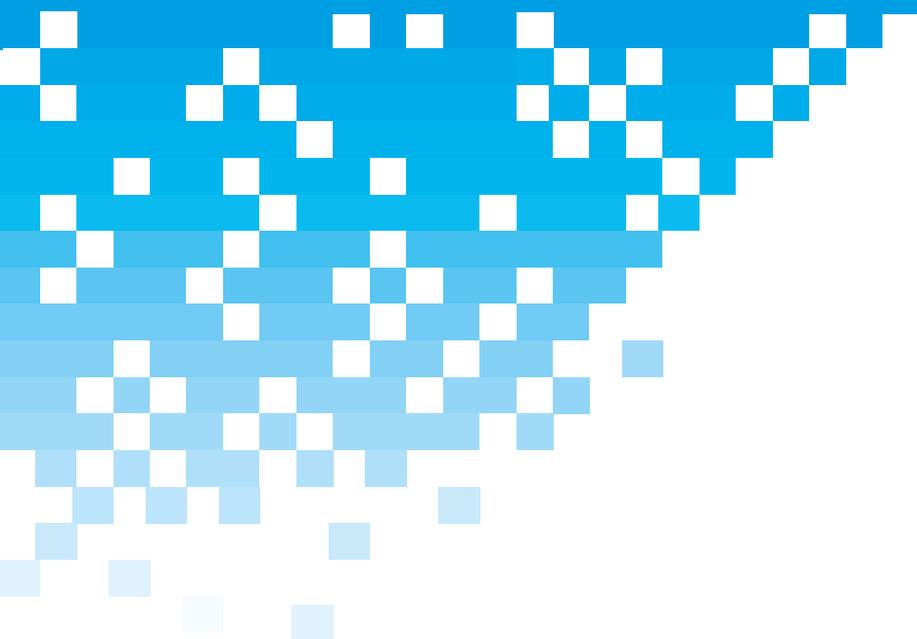


Airborne laser scanning 2017

English summary of:

HMK – Flygburen laserskanning 2017



Foreword

The first version of *HMK – Laserdata* (*HMK – Laser data*) was published in July 2014. [*HMK – Flygburen laserskanning 2017*](#) (*HMK – Airborne laser scanning 2017*) is the third version of that handbook.

This constitutes an English summary of the document, with emphasis on Appendix A: *Template and examples for establishing technical specifications*, which is supplemented by a brief introduction to HMK, a short review of the corresponding Swedish handbook and some additional information in Appendix B and C.

The document has been prepared by Clas-Göran Persson, Lantmäteriet. Language examination was conducted by Sofie Adler Kleborgh, New York University, and a technical, pre-publication, expert review was carried out during September/October 2018.

The tests with English-language short versions of HMK documents will be evaluated by the end of 2019. Before that, no more documents will be translated.

Gävle 2018-11-06

/Anders Grönlund,
Uppdragsledare HMK

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1 Introduction

Information

For any ongoing adjustments of the document, see [HMK-nytt](#).

1.1 Objectives, purposes and needs

The goal of the work with HMK, *Handbok i mät- och kartfrågor* (*Handbook in surveying and mapping*), is to contribute to an effective handling of procurements and products associated with surveying and mapping.

HMK aims at unified geodata acquisition and control of geodata, as well as high data quality. The collected data should be stored and provided in accordance with the principles applicable to Swedish data sharing and for Inspire (see Section 1.9).

The overall needs are:

- modern manuals aimed for customer/supplier relationships
- support for new employees, in new industries requiring new technology
- requirements for increased uniformity and standardization
- greater efficiency and thus lower costs.

1.2 Background

The older HMK handbook series was published in nine printed bands during the period 1993-1994. These documents have largely become out of date due to technology development and legislative changes.

The building and civil engineering works sector (Bygg- och anläggningssektorn) has developed parts of its regulations regarding procurement, specification and control of surveying services in relation to the older handbooks. This material is facing a renewal, with the wish to still have HMK as a base. Therefore, there is a need for new documents for today's technology and the customer/supplier situation.

1.3 Target group

HMK is mainly a support tool for state and municipal authorities for acquisition, quality assurance, storage and provision of basic geodata.

The content of the handbooks is primarily based on the experience and requirements that [Lantmäteriet](#) (*Swedish Mapping, Cadastral and Land Registration Authority*), the Swedish municipalities and [Trafikoverket](#) (*Swedish Transport Administration*) have as actors in their respective areas of activity.

However, much of the content is universal and can with minor modifications be used in other activities. HMK is supplemented, as needed, by government-specific regulations and requirements or technical specifications and formal standards of the *Swedish Standards Institute (SIS)*.

1.4 Legal status of the documents

The regulation SFS 2009:946 “Lantmäteri-instruktionen” (*Instructions for Lantmäteriet*) states that (excerpt):

- Lantmäteriet has a national co-responsibility for production, co-operation, provision and development in the field of geographic information and property information.
- Lantmäteriet shall promote uniformity, coordination and quality in the field of surveying and mapping.
- Lantmäteriet shall, within the scope of its area of activity, give advice and support.
- Lantmäteriet shall ensure that the regulations and procedures available to the authority are cost-effective and simple for citizens and businesses.

The advice given in HMK is based on proven, professional work. Recommendations are not binding but can be given legal status by including them in, for example, procurement documents and employment contracts.

1.5 Introductory documents

After the 2017 update, the introduction to HMK consists of three collaborative documents:

- [HMK – Introduktion 2017](#) (HMK – Introduction 2017).
- [HMK – Geodatakvalitet 2017](#) (HMK – Geodata quality 2017), which is a reference work on quality issues.
- [Terminologi, principer och trender inom geodatakvalitet](#) (*Terminology, principles and trends in geodata quality*), a complementary report in the HMK series “Technical reports”, titled HMK-TR 2016:1.

The document [HMK – Geodatakvalitet 2017](#) (HMK - Geodata quality 2017) is based primarily on the following international standards:

- [SS-EN ISO 19115-1:2014](#), *Geografisk information – metadata; Del 1: Grunder (Geographic information - Metadata - Part 1: Fundamentals)*.
- [SS-EN ISO 19131:2008](#), *Geografisk information – specifikation av datamängder (Geographic information – Data product specifications)*; a new version is expected in 2019.

- [SS-EN ISO 19157:2013](#), *Geografisk information – datakvalitet (Geographic information - Data quality)*.
- [SIS-ISO/TS 19158:2012](#), *Geografisk information – kvalitetssäkring av dataförsörjning (Geographic information – Quality assurance of data supply)*.

SIS is the Swedish equivalent of the *International Standardization Organization (ISO)*, and the European body *CEN*. Information on the above and other standards in the *ISO 19100 Series on geographic information* can be found on the [SIS-TK323 website](#).

However, the terminology regarding *measurement uncertainty* and *positional uncertainty* complies with the international standard *GUM: Guide to the expression of Uncertainty in Measurement*. This standard has been developed by the *Joint Committee for Guides in Metrology (JCGM)*, which consists of ISO and six other international organizations. A complete html-version of the standard (ISO/IEC Guide 98-3:2008) is published on: www.iso.org/sites/JCGM/GUM-JCGM100.htm.

1.6 Competency and formal eligibility

In order to carry out surveying work, the person responsible and/or the performer should have sufficient competency. However, there is no formal and universally recognized competency tests or skills assessments in Sweden in this area. Therefore, the responsibility of assessing competency has fallen on the individual customer/employer.

Lantmäteriet has, however, developed a draft concept called *Grundläggande mätningsteknisk färdighet (Basic surveying skills)*. This concept is by no means legally binding. It is only a recommendation intended to be applied in procurement and employment situations, for example in business agreements.

The basic principles of this construction are:

- Basic surveying skills mean sufficient skills to independently be responsible for most types of surveying engineering activities.
- For this skill, a degree from a two-year technical university education in surveying engineering is required, supplemented with two years of practical training, so that the total amount is at least 5 years.

Example: Two years of education and three years of practical experience.

The assessment of surveying skills can be part of a proficiency assessment, which is also based on specific industry requirements. For more information, see *Mätningsteknisk färdighet* under *Referensbibliotek* at HMK's website, www.lantmateriet.se/HMK (in Swedish only).

1.7 Procurement authorities and legislation

[Konkurrensverket](#) (*Swedish Competition Authority*) is an authority working to safeguard and increase competition and supervise public procurement in Sweden.

General information on procurement issues and its legislation, such as [Lagen om offentlig upphandling](#), SFS 2016:1145 (*Public Procurement Act*), can be downloaded from their website. Please note, though, that only the Swedish version of this act is authentic.

[Upphandlingsmyndigheten](#) (*The National Agency for Public Procurement*) has an overall responsibility for developing and supporting the procurement carried out by the contracting authorities, entities and suppliers.

1.8 Legislation regarding publicity and confidentiality

The most important laws and regulations regarding publicity and confidentiality regarding acquisition of geodata and the creation of geodatabases are:

- Offentlighets- och sekretesslagen, SFS 2009:400. (Publicity and Privacy Act).
- Lag (SFS 2016:319) och förordning (SFS 2016:320) om skydd för geografisk information. (Act and Regulation on the Protection of Geographic Information).
- Säkerhetsskyddslagen (SFS 1996:627) och säkerhetsskydds-förordningen, SFS 1996:633. (Security Act and Security Regulation).
- Skyddslagen (SFS 2010:305) och skyddsförordningen (SFS 2010:523). (Protection Act and Protective Regulation).

1.9 EU directive Inspire

The Geographical Environmental Information Act and Regulation regulate the Swedish implementation of the EU Directive [Inspire](#).

The act (SFS 2010: 1767) aims to establish a coherent infrastructure, which makes it easier to access and exchange digital geodata. The infrastructure shall include geodata that are useful for activities/ actions that affect health or the environment.

The regulation (SFS 2010: 1770) outlines the information responsibility of the organizations. Lantmäteriet has the task of coordinating the Swedish infrastructure for access to and exchange of geodata.

The act requires that responsible organizations make geodata and geodata services available to all.

1.10 Published documents

Current HMK documents, at the time of writing, are presented in Table 1.6.

Tabell 1.6. Current HMK documents (November 2018) with English translation.

Current HMK document	English translation
HMK - Introduktion 2017	HMK - Introduction 2017
HMK - Flygfotografering 2017	HMK - Aerial photography 2017
HMK - Flygburen laserskanning 2017	HMK - Airborne laser scanning 2017
HMK - Fordonsburen laserskanning 2017	HMK - Mobile laser scanning 2017
HMK - Terrester laserskanning 2017 (publiceringen försenad)	HMK - Terrestrial laser scanning 2017 (publication delayed)
HMK - Höjddata 2017	HMK - Elevation data 2017
HMK - Ortofoto 2017	HMK - Orthophoto 2017
HMK - Fotogrammetrisk detaljmätning 2017	HMK - Photogrammetric detail surveying 2017
HMK - Geodatakvalitet 2017	HMK - Geodata quality 2017
HMK - Ordlista och förkortningar, <mån> <årtal> (senaste version gäller, se hemsidan www.lantmateriet.se/hmk)	HMK - Glossary and abbreviations, <month> <year> (latest version applies, see website www.lantmateriet.se/hmk)
HMK - Geodetisk infrastruktur 2017	HMK - Geodetic infrastructure 2017
HMK - GNSS-baserad detaljmätning 2017	HMK - GNSS-based detail surveying 2017
HMK - Terrester detaljmätning 2017	HMK - Terrestrial detail surveying 2017
HMK - Stommätning 2017	HMK - Control surveying 2017
HMK - Kravställning vid geodetisk mätning 2017	HMK - Requirements for geodetic surveying 2017

The documents that are valid at any given time are continuously reported on the website www.Lantmateriet.se/HMK. For any adjustments of the documents between the major, usually annual revisions, see [HMK-Nytt](#).

Please note that a document can be included as a basis – and therefore valid – in an ongoing procurement, even though newer versions have been published.

2 HMK – Flygburen laserskanning 2017 (HMK – Airborne laser scanning 2017)

2.1 General description

[HMK – Flygburen laserskanning 2017](#) (HMK – Airborne laser scanning 2017) deals with the establishment of a technical specification for the procurement of georeferenced laser point clouds and how these are produced, checked and documented. The focus is on airborne acquisition of laser data with a laser scanner system georeferenced by GNSS/INS. It shall be possible to use the point cloud for developing elevation models and for mapping.

The document supports:

- establishment of a technical specification (Chapter 2 and Appendix A), see [HMK – Introduktion 2017](#) (HMK - Introduction 2017), Section 2.1
- implementation of an airborne laser data acquisition project (Chapter 3 and Appendix B)
- check of delivery (Chapter 4 and Appendix C).

The following HMK standard levels are covered, see [HMK – Geodata-kvalitet 2017](#) (HMK - Geodata quality 2017), Section 2.6.

- HMK standard level 1: National/regional surveying and mapping for overall planning and documentation.
- HMK standard level 2: Surveying and mapping of urban areas for municipal detailed planning and documentation.
- HMK standard level 3: Project-oriented surveying and mapping for design and construction.

Issues of procurement, permits and confidentiality are dealt with in [HMK – Introduktion 2017](#) (HMK – Introduction 2017), Chapter 3. Technical terms and abbreviations are explained in [HMK-Ordlista](#) (HMK-Glossary), latest version. Document structure and references are explained in [HMK – Introduktion 2017](#) (HMK – Introduction 2017), Section 1.7.

Limitations

Laser scanning for bathymetric mapping of deep conditions is not discussed in [HMK – Flygburen laserskanning 2017](#) (HMK – Airborne laser scanning 2017), nor photogrammetrically determined point clouds. Data acquisition with mobile systems is described in [HMK – Fordonsburen laserskanning 2017](#) (HMK – Mobile laser scanning 2017) and terrestrial scanning in [HMK – Terrester laserskanning 2017](#) (HMK – Terrestrial laser scanning 2017). Concerns regarding derivations, formulas, etc. are referred to Chapter 5: *References*.

2.2 Positional uncertainty and HMK standard levels

In HMK, the basic assumption is that geodata is *geo referenced*, that is, linked to an official reference system. In Sweden, this usually means that coordinates and heights are specified in the national systems SWEREF99 and RH2000 respectively.

Requirements for positional uncertainty in Table 2.2 refer to “absolute” uncertainty in these or other official reference systems.

Table 2.2. Compilation of parameters per HMK standard level for airborne laser scanning. Identical to Table 2.3.1 in HMK – Flygburen laserskanning 2017 (HMK – Airborne laser scanning 2017).

Parameters	HMK standard level 1	HMK standard level 2	HMK standard level 3
Point density, airborne laser scanning (points/m ²) ^{I)}	0.5-2	6-12	20-30
Positional uncertainty, ideal conditions Horiz./Vert. (m) ^{II)}	0.30/0.10	0.15/0.05	0.05/0.02
Maximum scanning angle (degrees) ^{III)}	± 20°	± 20°	-

^{I)} For a definition of point density in laser data for airborne acquisition, see Section 2.3.2. The interval refers to a span within which the value of point density usually lies. The customer chooses a value for their purpose.

^{II)} Positional uncertainty refers to horizontal (planimetric) standard uncertainty for well-defined objects and to vertical standard uncertainty for flat, well-defined surfaces. The specified parameter value can be seen as a rule of thumb. Other values may be selected by the customer but these should not exceed the table values, see recommendation in Section 2.3.3.

^{III)} Commonly occurring values, see recommendation in Section 2.3.4.

N.B. The references above refer to Chapter 2 in HMK – Flygburen laserskanning 2017 (HMK – Airborne laser scanning 2017).

3 Use of this document

Disclaimer

The information provided in this document is intended for general information purposes only. Lantmäteriet accepts no responsibility or liability regarding the information.

Only Swedish editions of HMK shall be regarded as authentic.

The customer is always responsible for the information that is part of a procurement. This also applies to any errors, imperfections or other shortcomings in the HMK documents that the customer chooses to use, and Lantmäteriet accepts no responsibility or liability regarding the information in these documents.

The current document is a shortened, English translation of the Swedish original document [HMK - Flygburen laserskanning 2017](#) (HMK - Airborne laser scanning 2017). It is only intended as a service for HMK users whose native language is not Swedish. In cases where differences between the Swedish and English document versions are discovered, the Swedish HMK edition shall be regarded as authentic (master document) and shall take precedence.

4 References

The numbering of references refers to the Swedish document [HMK – Flygburen laserskanning 2017](#) (HMK – Airborne laser scanning 2017).

- [1] Trafikverket (2012): [NNH i Trafikverket](#) (*Use of the New National Elevation Model within the Swedish Transport Administration*), Report 2012:198).
- [2] SIS, Swedish Standards Institute (2016): [Byggmätning – Specifikationer vid framställning och kontroll av digitala markmodeller](#) (*Building surveying – Specifications for the production and control of digital terrain models*). Technical specification SIS-TS 21144:2016.
- [3] Rönnerberg, A. (2011): [Höjdmodellens noggrannhet](#) (*The accuracy of the elevation model*). Lantmäteriet, PM - Ny Nationell Höjdmodell (New National Elevation Model), 2011-04-06).
- [4] Persson, C-G et.al. (2014): [Kontroll av lägesosäkerheten i laserdata](#) (*Control of the positional uncertainty in laser data*). HMK, Technical report 2014:1.
- [5] Svensk geoprocess: [Geodataspecifikation "Höjd"](#) (*Swedish geoprocess, geodata specification "Height"*). Current version with XML/GML schemas, instructions for data acquisition etc. is available on the [Swedish geoprocess website](#).
- [6] [ASPRS LAS file format](#). Available, in different versions, on the [ASPRS website](#).
- [7] [Nationell metadataprofil – Specifikation och vägledning](#) (*National metadata profile - Specification and guidance*), SS-EN ISO 19115:2005-geodata.se. Current version, instructions etc. for publication on [Geodataportalen](#) (*Geodata portal*) can be found on [geodata.se](#).

The Norwegian Mapping Authority's website contains documents corresponding to those published by HMK and Swedish geoprocess:

- The website [Standarder for geografisk informasjon](#) (*Geographic information standards*) includes the latest version of *Produksjon av basis geodata* (*Production of basic geodata*).
- The website [SOSI del 3 Produktspesifikasjoner](#) (*SOSI part 3, Product specifications*) includes the latest version of the data product specification *Nasjonalt modell for høydedata fra laserskanning, FKB-Laser* (*National elevation model from laser scanning, FKB-Laser*).

Appendix A: Template and examples for establishing technical specifications

The text in Appendix A.1–A.5 is an English translation of the Swedish original. In case there are any differences between the Swedish and English text, the Swedish version shall take precedence, see Chapter 3.

Appendix A.1 Technical specification template

0 Technical specification

Implementation shall be made according to this technical specification. Explanation of requirements and definitions of terms can be found in [HMK - Flygburen laserskanning 2017](#) (HMK - Airborne laser scanning 2017) and [HMK-Ordlista](#) (HMK-Glossary), latest version.

1 General description (HMK - Flygburen laserskanning 2017, Section 2.1)

Required services:.....

Required products:.....

Planned use of products:

2 Specification of existing source material (HMK - Flygburen laserskanning 2017, Section 2.2)

Mapping area, including format and reference system:.....

Other source material, including their characteristics:.....

3 Product specifications (HMK - Flygburen laserskanning 2017, Section 2.3)

Requirements for HMK standard level:

Requirements for point density:

Requirements for horizontal and vertical standard uncertainty:.....

Requirements for scanning angle:.....

Requirements for data acquisition period:.....

Requirements for subsequent products:.....

Requirements for supplementary specifications: (*e.g. requirements for overlap and cross strips, flight direction, repetitive data acquisition, check points, ground control points/objects, simultaneous image acquisition, waveform*):.....

4 Specification of delivery (HMK - Flygburen laserskanning 2017, Section 2.4)

Reference systems

Requirements for horizontal reference system:.....

Requirements for vertical reference system:.....

Flight and ground control plan

Format requirements:.....

Naming requirements:.....

Ground control

Format requirements:.....

Naming requirements:.....

Laser data

Format requirements, and version if any.....

Requirements for data compression:.....

Requirements for geographical division and index system:.....

Naming requirements:.....

Position and orientation data (GNSS/INS)

Format requirements:.....

Naming requirements:.....

Additional requirements for information content:.....

Production documentation

Additional requirements for production documentation:

Meta data

Content requirements:.....

Format requirements:.....

Additional specifications of delivery

Requirements for additional specification of the product (*e.g. sample and partial deliveries, delivery media and catalogue structure, handling of raw data*):

5 Specification of implementation (HMK – Flygburen laserskanning 2017, Chapter 3)

Requirements 3 a-b in HMK – Flygburen laserskanning 2017 applies

Recommendation 3 c in HMK – Flygburen laserskanning 2017 applies

Requirements 3.1.1 a-c in HMK – Flygburen laserskanning 2017 applies

Recommendations 3.1.1 d-g in HMK – Flygburen laserskanning 2017 applies

Requirement 3.1.1 h in HMK – Flygburen laserskanning 2017 applies

Requirements 3.1.2 a-c in HMK – Flygburen laserskanning 2017 applies

Requirements 3.1.3 a-h in HMK – Flygburen laserskanning 2017 applies

Requirements 3.2 a-j in HMK – Flygburen laserskanning 2017 applies

Requirements 3.2.1 a-e in HMK – Flygburen laserskanning 2017 applies

Requirements 3.3.1 a-e in HMK – Flygburen laserskanning 2017 applies

Recommendation 3.3.2 a in HMK – Flygburen laserskanning 2017 applies

Requirements 3.3.3 a-e in HMK – Flygburen laserskanning 2017 applies

Requirements 3.3.4 a-j in HMK – Flygburen laserskanning 2017 applies

Comments on the template:

- Section 5 of the template gives references to the requirements in [HMK - Flygburen laserskanning 2017](#) (HMK - Airborne laser scanning 2017), Chapter 3, *Genomförande (Implementation)*, which shall apply.
- The list in section 5 of the template contains all requirements and recommendations in Chapter 3. Not applicable requirements shall be removed by the customer when using the template.
- See [HMK - Introduktion 2017](#) (HMK - Introduction 2017), Section 1.7, for principles regarding references to requirements as well as examples of how referrals, deviations and additions can be phrased.

Appendix A.2 Example of a completed template for Lantmäteriet

0 Technical specification

Implementation shall be made according to this technical specification. Explanations of requirements and definitions of terms can be found in [HMK – Flygburen laserskanning 2017](#) (HMK – Airborne laser scanning 2017) and [HMK-Ordlista](#) (HMK-Glossary), latest version.

1 General description

(HMK – Flygburen laserskanning 2017, avsnitt 2.1)

Required services: *Planning and implementation of laser scanning and possible supplementary survey of ground control, as well as geo-referencing, classification and quality control of collected laser data. The goal is to scan about 70 000 km² per year over a five-year period.*

Required products: *Classified laser point clouds including ephemeris, meta data, and any additional ground control.*

Planned use of products: *Update of the National Elevation Model (NH), forestry analysis by Skogsstyrelsen (Swedish Forest Agency) and for other unspecified purposes.*

2 Specification of existing source material

(HMK – Flygburen laserskanning 2017, Section 2.2)

Mapping area, including format and reference system: *Delimitations and names of all scanning areas (usually 50 X 25 km). Minor adjustments in the form of mergers or divisions are possible, by agreement with Lantmäteriet*

Other source material, including their characteristics: *Lantmäteriet provides source materials to support implementation of the mission.*

- *2.5 index squares in Sweref99 TM. The index squares are available on Lantmäteriet's website.*
- *Complete, surveyed points/objects for ground control and checking.*
- *Public maps and orthophotos, primarily via WMS.*
- *Elevation model (NH), primarily via WCS*
- *GSD-Höjddata (Elevation data), Grid 50+. Available as open data via Lantmäteriet's website.*
- *A selection of vector information from GSD-Fastighetskartan (Property map), such as water surfaces, buildings and roads.*
- *List of the coordinates and heights of SWEPOS permanent reference stations – and other Sweref points, if any.*

- Current geoid model, for the moment SWEN08_RH2000. Available via Lantmäteriet's website.
- If required, SWEPOS data for postprocessing of GNSS positions.

Data format by agreement. Reference systems: Sweref99 TM and RH2000.

3 Product specifications (HMK – Flygburen laserskanning 2017, Section 2.3)

Requirements for HMK standard level: *Standard level 1*

Requirements for point density: *1 point/ m²*

Requirements for horizontal and vertical standard uncertainty: *0,3/0,1 m*

Requirements for scanning angle: *The entire scanning area shall be covered by laser data with a maximum scan angle of 20°.*

Requirements for data acquisition period: *In the southern part of the country, scanning shall only take place during the leaf-free season (see attachment with map showing borders). Throughout the country, scanning during the birch's leafing or defoliation shall be avoided.*

Requirements for subsequent products: *Requirements for classification of land, water and unclassified – according to a separate specification prepared using HMK-Höjddata 2017 (HMK Elevation data 2017).*

Requirements for supplementary specifications

- *The laser beam's diameter on the ground (footprint) shall be less than 0.75 m, measured as $1 / e^2$.*
- *The planned flight line overlap shall be at least 10% at 40° opening angle.*
- *The planned coverage shall be at least 200 m outside the respective scanning area.*

4 Specification of delivery (HMK – Flygburen laserskanning 2017, Section 2.4)

Reference systems

Requirements for horizontal reference system: *All work shall be reported in Sweref99 TM*

Requirements for vertical reference system: *All work shall be reported in RH 2000*

Flight and ground control plan

Format requirements: *PDF and ESRI shape*

Naming requirements: *According to 18A001_plan.pdf, where 18A001 refers to the scanning area.*

Other requirements: The layout, in PDF format, shall include a map and clearly state the most important conditions:

- Equipment
- Scanning parameters
- Number and location of regular strips and cross strips
- Placement of ground control and check points, in plane and height respectively

Planning for each scanning area shall be approved by Lantmäteriet before scanning begins

Ground control

Format requirements: ASCII file

Naming requirements: Determined in consultation with Lantmäteriet

Other requirements:

Regarding ground control objects:

- The contents of the ASCII file shall be: Identity of ground control objects, and run numbers for surveyed points within the object, N, E, H, estimated measurement uncertainty (3D), surveying date, and "detaljtyp" (detail type)
- Each recorded ground control object shall be accompanied by a photo in JPEG format that clearly shows the position of the object in the terrain
- Any additional ground control object shall be included in the delivery of each affected scanning area. The objects may be surveyed using GNSS/SWEPOS or be based on information from the national elevation model (NH)

Laser data

Format requirements, and version if any: ASPRS LAS, version 1.4, point data record format 6.

Requirements for data compression: The files shall be compressed with Lzip and will thus have the file extension .LAZ. Requirements for data formats and compression may change over time

Requirements for geographic division and index system: The files shall include 2.5x2.5-km squares in the national index system of Sweref99TM.

Naming requirements: According to 18A001_61325_3875_25.las where 18A001 relates to the scanning area and 61325_3875_25 relates to the 2.5 km index square in SWEREF 99 TM. The first two-digit groups indicate the coordinates of the square (N and E) into the 100's of meters for the southwest corner.

Position and orientation data (GNSS/INS)

Format requirements: Terrasolid TRJ.

Naming requirements: According to 18A001_00001.trj, where 18A001 refers to the scanning area and 00001 to Point Source ID. Cross strips are named according to 18A001_00001_cross.trj

Additional requirements for information content: -

Production documentation

The report shall be in accordance with Appendix. Reports are delivered in PDF format and are named according to 18A001_leveransrapport.pdf, where 18A001 refers to the scanning area.

Additional requirements for production documentation: -

Meta data

Content requirements: The following shall apply for each scanning area:

- Meta data for flight sessions is delivered as a table, see attachment for content.
- Map of deviations in height between flight line overlap zones is delivered according to HMK – Flygburen laserskanning 2017 (HMK – Airborne laser scanning 2017), Tabell 2.4.7.a.
- Map of point density for last and only return is delivered according to HMK – Flygburen laserskanning 2017 (HMK – Airborne laser scanning 2017), Table 2.4.7.b

Format requirements: A flight session meta data table shall be delivered in text format (ASCII), meta data in map format shall be delivered in TIFF format (+ control file TFW) with 5x5 meter resolution

Additional specifications of delivery

Requirements for catalogue structure: The file structure is determined in consultation with Lantmäteriet.

Requirements for delivery media: Lantmäteriet provides the hard drives that shall be used for delivery

Requirements for handling of raw data: After completion of the assignment, at the latest, complete raw data shall be submitted for archiving. This applies to both GNSS / INS data and laser data, in original format.

5 Specification of implementation (HMK – Flygburen laserskanning 2017, Chapter 3)

Requirements 3 a-b in HMK – Flygburen laserskanning 2017 applies
Recommendation 3 c in HMK – Flygburen laserskanning 2017 applies as a requirement

Requirements 3.1.1 a-c in HMK – Flygburen laserskanning 2017 applies
Recommendations 3.1.1 d-g in HMK – Flygburen laserskanning 2017 applies
Requirement 3.1.1 h in HMK – Flygburen laserskanning 2017 applies
Requirements 3.1.2 a-c in HMK – Flygburen laserskanning 2017 applies
Requirements 3.1.3 a-g in HMK – Flygburen laserskanning 2017 applies
Requirements 3.2 a-j in HMK – Flygburen laserskanning 2017 applies
Requirements 3.2.1 a-d in HMK – Flygburen laserskanning 2017 applies
Requirements 3.3.1 a-e in HMK – Flygburen laserskanning 2017 applies
Recommendation 3.3.2 a in HMK – Flygburen laserskanning 2017 applies
Requirements 3.3.3 a-e in HMK – Flygburen laserskanning 2017 applies
Requirements 3.3.4 a-g and i-j in HMK – Flygburen laserskanning 2017 applies

Comment on the example:

- The annexes with a map showing the borders for leaf-free data acquisition periods, content in the production documentation, and flight session meta data are not included this example.
- Requirements 3.1.3 h), 3.2.1 e) and 3.3.4 h) are removed because the customer refers to his own attachment for content in the production documentation.
- The requirements for the subsequent product *classified point cloud* are not included in the example. For the formulation of requirements, see [HMK – Höjddata 2017](#) (HMK - Elevation data 2017).

Appendix A.3 Example of a completed template for a municipality

0 Technical specification

Implementation shall be made according to this technical specification. Explanations of requirements and definitions of terms can be found in [HMK – Flygburen laserskanning 2017](#) (HMK – Airborne laser scanning 2017) and [HMK-Ordlista](#) (HMK-Glossary), latest version.

1 General description (HMK – Flygburen laserskanning 2017, Section 2.1)

Required services: *The specification includes planning, laser scanning, georeferencing, and classification of laser point clouds. The customer carries out surveying and calculation of ground control.*

Required products: *Classified laser point cloud*

Planned use of products: *Laser data will be used as a basis for the production of a terrain model and building models. The terrain model will be used as a basis for the municipality's elevation model.*

2 Specification of existing source material (HMK – Flygburen laserskanning 2017, Section 2.2)

Mapping area, including format and reference system: *This includes area limitation in the form of an image (jpeg) with map background as well as area delimitation in the form of a Mapinfo file (tab). Provided in Sweref99 1200.*

Other source material, including their characteristics: *If desired, break lines could be provided in the form of dwg files from primärkartan (base map), to refine elevation model and filtering. For example, stereo mapped roadsides, bridges and roof details are available. Provided in Sweref99 1200 and RH2000*

3 Product specifications (HMK – Flygburen laserskanning 2017, Section 2.3)

Requirements for HMK standard level: *Standard level 2*

Requirements for point density: *10 points/ m²*

Requirements for horizontal and vertical standard uncertainty:
0,15/0,05 m

Requirements for scanning angle: *20 degrees*

Requirements for data acquisition period: *Spring season (leaf-free trees and snow-free ground)*

Requirements for subsequent products: *Requirements for classification of land, water, bridges and "unclassified" according to a special specification, developed using HMK-Höjddata 2017 (HMK Elevation data 2017).*

Requirements for supplementary specifications: -

4 Specification of delivery (HMK – Flygburen laserskanning 2017, Section 2.4)

Reference systems

Requirements for horizontal reference system: *All material shall be delivered in the reference system Sweref99, projection zone 1800*

Requirements for vertical reference system: *RH 2000*

Other requirements: *The geoid model SWEN 08 shall be used for calculation of heights.*

Flight and ground control plan

Format requirements: *ESRI-shape or KML*

Naming requirements: *As agreed upon signing*

Other requirements: *The supplier shall establish a flight and ground control plan in consultation with the customer. The number, location and design of the ground control are reported in the signalling plan. This plan shall be delivered to the customer no later than three weeks before scheduled flight.*

Ground control

Format requirements: *ASCII file*

Naming requirements: *As agreed upon signing*

Other requirements: *The customer surveys horizontal and vertical ground control points/objects for georeferencing according to the agreed signalling plan.*

Laser data

Format requirements, and version if any: *LAS, version 1.2*

Requirements for data compression: -

Requirements for geographical division and index system: *As agreed upon signing*

Naming requirements: *As agreed upon signing*

Position and orientation data (GNSS/INS)

Format requirements: *By agreement*

Naming requirements: *By agreement*

Additional requirements for information content: -

Production documentation

Additional requirements for production documentation: -

Meta data

Content requirements: Deviations in height between strip overlap zones shall be delivered according to Table 2.4.7.a. Point density map for last and only return shall be delivered according to Table 2.4.7.b.

Format requirements: Point density maps and deviations in height between strips shall be delivered as a georeferenced tiff image with 2.5x2.5-meter resolution.

Additional specifications of delivery

Requirements for delivery media: USB 3.0 hard drive

Requirements for handling of raw data: The supplier shall keep raw data, i.e. unprocessed point cloud and orientation data, for four years from the photography date.

5 Specification of implementation (HMK – Flygburen laserskanning 2017, Chapter 3)

Requirements 3 a-b in HMK – Flygburen laserskanning 2017 applies

Recommendation 3 c in HMK – Flygburen laserskanning 2017 applies

Requirements 3.1.1 a-c in HMK – Flygburen laserskanning 2017 applies

Recommendations 3.1.1 d-g in HMK – Flygburen laserskanning 2017 applies

Requirement 3.1.1 h in HMK – Flygburen laserskanning 2017 applies

Requirements 3.1.2 a-c in HMK – Flygburen laserskanning 2017 applies

Requirements 3.1.3 a-h in HMK – Flygburen laserskanning 2017 applies

Requirements 3.3.1 a-e in HMK – Flygburen laserskanning 2017 applies

Recommendation 3.3.2 a in HMK – Flygburen laserskanning 2017 applies

Requirements 3.3.3 a-e in HMK – Flygburen laserskanning 2017 applies

Requirements 3.3.4 a-j in HMK – Flygburen laserskanning 2017 applies

Comment on the example:

- Requirements 3.2 and 3.2.1 are not included in the example because the customer performs signalling, surveying and calculation of ground control objects on their own.
- The requirements for the subsequent *classified point cloud* are not included in the example. For the formulation of requirements see [HMK – Höjddata 2017](#) (HMK - Elevation data 2017).

Appendix A.4 Example of a completed template for the Swedish Transport Administration

0 Technical specification

Implementation shall be made according to this technical specification. Explanations of requirements and definitions of terms can be found in [HMK – Flygburen laserskanning 2017](#) (HMK – Airborne laser scanning 2017) and [HMK-Ordlista](#) (HMK-Glossary), latest version.

1 General description (HMK – Flygburen laserskanning 2017, Section 2.1)

Required services: *The specification covers planning and implementation of simultaneous laser scanning and aerial photography, including surveying and calculation of ground control objects.*

Required products: *Laser point cloud*

Planned use of products: *Laser data will be used in the production of a terrain model and ortho photos, as a basis for development of a road plan.*

2 Specification of existing source material (HMK – Flygburen laserskanning 2017, Section 2.2)

Mapping area, including format and reference system: *Current mapping area (KML file) is provided in Sweref99, projection zone 1800*

Other source material, including their characteristics: *The Swedish Transport Administration could provide the following materials digitally, for the planning and implementation of laser scanning:*

- *Horizontal and vertical control points*
- *GSD-Terrängkartan (terrain map) in raster format with the national road network*
- *GSD-Fastighetskartan (property map) in shape and DWG format*

Provided in Sweref99, projection zone 1800 and RH 2000.

3 Product specifications (HMK – Flygburen laserskanning 2017, Section 2.3)

Requirements for HMK standard level: *Standard level 3*

Requirements for point density: *20 points/m²*

Requirements for horizontal and vertical standard uncertainty: *0,02/0,02 m*

Requirements for scanning angle: *-*

Requirements for data acquisition period: *Spring season (leaf-free trees and snow-free ground)*

Requirements for subsequent products: Requirements for classification of point clouds as well as development of elevation model and ortho photos according to separate specification, developed with the use of HMK-Höjd-data 2017 (HMK Elevation data 2017) and HMK-Ortofoto 2017 (HMK Ortho photo 2017), respectively.

Requirements for supplementary specifications: Simultaneous aerial photography shall be performed according to a special specification, developed with the use of HMK-Flygfotografering 2017 (HMK Aerial photography 2017).

4 Specification of delivery (HMK – Flygburen laserskanning 2017, Section 2.4)

Reference systems

Requirements for horizontal reference system: All material shall be delivered in the horizontal reference system Sweref99, projection zone 1800

Requirements for vertical reference system: RH 2000

Flight and ground control plan

Format requirements: KML

Naming requirements: As agreed upon signing

Ground control

Format requirements: ASCII file

Naming requirements: As agreed upon signing

Laser data

Format requirements, and version if any: LAS, version 1.4

Requirements for data compression: -

Requirements for geographical division and index system: As agreed upon signing

Naming requirements: As agreed upon signing

Position and orientation data (GNSS/INS)

Format requirements: -

Naming requirements: -

Additional requirements for information content: -

Production documentation

Additional requirements for production documentation: -

Meta data

Content requirements: Deviations in height between flight line overlap zones shall be delivered according to Table 2.4.7.a. Point density map for last and only return shall be delivered according to Table 2.4.7.b.

Format requirements: Deviations in height between strips and point density maps shall be delivered as georeferenced tiff images with 2x2-meter resolution.

Additional specifications of delivery

Requirements for delivery media: USB 3.0 hard drive

Requirements for handling of raw data: The supplier shall keep raw data, i.e. unprocessed images and orientation data, for four years from the photography date.

Other requirements: Aerial photos, orthophotos and elevation models shall be delivered according to special specifications.

5 Specification of implementation (HMK – Flygburen laserskanning 2017, Chapter 3)

Requirements 3 a-b in HMK – Flygburen laserskanning 2017 applies
Recommendation 3 c in HMK – Flygburen laserskanning 2017 applies
Requirements 3.1.1 a-c in HMK – Flygburen laserskanning 2017 applies
Recommendations 3.1.1 d-g in HMK – Flygburen laserskanning 2017 applies
Requirement 3.1.1 h in HMK – Flygburen laserskanning 2017 applies
Requirements 3.1.2 a-c in HMK – Flygburen laserskanning 2017 applies
Requirements 3.1.3 a-h in HMK – Flygburen laserskanning 2017 applies
Requirements 3.2 a-j in HMK – Flygburen laserskanning 2017 applies
Requirements 3.2.1 a-e in HMK – Flygburen laserskanning 2017 applies
Requirements 3.3.1 a-e in HMK – Flygburen laserskanning 2017 applies
Recommendation 3.3.2 a in HMK – Flygburen laserskanning 2017 applies
Requirements 3.3.3 a-e in HMK – Flygburen laserskanning 2017 applies
Requirements 3.3.4 a-j in HMK – Flygburen laserskanning 2017 applies

Comment on the example:

- Requirements for aerial photography, elevation models and ortho photos are not included in the example. For the formulation of requirements, see [HMK – Flygfotografering 2017](#) (HMK – Aerial photography 2017), [HMK – Höjddata 2017](#) (HMK – Elevation data 2017), and [HMK – Ortofoto 2017](#) (HMK – Ortho photo 2017), respectively.

Appendix A.5 List of requirements

This appendix contains all the requirements and recommendations in Chapter 3 of [HMK - Flygburen laserskanning 2017](#) (HMK - Airborne laser scanning 2017). The numbering refers to sections in the corresponding chapter.

3 Implementation

Requirements

- a) The supplier shall be responsible for quality assurance of the production and for the material delivered to be quality controlled and complete according to the customer's specification.
- b) All collected material shall be checked continuously during the acquisition, so that any deficiencies can be identified early and corrected.

Recommendation

- c) A quality plan should be established.

3.1 Planning of data acquisition

3.1.1 Selection of flying altitude and strip planning

Requirements

When selecting flying altitude and during strip planning:

- a) requirements for point density for last or only return shall be met in all parts of the mapping area
- b) consideration shall be given to hilly terrain and high objects, such as buildings or trees, to ensure that all objects are depicted
- c) overlap between strips shall be at least 10%, unless otherwise specified by the customer.

Recommendations

Cross strips should be

- d) placed at both ends of the mapping area and, for larger areas, even inside the area
- e) placed at right angles to the flight direction
- f) placed above ground control objects
- g) avoided in areas with water surfaces.

Requirement

Repetitive data acquisition may not:

- h) be made to increase the point density.

3.1.2 Planning of ground control

Requirements

Ground control objects shall be:

- a) adjusted in number according to the final product's expected measurement uncertainty and the size of the mapping area
- b) distributed evenly but in particular in strip crossings, the corners, the outer edge and the centre of the mapping area, to obtain good controllability (Figure 3.1.2)
- c) adapted in shape and size to be interpreted and measured in the point cloud.

3.1.3 Delivery

Requirements

Delivery of the flight plan shall be:

- a) quality controlled and complete
- b) made in the form of a file of the planned strips, with their names and positions; coordinate and height values are reported in meters
- c) made in the file format and with the naming specified by the customer.

Delivery of the planned ground control objects shall:

- d) be quality controlled and complete
- e) contain the name and position of planned objects; coordinate and height values are reported in meters
- f) be made in the file format and with the naming specified by the customer.

Delivery of production documentation shall:

- g) be quality controlled and complete
- h) consist of the report referred to in paragraph a) of Appendix B.1 *Stråk- och stödplanering (Flight and ground control planning)*, unless otherwise specified by the customer.

3.2 Signalling and surveying of ground control objects

Requirements

Signalling and surveying of ground control objects shall:

- a) take place in close connection to the data acquisition to ensure actuality.

Ground control objects:

- b) shall have good contrast against the surrounding ground and be free from vegetation and other obtruding objects
- c) for height control, shall be designed as a horizontal point grid with a maximum of 10% inclination
- d) for height control, shall normally have an extension of at least 5×5 points, or the equivalent for a non-square area.
- e) for horizontal control, shall be designed as clear profiles in several directions
- f) shall be at least two per location if height profiles, roof sections or road markings in the form of solid lines are used.

The points within a ground control object (point grid) shall:

- g) have a mutual distance that is about twice as compared to the average point distance in the laser scanning
- h) be evenly distributed over the surface so that the terrain is described in the best way.

Surveying of ground control objects shall be made with:

- i) a standard uncertainty, including the positional uncertainty of reference points, which does not exceed $1/3$ of the standard uncertainty in the final product – according to the technical specification
- j) an appropriate geodetic measurement method according to [HMK – Kravställning vid geodetisk mätning 2017](#) (HMK – Requirements for geodetic surveying 2017), Chapter 3; surveying of painted road lines may require a special measuring instruction.

3.2.1 Delivery

Requirements

Delivery of ground control shall:

- a) be quality controlled and complete

- b) be in the form of a file containing the name and position of the ground control objects; coordinate and height values are reported in meters to three decimal places
- c) be made in the file format and with the naming specified by the customer.

Delivery of production documentation shall:

- d) be quality controlled and complete
- e) consist of the report referred to in paragraph a), and a list according to paragraph b), of Appendix B.2 *Signalering och inmätning av markstöd (Signaling and surveying of ground control)*, unless otherwise specified by the customer.

3.3 Acquisition of laser and GNSS/INS data and calculation of point cloud

3.3.1 Laser scanning

Requirements

- a) Calibration certificate for the laser scanner shall upon request be presented to the customer.
- b) A laser scanner shall be able to record multiple returns from a transmitted laser pulse, including the intensity (amplitude) of the respective return.

Scanning parameters shall be selected so that:

- c) similar point distances are obtained along and across the acquisition path
- d) individual maximum values do not exceed the double point range
- e) the selected point density is obtained in at least 95% of the scanned area, measured in number of squares, excluding water areas (Table 3.3.1).

3.3.2 Calculation of orientation data from GNSS/INS data

Recommendation

- a) GNSS/INS data should be calculated according to [HMK - Geodetisk infrastruktur 2017](#) (HMK - Geodetic infrastructure 2017), Appendix B.6.3.

3.3.3 Calculation of point cloud

Requirements

- a) System-dependent corrections shall be performed and reported according to the system vendor's recommendations.
- b) Strip adjustment shall be performed in such a way that remaining errors are minimized.
- c) Deviations in the overlap zones – before and after strip adjustment – shall be reported numerically and graphically.
- d) Fitting on horizontal and vertical ground control objects – in the specified reference systems – shall be performed in such a way that deviations are minimized.
- e) The results from this fitting shall be reported.

3.3.4 Delivery

Requirements

Delivery of laser data shall:

- a) be quality controlled and complete
- b) have coordinates and height values reported in meters, with the number of decimals based on the positional uncertainty of the final product ^{D)}
- c) be made in the file format and with the point density and naming specified by the customer.

Delivery of GNSS/INS data shall:

- d) be quality controlled and complete
- e) for all flight strips, be made in the form of a file containing the flight line ID, X_0 , Y_0 , Z_0 , ω , φ , κ and GPS time, as well as any other requirements for the content that has been specified by the customer; coordinate and height values (X_0 , Y_0 , Z_0) are reported in meters to three decimal places, image rotations (ω , φ , κ) in degrees to five decimal places and GPS time in seconds to four decimal places. ^{D)}
- f) be made in the file format and with the naming specified by the customer.

Delivery of production documentation shall:

- g) be quality controlled and complete

h) consist of the report referred to in paragraph a) of Appendix B.3 *Insamling av laser- och GNSS/INS-data och beräkning av punktmoln (Acquisition of laser and GNSS/INS data and calculation of point cloud)*, unless otherwise specified by the customer.

Delivery of any metadata shall:

- i) be quality controlled and complete
- j) be made in the file format and with the naming specified by the customer.

¹⁾ Read more in [HMK – Geodatakvalitet 2017](#), (HMK – Geodata quality 2017), Appendix A.8, on why you should be generous with the number of digits during the calculation process and not round off – to about one tenth of the positional uncertainty – until the final product.

Appendix B: Table of content, HMK – Flygburen laserskanning 2017 (the complete Swedish version)

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2 Technical specification

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- 2.2 Specification of existing source material
- 2.3 Specification of the product
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- 3.3 Acquisition of laser data and GNSS/INS data, including calculation of point cloud
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4 Customer's control

5 References/read more

Appendix A: Template and examples for establishing technical specifications

- Appendix A.1 Technical specification template
- Appendix A.2 Example of a completed template for Lantmäteriet
- Appendix A.3 Example of a completed template for a municipality
- Appendix A.4 Example of a completed template for the Swedish Transport Administration

Appendix B: Production documentation

- Appendix B.1 Flight and ground control planning
- Appendix B.2 Signalling and surveying of ground control
- Appendix B.3 Acquisition of laser and GNSS/INS data,
including calculation of point cloud

Appendix C: Control of laser data

- Appendix C.1 Complete delivery
- Appendix C.2 Product
- Appendix C.3 Detailed examination if required

Appendix C: Some comments regarding terminology

Here, some of the terms used in the document are commented. This is to clarify which terminological choices have been made and to avoid misunderstandings due to minor differences in the meaning of the words between the Swedish original text and the English translation.

Swedish	English	Comment
mätosäkerhet	measurement uncertainty	uncertainty in measurement, according to GUM (see Section 1.5); ISO uses the term <i>accuracy</i> instead of <i>uncertainty</i> in its 19100-standard series
lägesosäkerhet	positional uncertainty	an extension of GUM to uncertainty in positions; corresponds to the term <i>positional accuracy</i> used in the standard SS-EN ISO 19157:2013 <i>Geographic information – Data quality</i>
standardosäkerhet	standard uncertainty	the uncertainty measure applied in GUM, which corresponds to the term <i>standard deviation</i> in ISO 19157; older terms are <i>mean error</i> or <i>standard error</i> (Sw. <i>medelfel</i>)
beställare/utförare	customer/supplier	the two parties in a procurement, according to the standard SIS-ISO/TS 19158:2012 <i>Quality assurance of data supply</i> ; English synonyms are e.g. <i>client/provider</i>
insamlingsområde	mapping area	the term <i>insamlingsområde</i> in the Swedish HMK is translated into <i>mapping area</i> , even if it refers to a more general data acquisition, e.g. laser scanning
stompunkter	(geodetic) control points	points in a geodetic control network
stödpunkter	ground control (points/objects)	position-determined points on the ground used for connection to a reference system in, for example, aerial photography or laser scanning *)
kontrollpunkter	check points	independent, position-determined points for checking of such connections *)

*) can be 2- or 3-dimensional objects, not just points

The compilation is by no means complete, but clearly shows that parallel bilingual texts can sometimes be difficult to handle. To avoid disputes about what has been agreed, it is often appropriate to designate one of the languages as “main language” in a procurement, see Chapter 3.