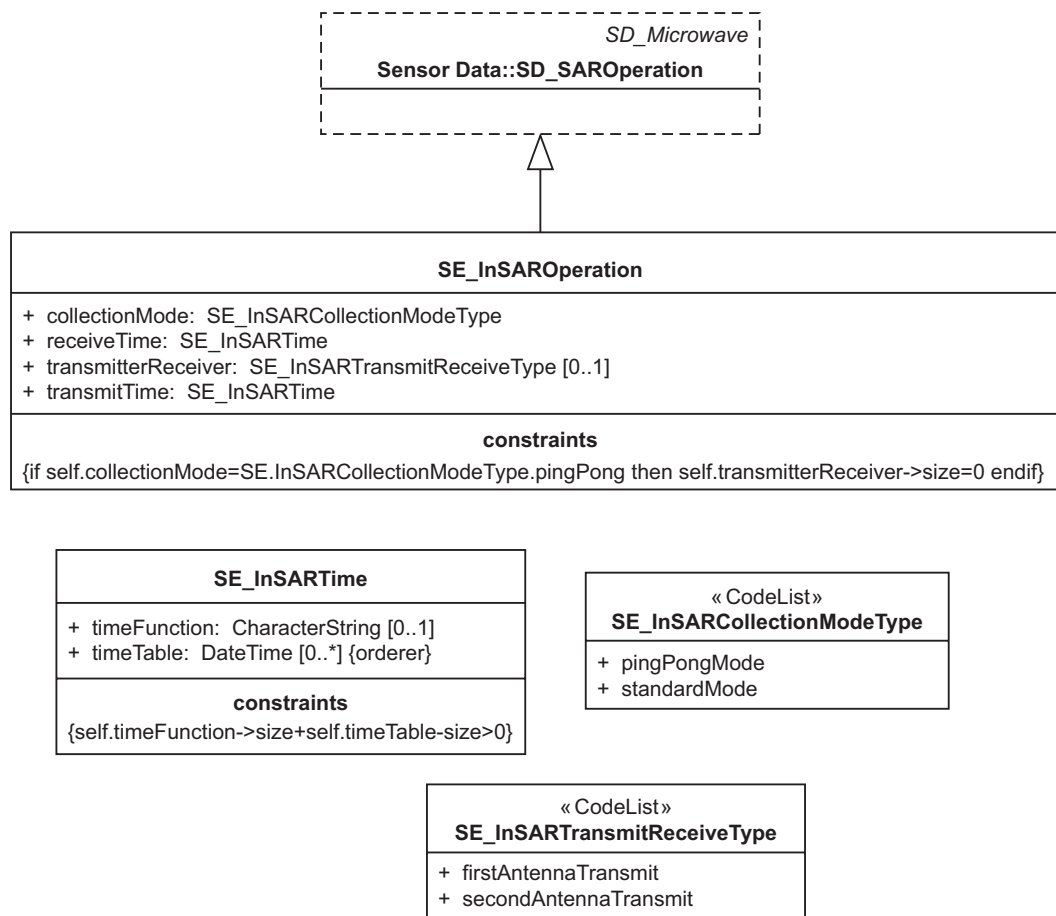


Figure 9 — InSAR Operation

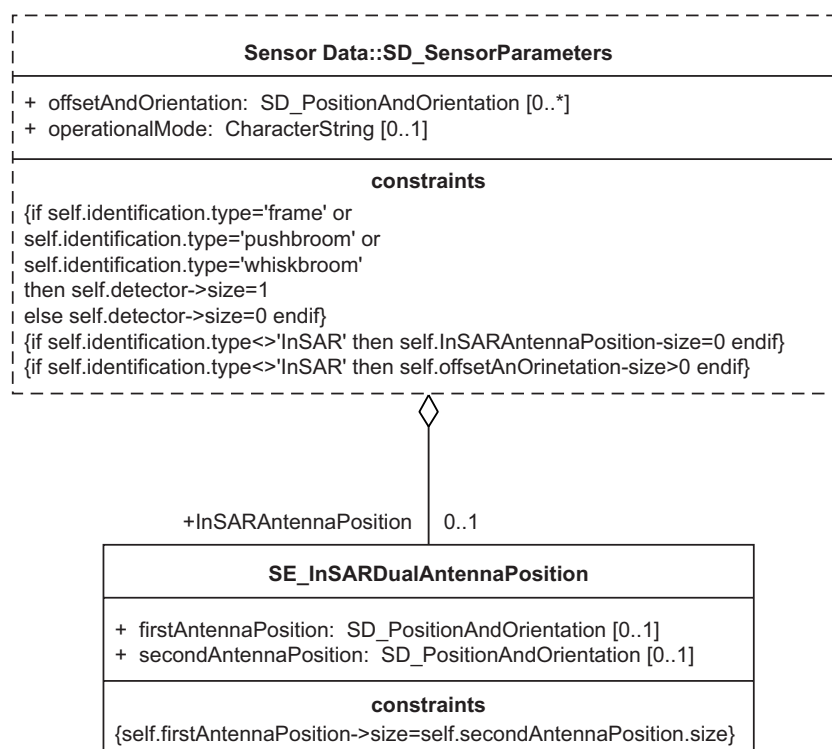


Figure 10 — InSAR dual antenna position

9 Lidar physical sensor model

9.1 Description of sensor

9.1.1 Introduction

A lidar (LIght Detection And Ranging) sensor is often mounted on-board an aircraft or a satellite. During the flight, the lidar sensor pulses a narrow, high frequency laser beam toward the Earth through an opening in the bottom of the platform. The lidar sensor records the time difference between the emission of the laser beam and the return of the reflected laser signal to the platform. Multiple reflections of a signal pulse emission are also possible.

9.1.2 Types of lidar

There are five basic types of lidar systems:

— Range finder

Range finders are used to measure the distance from the lidar sensor to a solid or hard target.

— DIAL

Differential Absorption lidar (DIAL) is used to measure chemical concentrations (such as ozone, water vapour and pollutants) in the atmosphere. A DIAL lidar uses two different laser wavelengths, which are selected so that one of the wavelengths is absorbed by the molecule of interest while the other wavelength is not. The difference in intensity of the two return signals can be used to deduce the concentration of the molecule being investigated.

— Doppler lidar

Doppler lidar is used to measure the velocity of a target. When the light transmitted from the lidar hits a target moving towards or away from the lidar, the wavelength of the light reflected/scattered off the target will be changed slightly. If the target is moving away from the lidar, the return light will have a longer wavelength; if the target is moving towards the lidar, the return light will be at a shorter wavelength.

— Multiple receiver lidar

Using multiple receivers at different locations and triangulating the results allows accurate location of a target in three dimensions.

— Full waveform lidar

Used for studies of soft targets.

9.2 Information required for geolocating

As a subclass of SD_OpticsOperation, SE_LIDAROperation defines the lidar-specific metadata required for precise geopositioning of lidar data. Geolocation information for lidar shall include the direction and time of each laser pulse, as specified in the UML model shown in [Figure 11](#). The data dictionary for this diagram is defined in [Table B.7](#).

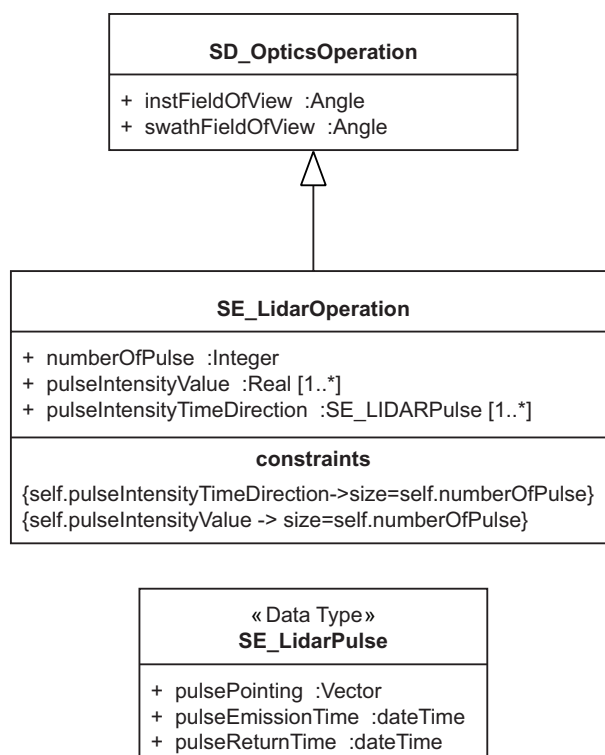


Figure 11 — Lidar operation

10 Sonar physical sensor model

10.1 Description of sensor

10.1.1 Introduction

Hydrographic surveying is usually conducted on a dynamic platform and in an environment that is constantly changing. As far as possible, the many influences that affect accuracy of survey measurements shall be accounted for and applied to the final survey data.

Sonar sensors are used to detect and survey objects in water using sound. Sound or ultrasonic waves are used underwater to obtain imagery of geological and manmade features at the bottom of seas, rivers or lakes, because electromagnetic radiation is generally not usable for imaging through water. Sound waves have many characteristics that are similar to electromagnetic waves, such as reflection, refraction, interference and diffraction. Unlike electromagnetic waves, they are elastic longitudinal waves whereas electromagnetic waves are transverse waves. The higher the frequency used, the greater will be the resolution and the attenuation.

As both horizontal and vertical positioning become increasingly more accurate (using code phase DGNSS [DGPS] and carrier phase DGNSS [kinematic]), knowledge of the vessel's attitude becomes critical for accurate positioning of sonar beams on the ocean floor. The increased path lengths of the outer beams in a multibeam system result in greater errors due to ray bending and require a more detailed knowledge of sound speed through the water column.

10.1.2 Configuration

10.1.2.1 Types of sonar

Four basic types of systems are currently used for hydrographic surveys.

— Single beam echo sounder system

A single beam echo sounder system produces one sonar beam directly beneath the transducer and receives a return from the closest point at which it intersects the seabed.

— Swath (multibeam or interferometric) sonar systems

Swath sonar systems have a single transducer or pair of transducers that transmit(s) a fan-shaped signal perpendicular to the ship's direction of travel. Returns are received from the points where this fan intersects the seabed and are converted into discrete depth values. Signal backscatter strength can be measured to provide imagery in a way similar to sidescan sonar systems.

— Sweep or boom systems

Sweep systems are characterized by several transducers mounted on a boom, which is then operated parallel to the water's surface and orthogonal to the vessel's direction of travel. This is the equivalent of having a number of single beam echo sounders mounted in a line. The transducers are equally spaced. If the echo comes, as is assumed, from the midpoint of the sonar beam, the result will be sonar bottom coverage with a constant width, independent of water depth.

— Sidescan sonar systems

Sidescan sonar systems generally have two transducers mounted transversely in a towfish. In a side scan the transmitted energy is formed into the shape of a fan that sweeps the seafloor from directly under the towfish to either side. Sidescan sonar sensors measure backscattered signal strength to provide qualitative information in the form of a "sound image". They do not provide definitive depth measurements. There are significant differences between interferometric and beamforming sonar.

Interferometric sonar, also referred to as Phase Differencing Bathymetric Sonar (PDBS) systems, use the measurement of phase at each of several receive elements to determine the angle from which

the acoustic return originates. Once the phase of the acoustic return has been precisely measured, the differences between the phase at each of the receive elements are used to calculate the angle from which the return originated. This angle of origin, in combination with range calculated from the two way travel time, provides a discrete location on the seafloor.

Beamforming is a signal processing technique used in sensor arrays for directional signal transmission or reception.

10.1.2.2 Single beam echo sounder system

A single beam echo sounder system consists of four basic components: a transducer or a transmitter and receiver, and a control and display system. These components are depicted schematically in [Figure 12](#).

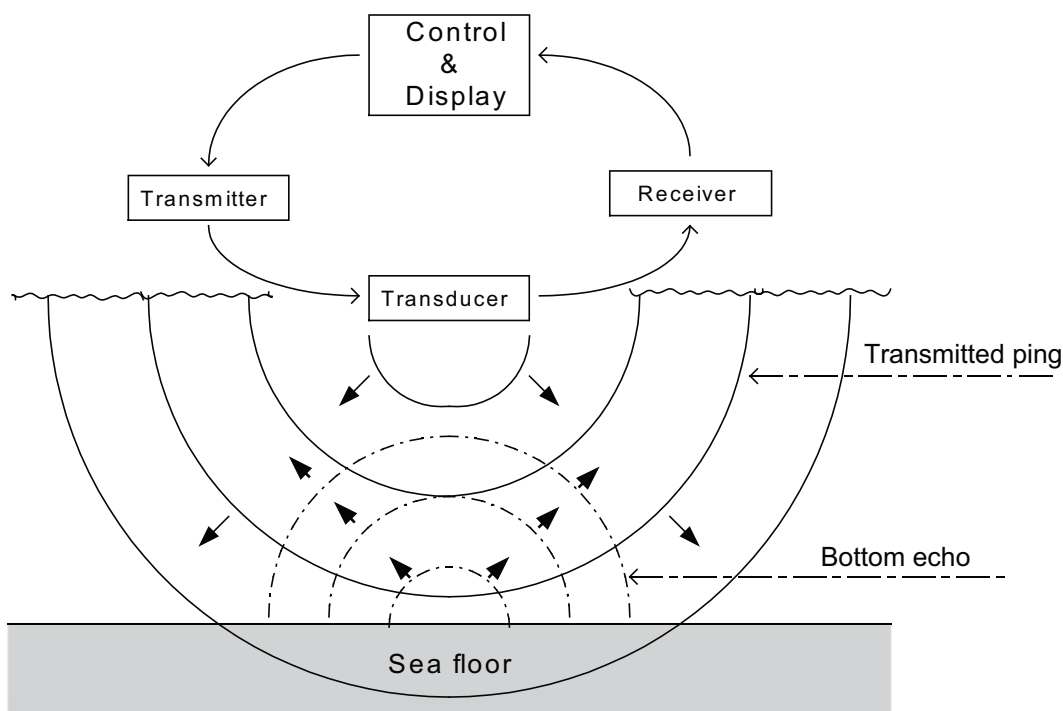


Figure 12 — Single beam sonar systems

10.1.2.3 Swath system

The sounding position coordinates shall be calculated by adjusting for system offsets such as the GNSS antenna, motion reference units, transducer position and alignment.

The cross-track distance and depth shall be calculated from the range (determined by measuring the two-way time travel) and the beam angle, as shown in [Figure 13](#). Depending on the system either phase, amplitude or a combination are used to measure depth.

In the scanning sonar/scanning profiler system for swath sounding, a single beam is mechanically rotated through (part of) a circular arc. A measurement is taken and then the transducer is rotated over an angle equal to the beam angle. A new measurement is taken, the transducer is rotated, and etc.

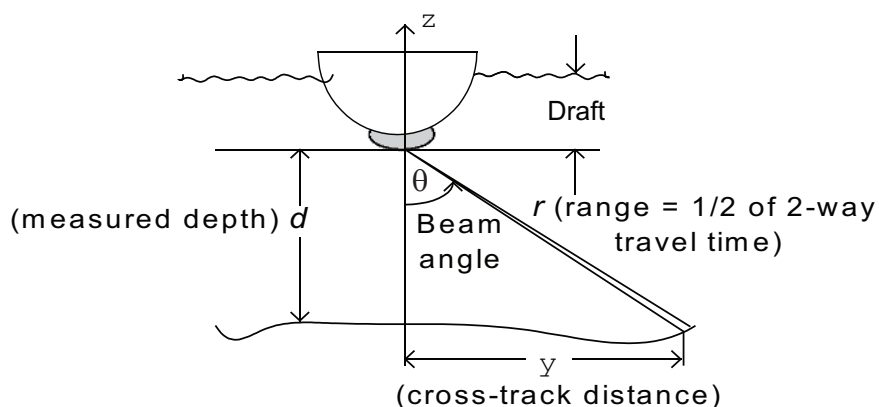


Figure 13 — Swath system

10.1.2.4 Sweep or boom system

Like swath systems, sweep systems produce soundings along a line oriented in the cross-track direction, except that the coordinates of each sounding are simply those of each transducer. [Figure 14](#) shows that there will be separate offset values for each transducer.

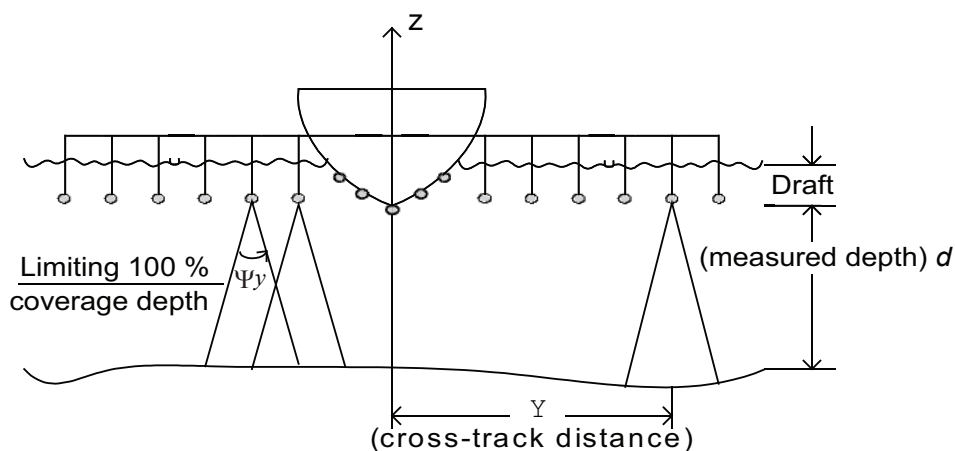


Figure 14 — Sweep system

10.1.2.5 Sidescan sonar system

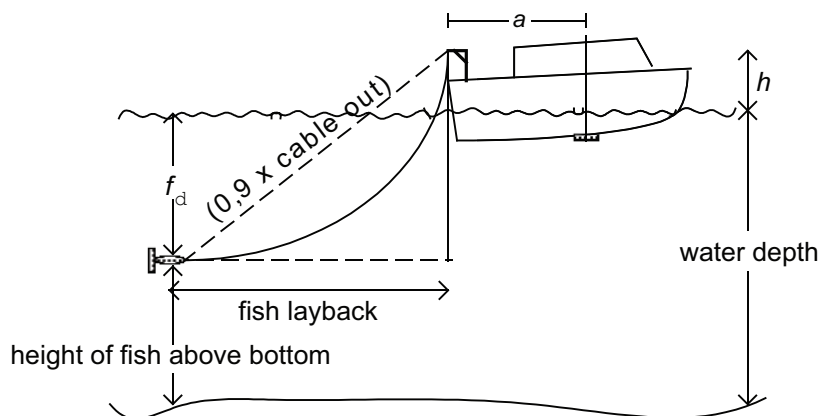


Figure 15 — Height and position determination of sidescan sonar system

$$\text{Fish layback} = \sqrt{[(0.9 \times \text{cable out})^2 - (h + f_d)^2]}$$

where

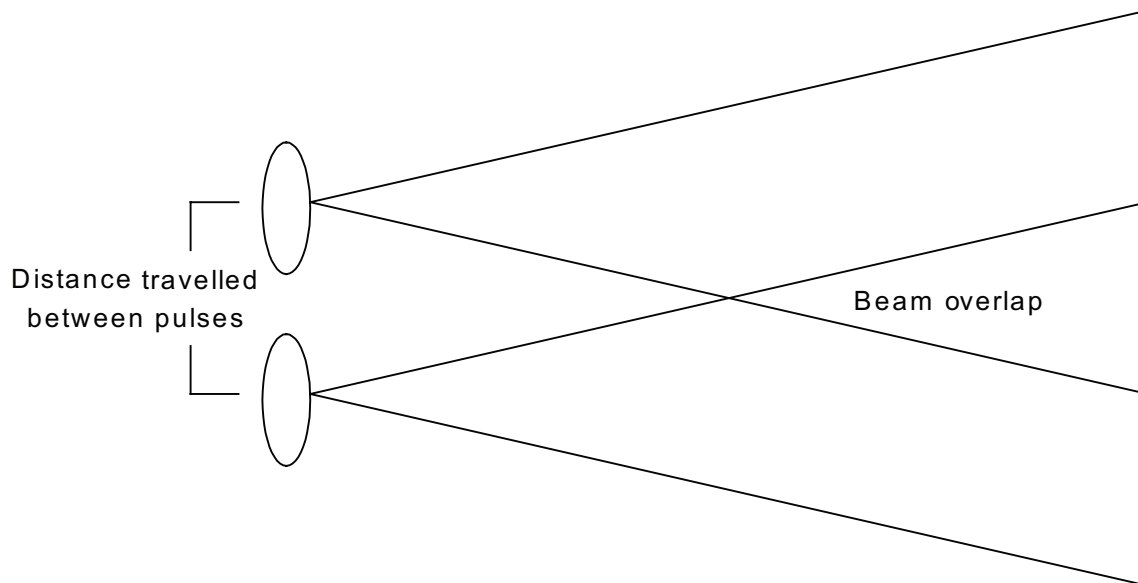
- a offset of tow point from echo sounder transducer;
- h height of tow point above waterline;
- f_d depth of sidescan sonar fish = water depth – height of fish above bottom.

NOTE 1 A factor of 0.9 of the towing cable length is sometimes used to calculate fish layback length, however this is dependent on the altitude of the sonar fish above the water bottom. This is recommended to be 10 % of water depth but is not always attained. For deep depths different factors may be used or an acoustic positioning system may be used to determine fish relative to either the towing vessel or a 'chase boat'.

Sidescan sonar is used to locate objects. A shallow water multibeam or single beam sonar system is used to determine the smallest depth over the objects. Sidescan sonar data are collected over the seafloor in addition to multibeam or single beam depth data. The operator acquires sidescan sonar data using a towed system. The sidescan sonar system used on the continental shelf can be operated out to a typical maximum range of 500 m although 150 m is commonly used. The towfish should be maintained at a height above the bottom of 8 % to 20 % of the range scale in use. The ideal value is 15 %, as shown in [Figure 15](#).

Since the sonar is pulsing at a fixed rate based on its range scale, the speed that the towfish is being towed will have an effect on the ability to resolve items. In general, the slower the fish is towed, the greater the resolution of the imagery obtained.

NOTE 2 Typically, sidescan sonar is towed at a speed such that objects to be detected would receive a minimum of three pings per pass for a digital system and 5 pings if using a paper recorder. [Figure 16](#) shows an example of how the required towing speed may be computed (if using a paper recorder replace the 3 in the equation for maximum speed with 5).



$$\text{Maximum speed (metres/second)} = \text{Target size (metres)} \times \text{prf}/3 \text{ (seconds}^{-1}\text{)}$$

where prf is the pulse repetition rate = reciprocal of pulse period and knots = metres/second $\times 1,9$

EXAMPLE For a 100 m range scale with 7,5 pulses/second:

- Maximum vessel speed = 4,8 kn
- For a 150 m range scale with 5 pulses/second
- Maximum vessel speed = 3,2 kn

Figure 16 — Speed calculation for sidescan sonar system

10.2 Information required for geolocating

10.2.1 Introduction

The sonar-specific metadata needed for geolocating sonar data are specified in [10.2.2](#) to [10.2.5](#). The metadata classes defined here, together with sensor-independent metadata classes defined in ISO/TS 19130 and in this Technical Specification, provide sufficient information to construct a physical sensor model for geolocating the sonar data. The informative [Annex E](#) provides a detailed description of Sonar systems and their operation and an example on how to use the metadata defined in ISO/TS 19130 and this Technical Specification to geolocate the sonar data.

10.2.2 SE_SonarOperation

The class SE_SonarOperation is a specified subclass of SD_SensorSystemAndOperation. SE_SonarOperation and its subclasses specify the sonar-specific metadata required to describe sonar operation for precise geopositioning of sonar data. This information shall be provided as shown in the UML model of [Figure 17](#). The classes shown in [Figure 17](#), their attributes and their associations, shall be used as specified in the data dictionary of [Table B.8](#).

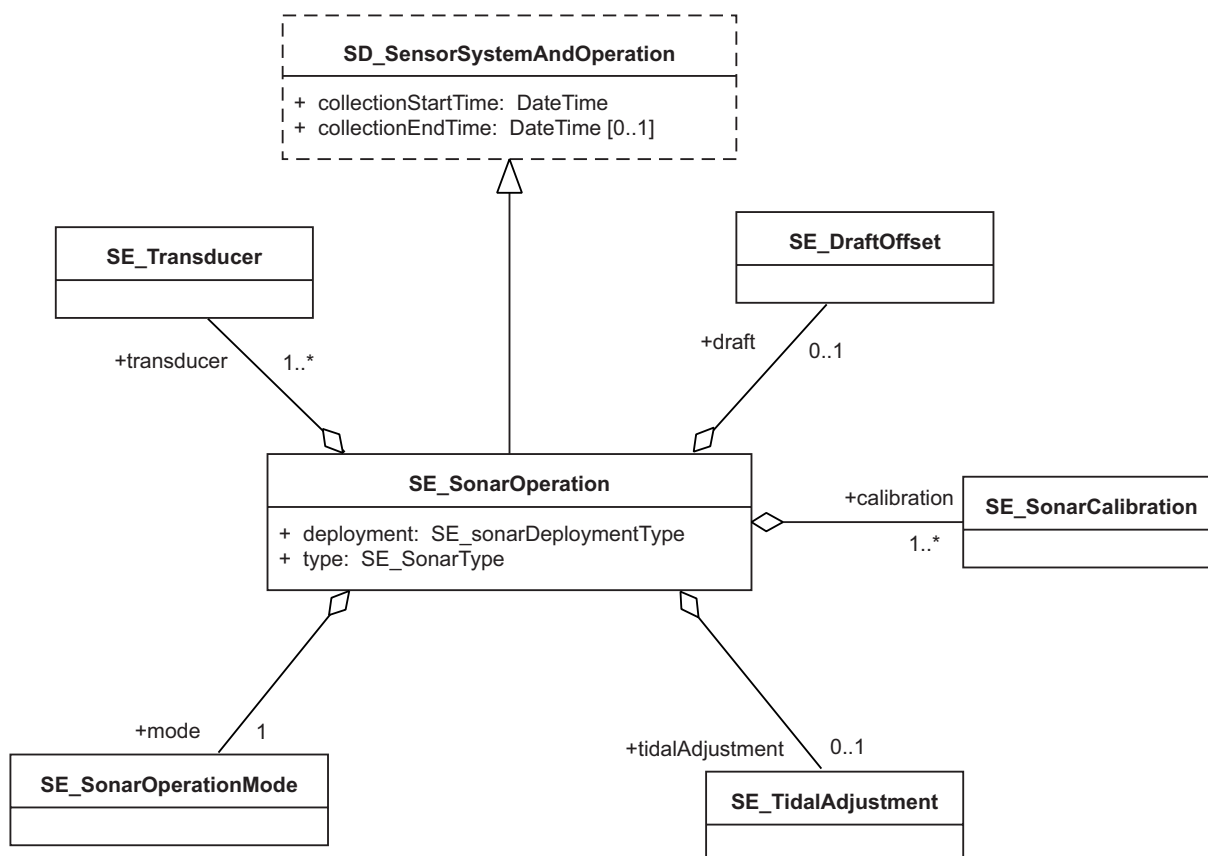


Figure 17 — Sonar operation

10.2.3 SE_SonarOperationMode

The class SE_SonarOperationMode specifies the operation modes of sonar. This information shall be provided as shown in the UML model of [Figure 18](#). The classes shown in [Figure 18](#), their attributes and their associations shall be used as specified in the data dictionary of [Table B.9](#), and the code lists given in [B.2.1.7](#), [B.2.1.8](#) and [B.2.1.9](#).

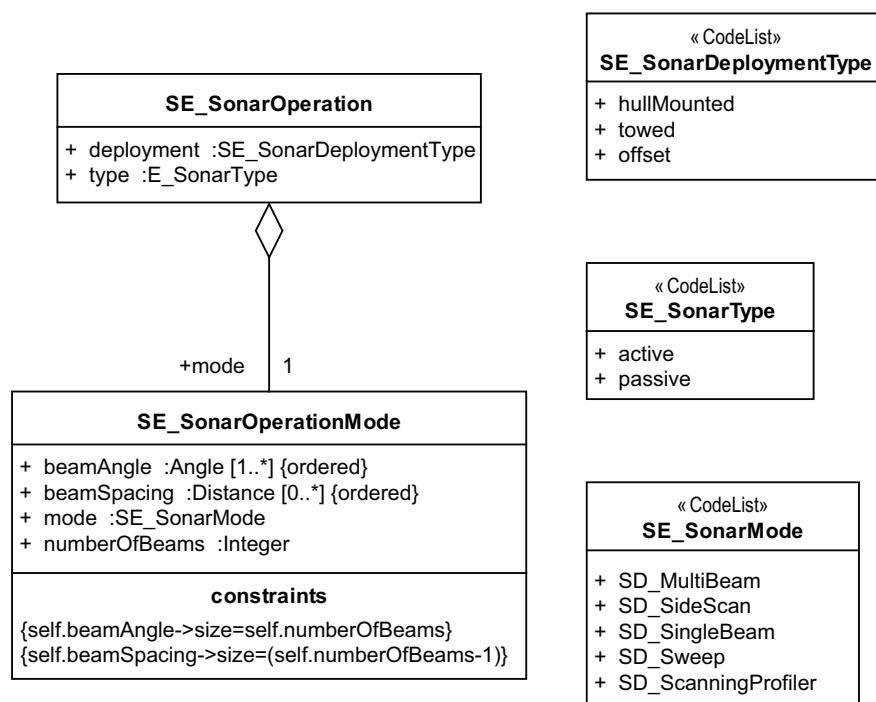


Figure 18 — Sonar operation mode

10.2.4 SE_SonarTransducer

The sonar transducer is a major component of the sonar system. It transmits the sound wave through the transmitter and receives the echo of the wave through the receiver. This information shall be provided as shown in the UML model of [Figure 19](#). The classes shown in [Figure 19](#), their attributes and their associations shall be used as specified in the data dictionary of [Table B.10](#). Position is defined as the x,y,z (layback or offset) distances from the RP (Reference Position). The RP is the 0,0,0 coordinates from which all system equipment is related, and “direction” is defined as the angular orientation from the RP.

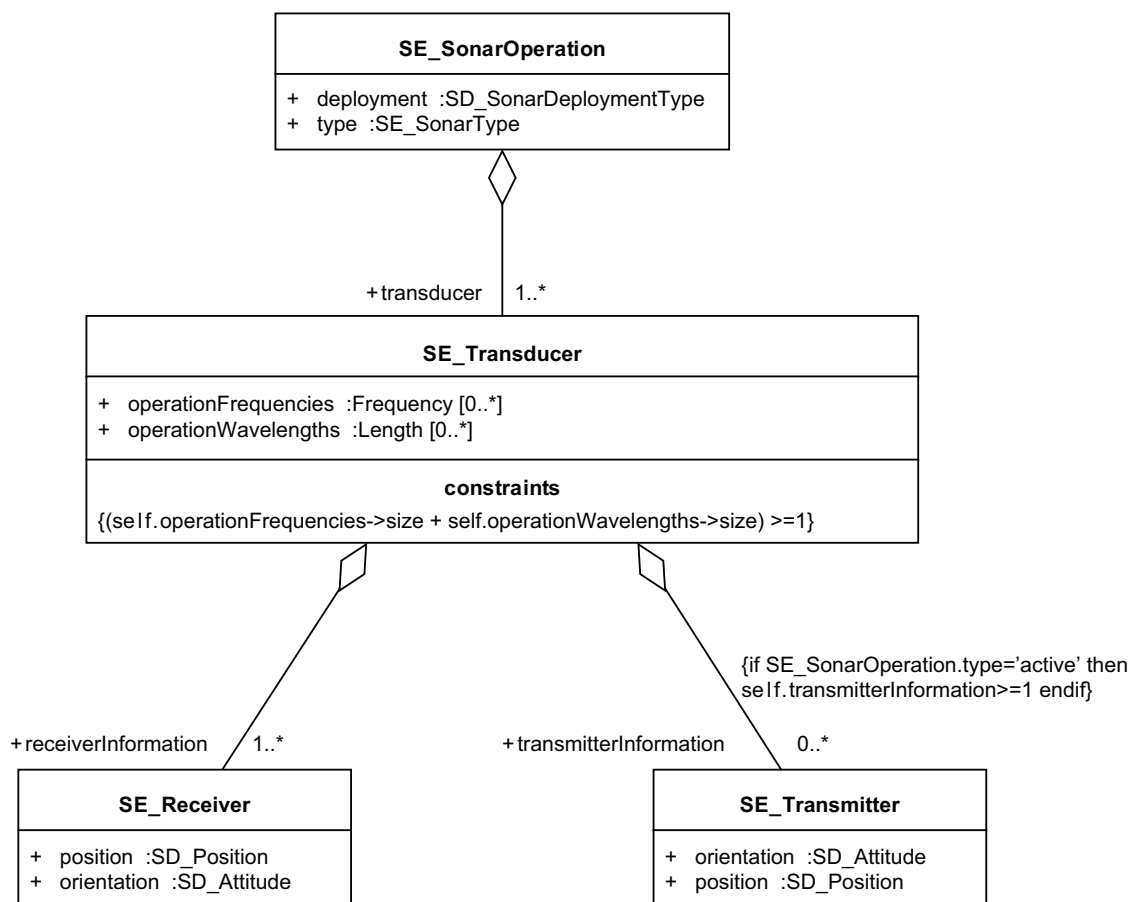


Figure 19 — Sonar transducer

10.2.5 Calibration and adjustment

A set of calibrations and adjustments have to be applied to data collected by a sonar system for geolocating the data. The calibration and adjustment information shall be provided as shown in the UML model of [Figure 20](#). The classes shown in [Figure 20](#), their attributes and their associations shall be used as specified in the data dictionaries of [Tables B.11](#), [B.12](#) and [B.13](#), and the code list given in [B.2.1.10](#). For depths greater than 200 m, it is not always required to correct the measured depths for sound velocity, as a standard sound velocity of 1500 m/s is usually used or values may be selected from the Mathews Correction Tables.

NOTE In some applications a sound velocity profile is used for giving more accurate depths.

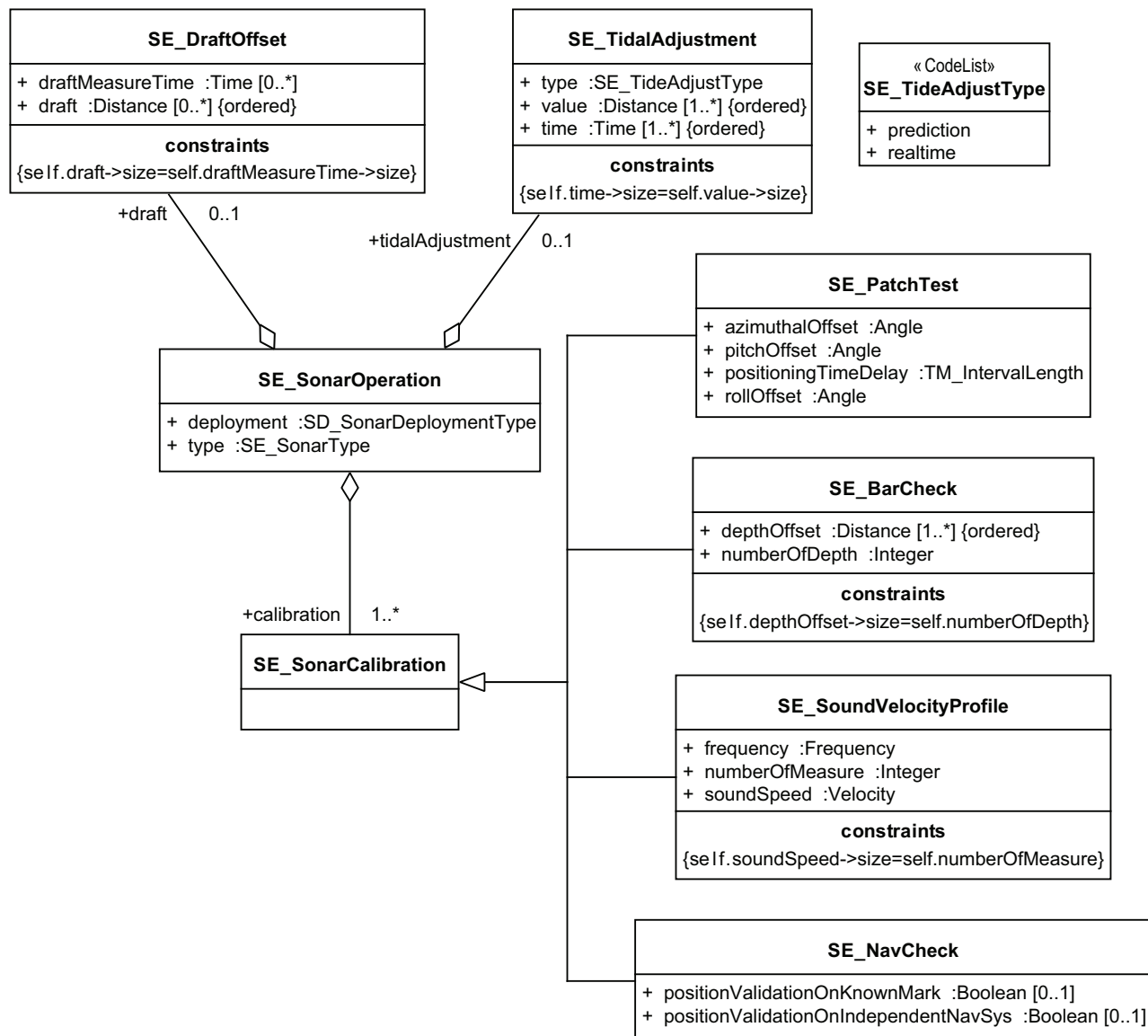


Figure 20 — Calibration and adjustment

11 Aerial triangulation

11.1 Introduction

Aerial triangulation is a method of determining the georeference and other parameters of a sensor and the imagery data taken by this sensor. Aerial triangulation requires an overlap of neighbouring images in order to allow for the creation of a so-called block which is the entirety of all images involved in a project. This requirement restricts aerial triangulation to the physical sensor model of area imaging arrays. This clause addresses only frame camera sensors.

In the past, aerial triangulation was applied in order to restrict the expensive measurement of Ground Control Points to a minimum. Today, a photo flight almost always includes the GNSS (e.g. GPS) measurement of every projection centre. Therefore, aerial triangulation is applied in order to improve the overall accuracy and the reliability. Ground Control Points are used only for a local and mostly unknown datum shift between the coordinate reference system (CRS) of the GNSS and the local CRS.

The heart of aerial triangulation is an adjustment process. The observations include the image coordinates of the tie points, the GNSS-measurements of the projection centres, the IMU-measurements of the projection centres (attitude), the image coordinates of the Ground Control Points, and the image coordinates of the Check Points. The unknowns include the exterior orientation (position and attitude) of every projection centre. The parameters describing the sensor (camera) may be taken as fixed (calibrated) or as unknowns. However, the latter case is not feasible for most aerial applications.

11.2 SE_AerialTriangulation

The information in the classes SE_AerialTriangulation and its subclasses is required for geolocation by aerial triangulation. This information shall be provided as shown in the UML model of [Figure 21](#). The classes shown in [Figure 21](#) their attributes and their associations shall be used as specified in the data dictionary of [Table B.14](#) and the code lists given in [B.2.1.1](#), [B.2.1.2](#), [B.2.1.3](#) and [B.2.1.4](#).

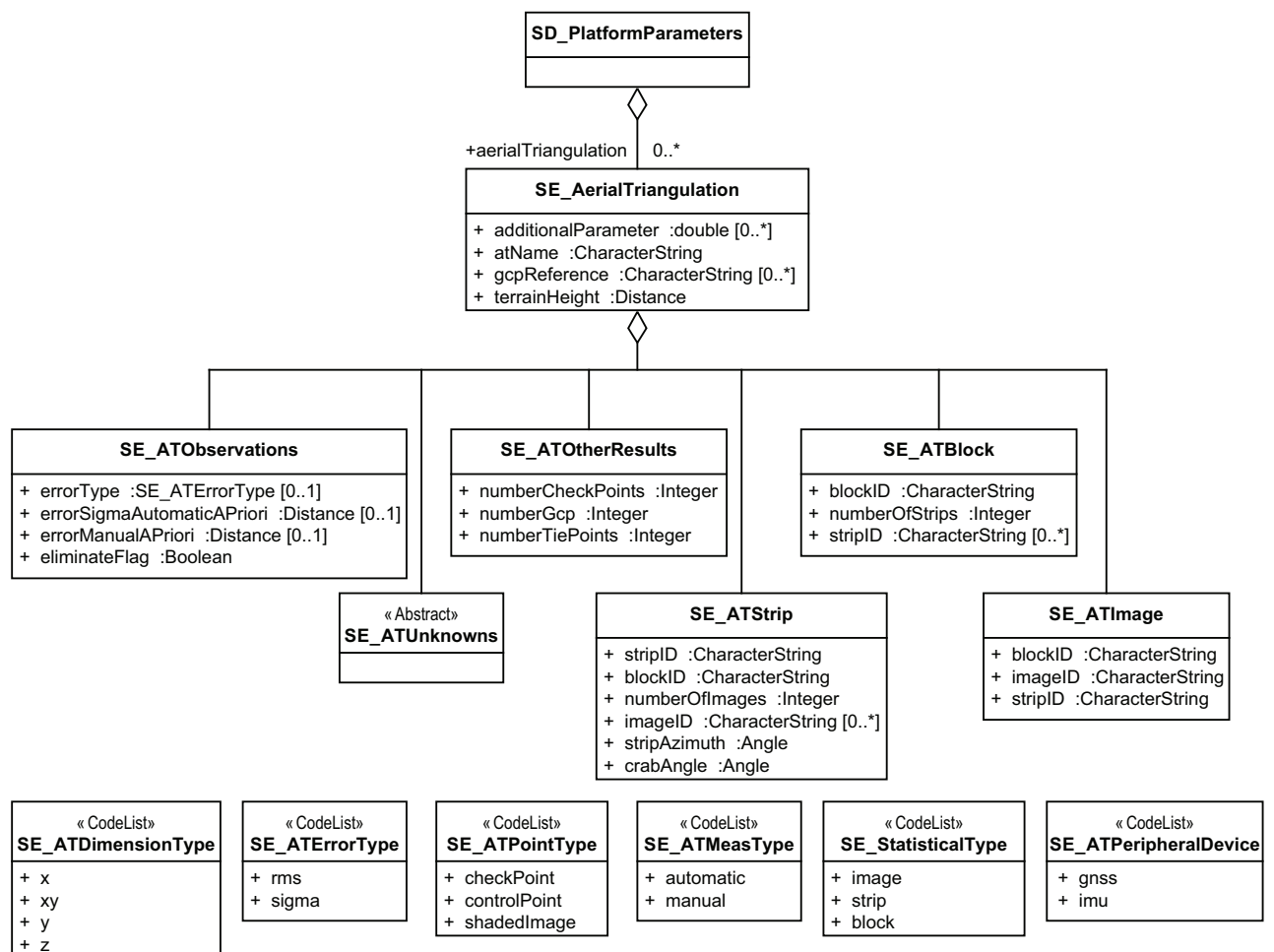


Figure 21 — Aerial triangulation

11.3 SE_ATObservations

Information about the individual observations, as defined in SE_ATObservations and its subclasses, is required for aerial triangulation. This Information shall be provided as shown in the UML model of [Figure 22](#). The classes shown in [Figure 22](#), their attributes and their associations shall be used as specified in the data dictionary of [Table B.21](#).

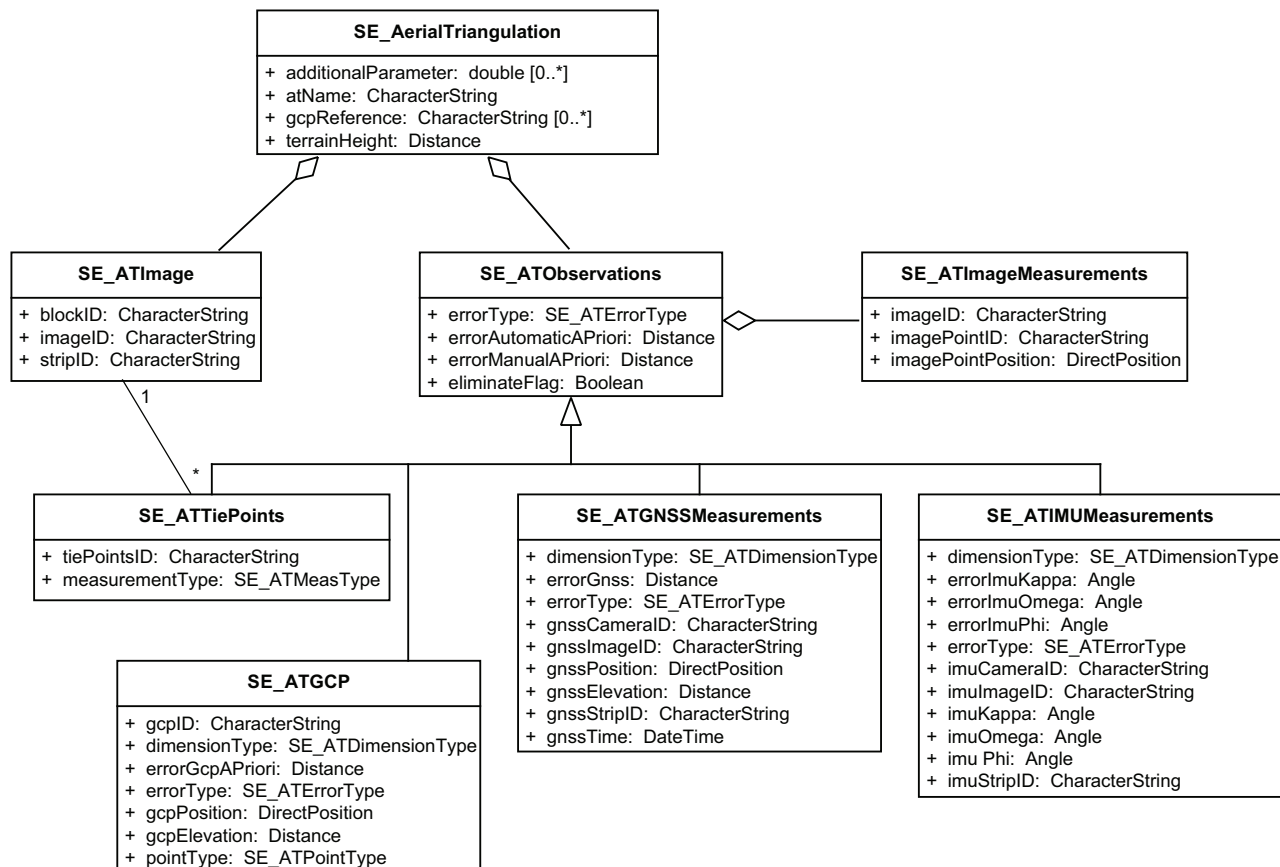


Figure 22 — Aerial triangulation observations

11.4 SE_ATOtherResults

Information about other results of aerial triangulation, as defined in SE_ATOtherResults and its subclasses, is required for aerial triangulation. This Information shall be provided as shown in the UML model of [Figure 23](#). The classes shown in [Figure 23](#), their attributes and their associations shall be used as specified in the data dictionary of [Table B.22](#).

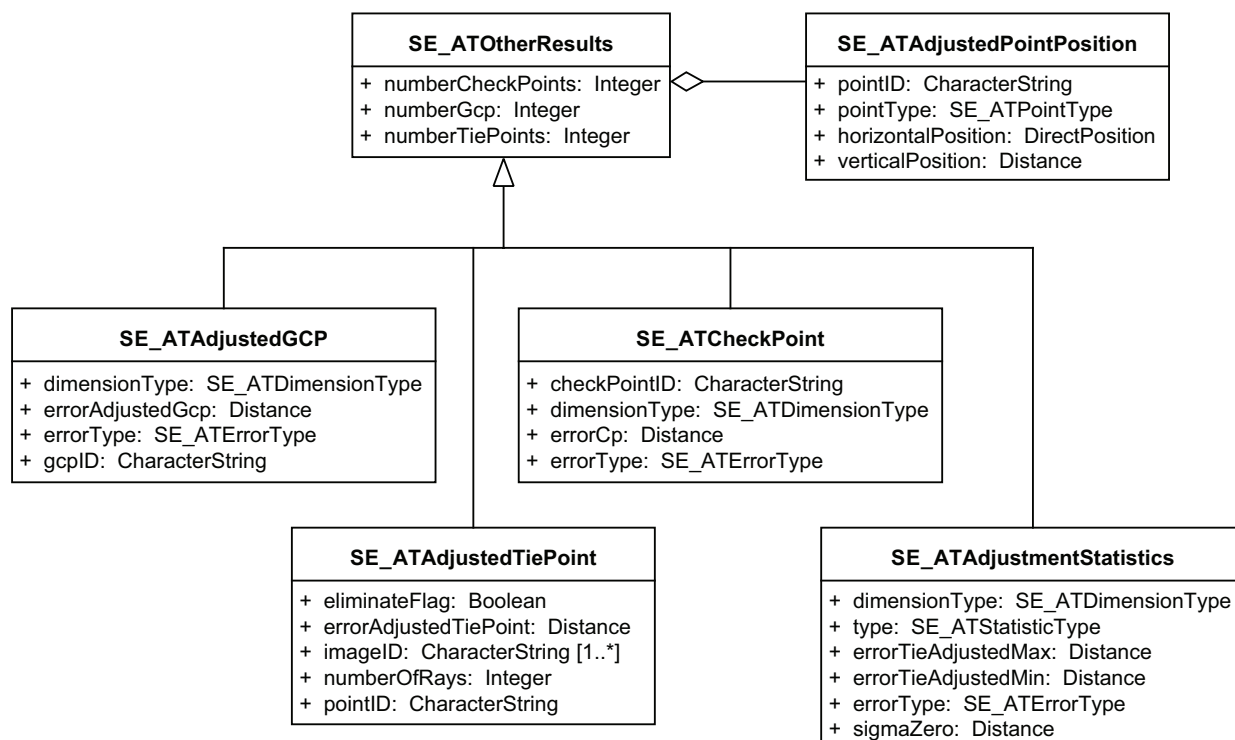


Figure 23 — Other result of aerial triangulation

11.5 SE_ATUnknowns

SE_ATUnknowns and its subclasses define required unknowns for aerial triangulation. This Information shall be provided as shown in the UML model of [Figure 24](#). The classes shown in [Figure 24](#), their attributes and their associations shall be used as specified in the data dictionary of [Table B.23](#).

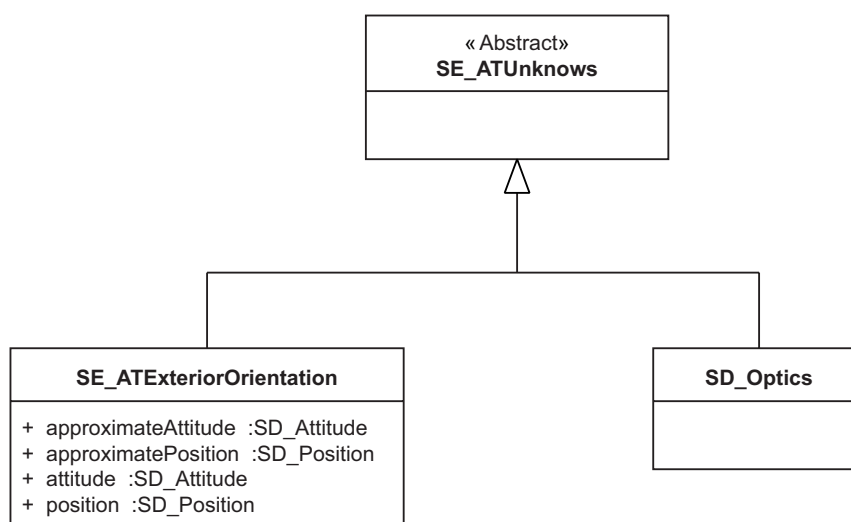


Figure 24 — Exterior orientation of aerial triangulation

Annex A **(normative)**

Conformance and testing

A.1 Sensor model extensions

A.1.1 Sensor model completeness

Test purpose: Verify that geopositioning information provided with the image data instantiates SE_SensorModel.

Test Method: Inspect the content of the metadata intended to support geopositioning.

Reference: [6.2](#)

Test Type: Basic

A.1.2 Dynamics

Test purpose: Verify that navigational confidence information provided with the image data instantiates SE_Dynamics.

Test Method: Inspect the content of the metadata intended to support the navigational confidence.

Reference: [6.3](#)

Test Type: Basic

A.1.3 Platform dynamics

Test purpose: If sensor is sonar or lidar, verify that platform dynamics information provided with the image data instantiates SE_PlatformDynamics.

Test Method: Inspect the content of the metadata intended to support the navigational confidence.

Reference: [6.3](#)

Test Type: Capability

A.2 SAR operation

Test purpose: If sensor is SAR, verify that SAR operation description provided with the image data instantiates SE_SAROperation.

Test Method: Inspect the metadata provided with the image.

Reference: [7.2](#)

Test Type: Capability

A.3 InSAR operation and dual antenna position

Test purpose: If sensor is InSAR, verify that metadata about InSAR operation and dual antenna position provided with the image data instantiates SE_InSAROperation and SE_InSARDualAntennaPosition.

Test Method: Inspect the metadata provided with the image.

Reference: [8.3](#)

Test Type: Capability

A.4 Lidar operation

Test purpose: If sensor is lidar, verify that metadata about lidar operation provided with the image data instantiates SE_LIDAROperation.

Test Method: Inspect the metadata provided with the image.

Reference: [9.2](#)

Test Type: Capability

A.5 Sonar operation

Test purpose: If sensor is sonar, verify that metadata about sonar operation provided with the image data instantiates SE_SonarOperation, SE_Transducer, SE_DraftOffset, SE_SonarCalibration, SE_SonarOperationMode, and SE_TidalAdjustment.

Test Method: Inspect the metadata provided with the image.

Reference: [10.2.2](#), [10.2.3](#), [10.2.4](#), and [10.2.5](#)

Test Type: Capability

A.6 Aerial triangulation

Test purpose: If aerial triangulation method is used, verify that metadata provided with the image data instantiates SE_AerialTriangulation and its subclasses.

Test Method: Inspect the metadata provided with the image.

Reference: [11.2](#), [11.3](#), [11.4](#), and [11.5](#)

Test Type: Capability