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D 2.2 –Revised ontology-based approach

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Work package / Task:

WP2 – Developing and operationalizing a Body of Knowledge for GI and EO

T2.2 – Defining and fine-tuning an ontology-based approach for the BoK

Short Description:

This report provides an integrated analysis of the current BoK, including identification of concepts relevant to EO and Copernicus. Based on this, an overview will be given about the way the BoK will be set-up and maintained (including definition of concepts and relationships between them). Additionally the roles of experts, editors and administrators will be discussed, as well as a first look into potential tools.

Keywords:

BoK (Body of Knowledge), ontology-based approach, identification of working groups, update/maintenance procedures, concepts relevant to EO and Copernicus

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1.0	28/01/2019	Danny Vandenbroucke	Final Draft	Adding conclusions, check references and list of abbreviations
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1. Introduction

1.1. EO4GEO Project

EO4GEO is an Erasmus+ Sector Skills Alliance gathering 26 partners from 13 EU countries, most of which are part of the Copernicus Academy Network. Be they from academia, public or private sector, they are all active in the education and training fields of the space / geospatial sectors. The project is also supported by a strong group of Associated Partners mostly consisting of associations or networks active in space/geospatial ecosystem. The project started on January 1st, 2018, upon approval by the EU Education, Audiovisual and Culture Executive Agency (EACEA) and runs over four years.

EO4GEO aims to help bridging the skills gap in the space/geospatial sector by creating a strong alliance of players from the sector/community reinforcing the existing ecosystem and fostering the uptake and integration of space/geospatial data and services. EO4GEO will work in a multi- and interdisciplinary way and apply innovative solutions for its education and training actions including: case based and collaborative learning scenarios; learning-while-doing in a living lab environment; on-the-job training; the co-creation of knowledge, skills and competencies; etc. The specific objectives of EO4GEO are:

1) to define a long-term and sustainable strategy to fill the gap between supply of and demand for space/geospatial education and training taking into account the current and expected technological and non-technological developments in the space/geospatial and related sectors (e.g. ICT);

2) to define an ontology-based Body of Knowledge for the space/geospatial sector based on previous efforts by mobilizing an extended network of domain experts in a collaborative environment;

3) to develop and integrate a dynamic platform with associated tools that allows: a collaborative method for integrating new concepts (theories, methods, technologies …) and update existing concepts of a Body of Knowledge for GI (Geo-information) and EO (Earth Observation); the design of curricula for (academic and) VET; direct access, not only to the

training materials, but also to space and geospatial data, case-based learning scenario's, self-tests and other relevant materials;

4) to design and develop a series of curricula for different types of occupational profiles in the sector, making use of the Body of Knowledge and taking into account the identified needs, and to develop a rich portfolio of training modules directly usable in the context of Copernicus and other relevant programmes;

5) to design, develop and conduct a series of training actions for a selected set of scenario's for three sub-sectors - integrated applications, smart cities and climate change – supported by remote sensing and geospatial technology in order to test and validate the approach, the platform, the designed curricula and developed training modules;

6) to develop and endorse a long-term Action Plan based on the strategy developed and the experience gained in the implementation phase including: a Governance Model and Structure; a Business Plan to become financially sustainable; a plan for mainstreaming, promoting and multiplying the approach in other sub-sectors; and a plan to roll-out the technical solutions developed.

This document reports the result of the work carried out regarding task 2.2. (WP2)- Defining and fine-tuning an ontology-based approach for the BoK.

1.2. Task 2.2.: Outline, goals and structure of the document

The second work package of EO4GEO is focused on developing and operationalizing a Body of Knowledge (BoK) for GI and EO. In order to be able to design curricula and to further define the required skills for the space/geospatial sector, the domain has to be defined in terms of concepts to be covered. A concept can be anything: a theory, a method, a technology … In the context of an earlier project, GI-N2K (http://www.gi-n2k.eu/), a dynamic Body of Knowledge in the GI S&T domain was developed including concepts related to (recent) technological developments and reflecting a 'European' perspective. In this work package the aim is to build further on the outcomes of this project and refine the geospatial ontology behind it, and to extend what exist with relevant concepts from the Earth Observation (and Copernicus) domain (Task 2.3), which is only partly covered now (certain aspects of Remote Sensing). Also possible links to BoK's from other domains will be explored (Task 2.4). Fundamental for achieving this is to mobilize and extend a network of European and worldwide recognized experts (Task 2.1). This work package builds also further upon the output and outcomes of the first work package (WP1), such as the skill needs assessment (Task 1.4) and the technology and non-technology watch (Task 1.3). The BoK itself will then give input and forms the basis for the design of the curricula (WP4). The tools to be used for updating and maintaining the BoK is still open, so several options will be provided in order to start the work.

Task 2.2. for which this report provides the output, is more specifically focused on defining and fine-tuning the ontology-based approach for the BoK. The network of experts resulting from GI-N2K worked on the definition of the BoK for GI S&T. They were organised in 10 working groups related a specific knowledge area. In each work group an ontology-based approach was followed, meaning that the domain GI S&T was described by a series of 'concepts' and their relationships. Since the BoK should be and remain dynamic, updates and changes (as well as the addition of new concepts) should be done continuously. Therefore, Task 2.2. will further work on the exploration of mechanisms for improving the current method for defining and describing the ontology. In addition, different possible working groups have been identified to organise the work for the revision and extension of the BoK. Existing maintaining and updating procedures were revised, and the current version of the BoK has been assessed in view of its extension and revision to support Copernicus activities. Related to this, existing concepts relevant to Copernicus and EO in general were identified, and the way potential EO concepts fit in the existing ontology are discussed.

The methodology for establishing this report is specified in Section 2, while Section 3 focuses on the ontology-based approach. The content of the current version of the BoK is explored in Section 4. More insight in the procedures for developing and maintaining the BoK is given in Section 5. In Section 6 some conclusions, next steps and discussions are outlined.

2. Methodology

The development of the ontology-based approach is not new. It is largely based on work done in previous projects such as GI-N2K – Geographic Information Need to Know (Brox et al., 2015) which in turn was based on work of and collaboration with colleagues in the USA from BigKnowledge (Ahearn et al., 2013). The basic idea for EO4GEO is to apply the approach already developed in GI-N2K, to fine-tune it where necessary and feasible, and to improve the procedures for maintaining the BoK where required.

A step-wise approach was defined for revising the ontology-based approach and for fine-tuning the procedures:

Step 1 – Analyse the current ontology-based method for defining concepts in the Body of Knowledge, as well as its content;

Step 2 – Revise where necessary and feasible the procedures followed for developing the current BoK;

Step 3 – Identify the best way to set-up working groups to work on the content of the BoK and how to populate them with experts;

Step 4 – Identify the revision cycle(s): the way of working (in different levels of detail), the timing, etc.;

Step 5 – Identify, test and decide on the platforms and tools to be used for maintaining the BoK in a continuous way.

During the Kick-off meeting in Milan (January 2018), a presentation was given on the ontology-based approach applied in GI-N2K and a first discussion took place on how to set-up the Working Groups (from the technological perspective or from the applications perspective). This discussion was refined before and during the Castellon meetings (May-June 2018): the collaboration with colleagues from UCGIS (exchange of content and sharing of experts); different platforms and tools were demonstrated, explored and discussed. In Autumn the procedures, including the final set-up of the Working Groups were detailed and decided upon, and written down in this report.

3. Ontology-based approach for the BoK

In more general terms, an ontology refers to a set of concepts and categories in a subject area or domain that shows their properties and the relations between them[1]. In computer science and information science, an ontology includes the representation, formal naming, and definition of the categories, properties, and relations between concepts, data, and entities that makes up a domain. Nowadays each domain, including the space and geospatial domain, creates ontologies to limit complexity and organize information into data and knowledge (Budin, 2005). This might be done by creating a common vocabulary, taxonomy or 'language' in order to understand and communicate with each other. However, a common vocabulary is not enough. An ontology also expresses the relationships between concepts. In information science, the term knowledge graph is often used. A knowledge graph represents then a collection of related descriptions of entities whether these are real-world objects, events, situations or abstract concepts (Ehrlinger and Wöß, 2016).

In the geospatial domain, major efforts have been made to define an ontology specific to geographic information (Couclelis, 2010), or to represent a web-based ontology model for the GI S&T (Painho et al., 2007). More recently, more systematic work has been done to re-engineer the 'old' GI S&T Body of Knowledge (diBiase, 2006) using a computational ontology-based framework to define and manage concepts in the geospatial field (Ahearn et al., 2013). The idea behind was that the original Core Curricula and the Body of Knowledge were too hierarchical using three fixed levels: knowledge areas, units and topics. It was acknowledged that in reality more (different types of) relationships exist, and that at the same time its content, the knowledge and skills required are continuously evolving and therefore the Body of Knowledge should be dynamic, rather than static, and that it should be created and maintained by the geospatial (expert) community. In order to express the ontology Ahearn et al. (2013) developed a solution making use of semantic web technology, i.e. linked data. The work of GI-N2K, an LLP Erasmus project, built further on this solution and developed a European version of the BoK for GI S&T (see http://gin2k.bigknowledge.net/bokwiki/).

In practical terms the ontology-based BoK consists of concepts. These can be 'anything': a theory, a method, a technology … They are defined as a term usually comprising one or more words and a 'definition'. For example 'sensor web enablement' is a concept, but also 'philosophy of being', 'data mining', 'TIN and Voronoi tesselation', 'Remote Sensing' …The relationships foreseen in the

[1] English Oxford Living Dictionary.

current BoK (GI-N2K) are mainly hierarchical, but of different types: super-concept, sub-concept which allows to generate the existing hierarchies that were already expressed in the 'old' BoK (diBiase, 2006) and relationships representing natural sequences – which are in fact also hierarchical in the sense they represent an order of things – such as pre- and post-requisites (Ahearn et al., 2013). One non-hierarchical relationship is foreseen, i.e. similarity. In total, there are 5 types of relationships (Augustijn et al., 2018). Other systems, such as the Living Text Books initiative developed by the University of Twente foresees more types of relationships. Examples of relationships are:

- <Concept_1> is a kind of <Concept_2>
- <Concept_1> is used by <Concept_2>
- <Concept_1> is modelled by <Concept_2>
- <Concept_1> is represented by <Concept_2>

Additional relationships might be added / defined. It would therefore be possible to generate the 5 types of relationships used in the current version of the BoK (GI-N2K).

Two other aspects are crucial for a BoK that should feed the design of curricula. First, concepts should have links to knowledge artefacts (Ahearn et al., 2013). In practice these might take different forms (a presentation, video, book(chapter), report …) and the link itself can be a DOI[2], URL/URI[3] or another 'name' or 'label'; but it might also contain full references as they are used in e.g. scientific papers and reports. Reference then have one or more authors. Secondly, an ontology-based BoK should include learning outcomes: what should a learner know (knowledge) or being able to do (skills) to 'master' the concept.

The different aspects described above: terms, definition, relationships, references and learning outcomes will form together the Body of Knowledge that can then be used (through different applications) to design curricula, to define learning paths, to describe a job profile or a task to be executed.

4. The current version of the BoK

This section summarizes the findings of the analysis of the current version of the Body of Knowledge for GI S&T. It also provides the results of the analysis of the current BoK from the perspective of Earth Observation, Remote Sensing and related fields. Finally it summarizes how the analysis of supply and demand could feed the BoK.

4.1. Analysis: overall BoK

The current GI Science & Technology Body of Knowledge (BoK from now on) covers 436 topics or concepts. Its last update was done in the context of the project GI-N2K, which finished in October 2016 and which started from the 'old' BoK developed and published by UCGIS in 2006 (diBiase, 2006). The latter contained 352 concepts (or topics) grouped in 72 units and 10 knowledge areas. Since the end of the GI-N2K project no other modifications or updates were made.

In this section the current state of the BoK is assessed in terms of:

- correct use of the ontology, to maximize its potential;
- completeness of the data, in terms of non-homogeneous description of different concepts and missing information.

Use of the ontology

Figure 1 shows the graphical interface (http://gin2k.bigknowledge.net/bokwiki/) of the BoKWiki, in which the BoK is contained.

There are a total of 436 nodes (concepts), of which 77 nodes (18%) are disconnected from the rest of the nodes. These nodes are not connected to the central node Geographic Information Science and Technology (which acts as the super concept of all other nodes through transitive super concept relationships).

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[2] Digital Object Identifier
[3] Uniform Resource Locator and Uniform Resource Identifier

As it can be clearly seen from the figure above, the bubbles appearing in the center of the image represent what were called Knowledge Areas, units and topics in the 'old' BoK (2006) and the ontological relationships amongst them. They form the actual BoK. On the other hand, all bubbles sticking to both sides of the diagram are the aforementioned "orphan" nodes: concepts that are missing their linkage to a parent concept (super-concept), and are disconnected from the actual BoK. As it can be also seen, some of the "orphan" nodes have their own sub-concepts and relationships amongst them, which turns into having "orphan families" of nodes. Some of these 'floating' concepts are in practice 'test concepts', defined by users in the context of some testing, or they can be concepts that became 'obsolete' over time (i.e. not often used anymore). An example of the latter is 'On-screen digitization' (which is almost not applied anymore). However, these concepts might remain valid in the context of teaching activities.

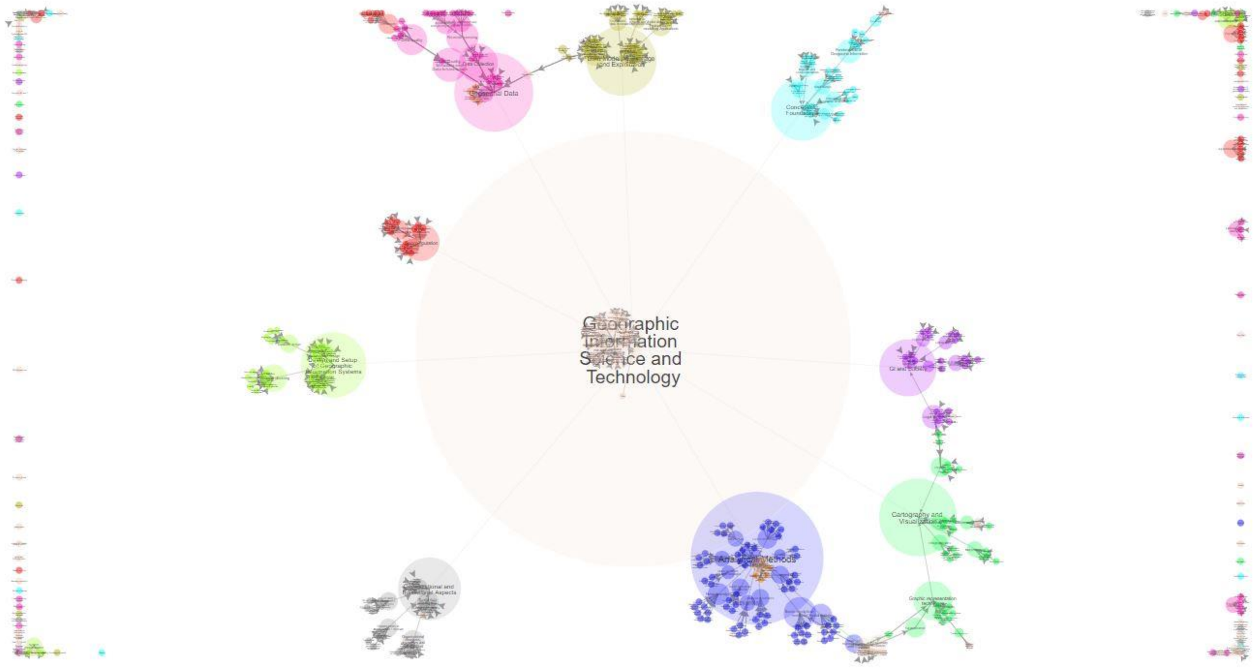

Figure 1: Graphical representation of the BoK and its ontological relationships

Completeness of the data

The assessment of the completeness of the data has been done taking into account which information was requested for each of the old hierarchical levels of the BoK: i.e. KAs, units and topics. Table 1 presents the percentage of coverage obtained for each level with respect to the information requested.

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		Information requested				
		Short code	Name	Description	Skills / Competences	Source documents
Levels	KA	100%	100%	100%	n/a	50%
	Unit	100%	100%	100%	n/a	62.5%
	Topic	100% (with some typos)	100%	41%	66%	60%

Table 1: Level of coverage fulfilled by levels and info. requested

From the table it can be seen that all levels have a “Short code” and “Name”.

Regarding the “Description” and considering that this field should have 100 characters or more in order to be a suitable description, an effort has to be made at the Topic level, because 59% of the nodes miss a description (only 41% already have a proper description). However, even for those nodes that have a description, some are just bullet points, and a more narrative way of description should be applied. So, the percentages in the table above should be interpreted with caution, and we should consider the nodes with just bullet points as a draft subject to further refinement. See the example below on web applications and geoportal frameworks:

Topic WB7-3 Web application Frameworks and Geoportal frameworks

OUTPUT FOR TOPICS (please fill in this form for topics and copy this template as needed)

```
1. Topic code:WB7-3
2. Name: Web application Frameworks and Geoportal frameworks
```

3. Description:

- Describe generally the main components and functionality of “Web Application Frameworks” such as AngularJS, Ext.js, Django, Java Server Faces (JSF), and the like.
- Describe generally the functionality offered by “portal frameworks” land Geoportals ike Geonetwork, Opengeoportal, Esri geoportal server, Deegree portal, Liferay, Jboss portal.
- Identify differences, advantages and disadvantages of web application framework based and portal framework based web applications from the geospatial data perspective.
- Describe generaly how “NSDI-requiring-scenarious” would be handled by web application framework based applications.
- Describe generally how JSON (GeoJSON)`s “schema-less” structure may be transformed into an application schema.

```
4. Learning outcomes.
5. References:
6. (If applicable) Relations: (please indicate the "Name" of a existing unit / topic)
similar:
super-concept:
sub-concept:
pre-requisite:
post-requisite:
```

Figure 2: Example of the abstract for the topic “Web application and Geoportal Frameworks”

"Skills/Competences" (learning outcomes) - just available at the original Topic level – were not addressed in the revision done during GI-N2K. However, 34% of the nodes have them, i.e. they were taken over from the 'old' BoK.

Regarding bibliography or "Source documents": in the UCGIS BoK, bibliography was just provided at the highest level (KA), in the end of each section in the book (diBiase, 2006). In the GI-N2K BoK, it depends on KAs, but there are bibliography at all levels with different levels of coverage and quality. In total, 50% of nodes are missing "source documents". Particularly at KA level, references were inherited from the UCGIS BoK. As for the description of nodes, also for bibliography we observed that some of them should be considered as draft rather than being a final version. For example, in some bibliographies, just links or references to Wikipedia are specified; clearly their quality needs to be verified and improved. The new EO4GEO BoK bibliography should clearly be provided at all levels.

4.2. Analysis of EO/Copernicus elements in the current BoK

What are the concepts on Earth Observation (EO) and Remote Sensing (RS) already described in the current BoK? EO can be defined as the gathering of information about the Earth's physical, chemical and biological systems using different remote sensing platforms and sensors. The existing BoK contains only a limited number of EO/Copernicus related concepts. No concepts related to Copernicus have been identified and only two main concepts relevant for EO. The most EO apposite concepts can be found in the following knowledge areas: Geospatial Data, Analytical Methods and Geocomputation. In the KA Geospatial Data and the Data Collection a Remote Sensing concept can be found. This concept consists of following sub-concepts:

1. Satellite and shipboard remote sensing
    a. Algorithms and processing
    b. Nature of multispectral image data
    c. Platforms and sensors
    d. Ground verification and accuracy assessment
    e. Applications and settings
2. Aerial imaging and photogrammetry
    a. Nature of aerial image data
    b. Platforms and sensors
    c. Aerial image interpretation

d. Stereoscopy and orthoimagery
e. Vector data extraction
f. Mission planning

Moreover, the expression ‘Earth Observation’ was found in the context of the Digital Elevation Model (DEM) calculation and the Next-generation SDI’s Global Earth Observation System of Systems (GEOSS).

Furthermore, other concepts that are in general common for both GI and EO can be found, e.g., Organizational and institutional aspects; Legal/Economic Aspects within the GI and Society; Web services within the Web-based GI; Visualization of temporal geographic data in Cartography and Visualization. These can be further revised and extended in the lifetime of the EO4GEO project taking into account the EO and Copernicus related aspects.

In the existing BoK, the airborne imagery has been identified as a primary remote sensing source of detailed geospatial data for extensive study areas. The satellite-based sensors are mentioned as another type of geospatial data source that “enable frequent mapping and analysis of very large areas”. With the EO related concepts the skills/competencies have been proposed (see table 2).

Table 2: .Learning Objectives of the EO/Copernicus related in the existing BoK

Unit	Topic	Learning Objective
Aerial imaging and photogrammetry	Nature of aerial image data	✓ Explain the phenomenon that is recorded in an aerial image ✓ Compare and contrast digital and photographic imaging ✓ Explain the significance of bit depth in aerial imaging ✓ Differentiate oblique and vertical aerial imagery Describe the location and geometric characteristics of the principal point of an aerial image ✓ Recognize the distortions and implications of relief displacement and radial distortion in an aerial image
	Platforms and sensors	✓ Compare common sensors-including LiDAR, and airborne panchromatic and multispectral cameras and scanners-in terms of spatial resolution, spectral sensitivity, ground coverage, and temporal resolution
	Aerial image interpretation	✓ Describe the elements of image interpretation ✓ Use photo interpretation keys to interpret features on aerial photographs ✓ Using a vertical aerial image, produce a map of land use/land cover classes ✓ Calculate the nominal scale of a vertical aerial image ✓ Calculate heights and areas of objects and distances

Unit	Topic	Learning Objective
		between objects shown in a vertical aerial image
	Stereoscopy and orthoimagery	✓ Explain the relevance of the concept parallax in stereoscopic aerial imagery ✓ Outline the sequence of tasks involved in generating an orthoimage from a vertical aerial photograph ✓ Evaluate the advantages and disadvantages of photogrammetric methods and LiDAR for production of terrain elevation data ✓ Specify the technical components of an aerotriangulation system
	Vector data extraction	✓ Describe the source data, instrumentation, and workflow involved in extracting vector data (features and elevations) from analog and digital stereoimagery ✓ Discuss the extent to which vector data extraction from aerial stereoimagery has been automated ✓ Discuss future prospects for automated feature extraction from aerial imagery
	Mission planning	✓ Plan an aerial imagery mission in response to a given RFP and map of a study area, taking into consideration vertical and horizontal control, atmospheric conditions, time of year, and time of day
Satellite and shipboard remote sensing	Algorithms and processing	✓ Differentiate supervised classification from unsupervised classification ✓ Produce pseudocode for common unsupervised classification algorithms including chain method, ISODATA method, and clustering ✓ Perform a manual unsupervised classification given a two-dimensional array of reflectance values and ranges of reflectance values associated with a given number of land cover categories ✓ Calculate a set of filtered reflectance values for a given array of reflectance values and a digital image filtering algorithm ✓ Describe a situation in which filtered data are more useful than the original unfiltered data ✓ Describe the sequence of tasks involved in the geometric correction of the Advanced Very High Resolution Radiometer (AVHRR) Global Land Dataset ✓ Compare pixel-based image classification methods with segmentation techniques ✓ Explain how to enhance contrast of reflectance values clustered within a narrow band of wavelengths ✓ Describe an application of hyperspectral image data
	Nature of multispectral image data	✓ Explain the concepts of spatial resolution, radiometric resolution, and spectral sensitivity ✓ Draw and explain a diagram that depicts the key

Unit	Topic	Learning Objective
		bands of the electromagnetic spectrum in relation to the magnitude of electromagnetic energy emitted and/or reflected by the Sun and Earth across the spectrum ✓ Draw and explain a diagram that depicts the bands in the electromagnetic spectrum at which Earth's atmosphere is sufficiently transparent to allow high-altitude remote sensing ✓ Illustrate the spectral response curves for basic environmental features (e.g., vegetation, concrete, bare soil) ✓ Describe an application that requires integration of remotely sensed data with GIS and/or GPS data ✓ Explain the concept of data fusion in relation to remote sensing applications in GIS and T
	Platforms and sensors	✓ Compare common sensors by spatial resolution, spectral sensitivity, ground coverage, and temporal resolution [e.g., AVHRR, MODIS (intermediate resolution ~500 m, high temporal) Landsat, commercial high resolution (Ikonos and Quickbird); LIDAR and microwave (Radarsat; SIR-A and -B); hyperspectral (AVRIS, Hyperion) ✓ Differentiate between active and passive sensors, citing examples of each ✓ Differentiate push-broom and cross-track scanning technologies ✓ Explain the principle of multibeam bathymetric mapping ✓ Evaluate the advantages and disadvantages of airborne remote sensing versus satellite remote sensing ✓ Evaluate the advantages and disadvantages of acoustic remote sensing versus airborne or satellite remote sensing for seafloor mapping ✓ Select the most appropriate remotely sensed data source for a given analytical task, study area, budget, and availability
	Ground verification and accuracy assessment	✓ Explain how U.S. Geological Survey scientists and contractors assess the accuracy of the National Land Cover Dataset ✓ Evaluate the thematic accuracy of a given soils map
	Applications and settings	✓ Outline a plausible workflow used by MDA Federal (formerly EarthSat) to create the high-resolution GEOCOVER global imagery and GEOCOVER-LC global land cover datasets ✓ Outline a plausible workflow for habitat mapping, such as the benthic habitat mapping in the main Hawaiian Islands as part of the NOAA Biogeography program ✓ Describe how sea surface temperatures are mapped

Unit	Topic	Learning Objective
		✓ Explain how sea surface temperature maps are used to predict El Nino events

After the revision of the existing BoK in the context of EO/Copernicus following extensions/new concepts could be proposed:

1. Remote sensing fundamentals
2. Division on passive and active platforms and sensors
3. Other than multispectral platforms and sensors: RADAR/SAR, LiDAR, thermal, proximal sensing
4. Remote sensing data providers (e.g., Copernicus), associations (e.g., EARSC, European Association of Remote Sensing Laboratories), societies (e.g., International Society for Photogrammetry and Remote Sensing), etc.
5. Sensor-specific algorithms, processing and data analysis, e.g. Amplitude (Calibration, Terrain correction (Terrain flattening, Rage Doppler), speckle filtering); Phase (Calibration, Co-registration, Baseline estimation, Interferogram creation, Phase unwrapping); Points calibration and classification; Big Data, data fusion
6. New processing algorithms, e.g., machine learning.
7. Remote sensing data management and visualization, e.g., Cloud-services, data cubes
8. Remote sensing product accuracy assessment and ground-based measurements
9. Dissemination of products and knowledge, e.g., products and scripts sharing

Of course, this list should be further analysed as part of Task 2.3

4.3. *Concepts from the surveys and trends analysis*

Based on the interviews and survey responses from the perspective of demand, Albrecht et al., (2018) (D1.3.) did some suggestions related to skills to be considered in the EO/GI BoK. It should be mentioned that the survey mainly focused on skills and less on potential concepts for the BoK. Respondents were not asked to indicate future concepts which should be included in the BoK and were neither asked to comment on concepts which are part of the existing BoK. Therefore the usability of the survey for identifying concepts for the BoK is rather limited. With regard to skill sets and skills, the authors points to the future relevance of programming and analytical methods, which should be incorporated as concepts in the BoK. Furthermore they argue that more insight should be gained into concepts related to cloud computing infrastructures and high performance computing resources. Although skills related to this were considered less important by respondents, this has probably to do with fewer occupational profiles and jobs related to this at present, while future changes can be expected. It should also be noted that prior to populating the new BoK, the supply survey (> 1000 learning resources identified) could be harvested to identify relevant concepts already referred to in the training materials.

5. Procedures for developing and maintaining the BoK

This section describes several aspects of the revision and extension process of the new BoK on GI and EO. First it describes the different roles for maintaining and extending the BoK. Second it describes how contributors might be awarded or acknowledged. Third, the organization of the work in different rounds is explained and finally the use of the possible tools is documented.

5.1. Roles in the BoK revision

For the BoK revision, experts from the EO4GEO consortium and external experts will contribute. Different roles have been foreseen: Working Group (WG) leaders, contributors and an editorial board. All will contribute to the BoK revision at different levels of intensity and involvement. The GIN2K BoK and its extension towards EO will be developed within the so-called working groups to which a GI/EO related topics or group of topics will be assigned. The proposal of the working groups' topics is given in table https://docs.google.com/spreadsheets/d/1ZsIKrPfvY5qy0exXofleVDwI6R-665kntdBtu1lCOec/edit?usp=sharing. At the time of writing the report, there are 7 groups defined.

The working groups will be composed by staff of the project partners that have allocated resources for Task 2.3 'Development of the EO and related parts of the BoK' (partners: GISIG, KU Leuven, PLUS, UJI, GEOF, ITC, UNIBAS, Spatial Services, CLIMATE-KIC, ROSA) as well as other partners that would like to contribute to the extension of the BoK. The experts from the partner institutions had an opportunity to register themselves as the contributors within the call for internal experts announced in the course of the Task 2.1 'Putting in place a network of GI and EO experts'. Based on the associated person-days the working group leaders were proposed – see table https://docs.google.com/spreadsheets/d/1SL8qnny55v2Jp_R1O3ooX12BS5PrGDwETlOAGy84ziI/edit?usp=sharing. An open call for external experts was also published in Summer 2018. It is expected that experts from the consortium will work more intensively and contribute more, than other experts that volunteer for the task. For the last group EO4GEO can't impose work, but should rather invite and stimulate to contribute (e.g. providing comments to abstracts and learning outcomes defined).

Regarding the roles, the WG leaders are expected to coordinate and manage the development and extension of the current BoK within the working groups, formed by EO4GEO experts and external experts. The WGs should review, discuss and propose new concepts for the development of the BoK. Particularly, external experts will take part in WGs providing comments or other kinds of feedback, and will be guided by leading experts in each WG. The Working Group leaders will have regular contacts with each other to discuss progress and exchange experiences.

The editorial board will consist of the Task 2.3 leader, the WP2 leader and one person that has extensive experience in the development of the current BoK (eventually a fourth person can be added, but it is not recommended to have a too big Editorial Board). The Editorial Board will act as the main editors as is the case for scientific conferences or Journals. Most decisions on the acceptance or rejection will be sorted out within the Working Groups, but in case of open issues or disagreement, it will be the Editorial Board to decide. Editorial board will meet between revision rounds, so in two periods (M19-M24 and M31-M36). Editors will supervise and provide feedback to WG leaders before the next round starts. Generally speaking they will follow-up the whole revision process in order to ensure all WGs meet the deadlines and there is a coherence amongst WGs.

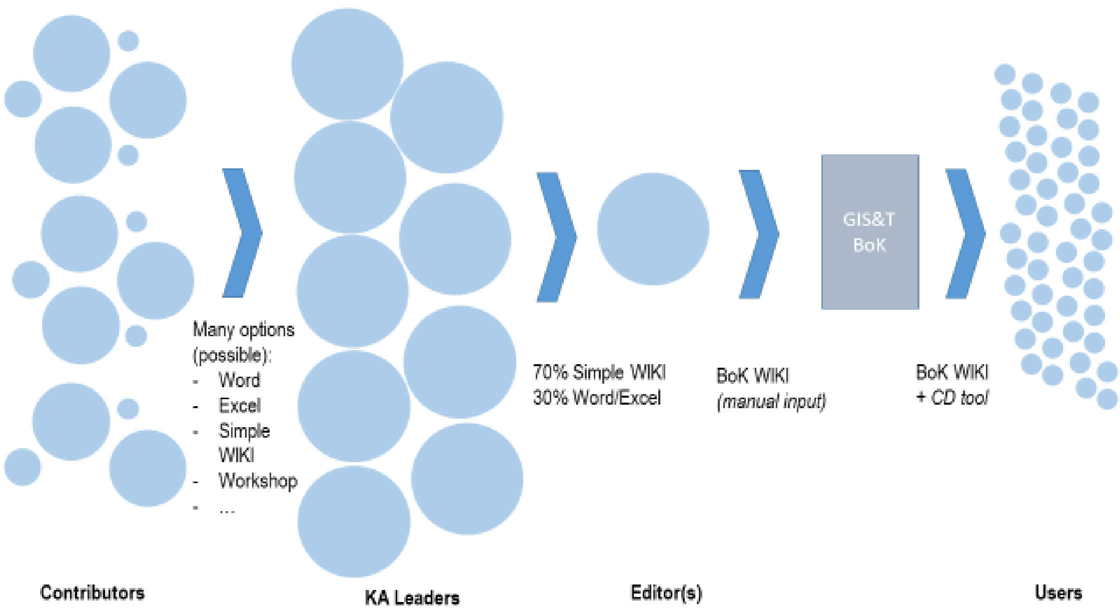

Figure 3: Main actors and their role in the maintenance of the BoK during the GI-N2K process[4]

[4] During the GI-N2K developments a 'simple wiki' was used as an intermediate step. Now or the BoKWiKi, or the Living Text Book Environment will be used.

The Working Group leaders are expected to coordinate and manage the development and extension of the current BoK within the Working Groups. The working group's leaders as well as the contributors within the Working Groups should review, discuss and propose the new concepts for the development of the BoK. The type of tools used might differ, but at the end all the concepts should be consolidated in one BoK (see also section 5.4)

5.2. Award mechanism for experts

Experts working for one of the partners of EO4GEO will work on the BoK for GI and EO since they have dedicated resources for doing that. Other experts might and will contribute to the development of the BoK, but there is no budget foreseen for covering those efforts. That is why most of them are expected to contribute in the revision, rather than the development of the BoK, e.g. by providing comments on concepts defined and described by experts of the EO4GEO consortium, by revising proposed learning outcomes or by providing relevant references for one or more concepts.

Their contribution might be compared with that of being member of a programme committee of a (scientific) conference or being reviewer for a scientific journal. In all these cases, there is a 'rewarding' mechanism in place to 'acknowledge' their contribution, usually by mentioning their name in the publication, or on a website, etc. Nowadays there are even more developed systems to 'count' and make visible this often very hard work, e.g. through the Publons platform[5].

In the context of EO4GEO, two main mechanisms are proposed:

1. **Making contributors visible**

The first mechanism is acknowledge of contributors by making their names visible in different places. The format is still to be defined, but it could be

- By putting their names and affiliation on the EO4GEO website – Often this information is a little bit hidden, so this should be be well-thought (for an example, see https://agile-online.org/conference-2019/committees-2019/scientific-programme-committee-2019);

[5] https://publons.com/about/home/

- By including their names in the BoK itself – the BoKWiKi already allows this, but currently derives the name automatically from the account name (and thus it is the person uploading the concept information and not necessarily the author);
- By having references in the BoK for which they are (co-)author – For each concept there will be one or more references in the form of books & book chapters, papers, reports, training materials such as presentations with audio, etc.

Of course, the mentioning of their names will be explicitly asked for in order to comply with potential GDPR issues and they will be able to withdraw from the lists at any time. Mentioning their names is good, but it is not a real reward and for the scientific community, not really 'counting'. Therefore a second mechanism might be applied.

2. Developing joint outputs

Working together on one or more concepts, especially when elaborating and discussing their abstracts, can be the starting point of more in depth work that leads to a real output in the form of a useful document that can be published. Several options can be thought of:

- Elaborate a document that goes beyond an abstract, e.g. a document of around 10 pages, and that can be developed at a later stage into a real paper or book chapter – This is how colleagues from UCGIS work in the US (in their case the document is published online as an HTML page);
- Elaborate a real paper or book chapter for a scientific journal, conference … on one or more (related) concepts – Of course this process will take more time since it will follow a formal review process and can also be rejected when going through this process.

The advantage of this approach is that these documents and papers can become references in the BoK (e.g. by referring to a DOI) which raise the visibility of the authors. Moreover, the second mechanism allows to build the network of experts as a real collaborative network in which colleagues work together on content. It is also a mechanism that allows people that want to work together on a GI/EO topic make them more visible. Moreover, the output in the form of e.g. a paper 'counts'. Working on the BoK becomes then the trigger to elaborate that paper they wanted to prepare already some time ago, but that was never started because so many other duties are/were waiting. In other cases, working on the paper/document was planned anyway and could easily fit in the development of the BoK without much additional work (e.g. to finish the abstract or define learning outcomes).

Finally, it should be noted that this second mechanism should not only take into account scientific work. Also reports, white papers or other documents being developed in the context of projects or other initiatives can be taken into account and become part of the BoK.

It is proposed that the second mechanism is tested by some of the working groups.

5.3. Different steps in the elaboration of the BoK- timing

According to the EO4GEO Gantt (T2.3) the update of the BoK will be done in three rounds M6-M18, M25-M30 and M37-M42. Different (minimum) outputs are expected at the end of each round. It is clear that in reality the process is a continuous process. Moreover, the process of updating and extending the BoK must be aligned with other work of EO4GEO that will start in the second year and will lead to the training actions in the third year, i.e. the design of the curricula (WP4) and the development of the training actions based on these (WP5).

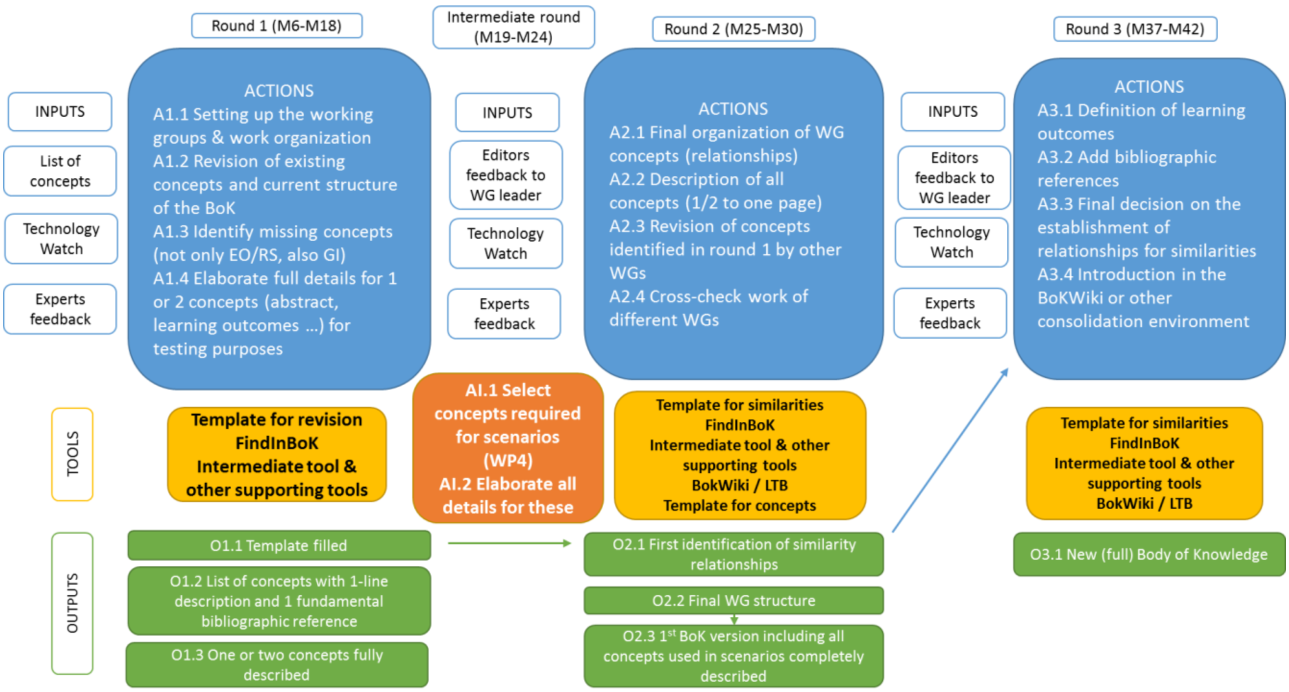

Figure 4: Workflow for developing the BoK

Based on these assumptions, the workflow shown above shows the three major rounds of revision and one intermediate round in which the experts will work together and the editors will intervene. Each round will have some <u>inputs</u>, <u>actions</u> to do, <u>tools</u> to be used and will generate certain <u>outputs</u>.

The whole revision process is composed of 14 actions and 7 concrete outputs, and a series of intermediate and supporting tools.

At the end of round 1 – i.e. M18 (June 2019) the following actions will be completed and outputs created.

Actions Round 1:

- A1.1 Setting up the working groups & work organisation – at the time of writing 7 working groups were identified, discussed and decided upon: working group leaders were identified as well and the first contacts with experts were established;
- A1.2 Revision of existing concepts and the current 'structure' of the BoK – the first cycle revising the current BoK is described in this report; but working groups that will work on the existing concepts will revise these in more detail. This also includes the Identification of missing information for existing concepts (description, learning outcomes, relationships and bibliography). For documenting this a template for revision was prepared (see annex 2)
- A1.3 Identify missing concepts, not only new concepts regarding Earth Observation and Remote Sensing, and concepts coming from the taxonomy of EARSC, but also new GI concepts identified in e.g. the Technology Trends watch. These will be first added to simple lists and for each one a line of description and one reference will be identified;
- A1.4 Elaborate the full details for 1 or 2 concepts in each working group. This is meant for 'testing' how this could/should work and is also a good way to 'exercise' within the WG. Moreover, these examples could then be used in the different workshops that will take place in this period (ESA, AGILE, EO Summit, all during the first half of the year).

Outputs Round 1:

- O1.1 As an output a template for revision must be fulfilled, it will serve as input for Round 2.
- O1.2 List of new concepts with 1-line description and at least 1 fundamental reference / paper per concept
- O1.3 – One or two concepts fully described (including an abstract, relationships; learning outcomes …) serving as examples

Outputs O1.1 and O1.3 must be described in Template for revision. In-between rounds 1 and 2 the editors will revise. For O1.2, the same or an adapted template will be used.

Then follows an **Intermediate Round** which is meant to develop the concepts that will be required in the Curriculum Design phase (WP4) for supporting the three scenarios for three sub-sectors: smart cities, climate change and integrated applications. For these scenarios, 'only' a sub-set of the BoK for GI and EO will be needed. But therefore those people involved can't wait the 'finalisation' of the full BoK. This Intermediate Round should follow immediately after Round 1, i.e.

the work should start in M19 and be ready by M24 (Task 4.1 and 4.2 relate to the identification of the business processes and the design of the curricula and should be finished by M26). In this Intermediate Round, there are two Actions:

- AI.1 Identification of the concepts that need to be fully elaborated in view of the Curricula Deign for the three scenarios. These will be identified in several steps:
    - Work flows for the scenarios will be modelled identifying activities, actors …;
    - The required knowledge, skills and competencies will be identified from the perspective of content and learning outcomes;
    - This might lead to missing concepts and definitely to a list of concepts to be fully elaborated (priority list in the BoK development)
- AI.2 For the identified concepts, all the details must be developed: abstract, relationships, learning outcomes and complete list of references (this might include existing training materials).

The output will be a full description for a sub-set of concepts and those will be revised by the Editorial Board.

At the end of Round 2 – i.e. M30 (June 2020) the following actions will be completed and the following outputs will be created.

Actions Round 2:

- A2.1 Final organization of concepts and establishment of relationships for super- and sub-concepts, post- and pre-requisites. This would mean that for the identified concepts the hierarchical relationships are established;
- A2.2 Description of all concepts (1/2 to 1 page). At this point a “Template for concepts” will be provided to state clearly which information should be gathered for each concept. The template will include some of the examples developed in Round 1;
- A2.3 Revision of concepts identified by the WGs in Round 1. Having as a starting point the template for revision as the main source of information a “Template for similarities” will be created to help WG in accomplishing this action;
- A2.4 Cross-checking the work of the different WGs including the applied style and level of detail and where needed the identification of potential revisions/adaptations.

Outputs Round 2:

- O2.1 The result of the first identification of similarity relationships will be an output in the form of a filled xls sheet indicating which WG share similar concepts (and of course also similarities within the same WG). This will serve as a starting point (input) for initiating discussions in Round 3.

- O2.2 Final BoK structure. By this round a fixed and freezed structure of the BoK will be provided. No additions or modifications of concepts/descriptions will be allowed anymore in order to finalize the BoK in the third Round.
- O2.3 1st consolidated version of the BoK by introducing it in the BokWiki or an alternative environment (e.g. The Living Text Book, LTB). With a fixed structure of the BoK, which entails assigning short codes, names and descriptions of concepts and relationships (super- and sub-concepts, post- and pre-requisites), the information will be transferred to the BokWiki in a consolidated BoK. This is independent from the tools used during the development phase (BoKWiKi, LTB, other tools).

In-between Round 2 and Round 3 a new cycle of editorial revision will be organised.

At the end of Round 3 – i.e. M42 (June 2021) the following actions will be completed and the following outputs will be created.

Actions Round 3:

- A3.1 Definition of learning outcomes, with priority one or more learning outcomes at the most detailed level in the BoK structure, and where feasible also at other levels; guidance will be provided on how to define correct learning outcomes (knowledge, skills and competencies);
- A3.2 Bibliographic references – a more complete set of bibliographic references will be added to the BoK; this can occur in different ways: preferably in the form of URI/DOIs providing a direct link to the resource; however that will not always be possible and therefore the title (of a paper, book …) and the author(s) … and other information might also be added (similar to what is done in papers);
- A3.3 Final decision on cross-cutting concepts and/or the establishment of relationships of type “similarities” should be finalized. During this round discussion between WG who have detected similarities in concepts during round 2 should take place in order to decide to which area a concept belongs to (i.e. how the relationships are defined);
- A3.4 Introduction of missing pieces in the BoK environment (BoKWiKi or LTB) and preparing a consolidated version of the BoK.

Outputs Round 2:

- O3.1 New (full) version of the BoK. The rest of the information that shapes a concept (learning outcomes, bibliographic references and similarity relationships) will be available in a consolidated environment.

In order to help WGs to reach these outcomes some inputs for discussion are going to be prepared by some partners. For round 1:

- JENA will prepare a list of identified concepts from different sources of information like surveys, trends, deliverables, GI-N2K reports…;
- UJI will provide a template "Template for revision" on Slack for helping current WGs during the revision process (see annex 2 Template + instructions);
- UJI will provide additional information from the intermediate tool used in GI-N2K upon request;

For round 2:

- KU Leuven will prepare a template "Template for similarities" for identifying similar concepts in different WGs (Template for similarities)
- JENA will prepare a "Template for concepts", information to be filled in per new concept

Finally it should be noted that one of the EO4GEO partners, UJI plans to set up a Trends Watch system that can be used by the WGs to feed their work with new publications appearing about concepts related to their area of work. The tool will basically prepare search alerts in some databases like Scopus or Web of Science (WoS).

5.4. Usage of tools for BoK development

There are several tools for extending and maintaining the BoK that can and will be used. It is also the ambition of EO4GEO to test the existing tools for carrying out Task 2.3. While one working group might work with one type of tools, another group might do that differently, even if the procedure and the way of adding or modifying concepts is the same. The development of the BoK through the different rounds – described in Section 5.3 – will also provide input to improve / change the existing tools where necessary and feasible. The current status of affairs and the requirements are documented in *"D3.1 – Method, architecture and specification of the collaborative platform"*. Broadly speaking, there are three types of tools (or rather environments):

1) Templates and supporting tools for preparing and guiding the development of the BoK. Several templates have developed or will be developed to prepare list of concepts to be revised or added, to collect (missing) information, to describe similarities between concepts, etc. Moreover for browsing the current BoK or for searching a particular concept the “FindInBoK” has been developed and is available for all experts;

2) Revising and adding concepts by entering the required information such as the description in one sentence, the abstract, the relationships, learning outcomes … can be performed using the BoKWiKi or the Living Text Book (LTB) tool. These tools are quite similar and have each pro’s and con’s. They allow, both in different ways – to collect the information and to discuss the content of the proposed concepts. The latter functionality is important to make the development of the BoK a collaborative endeavour.

Figure 5: Screenshot of the FindInBoK tool

3) The platform and tools for consolidating and making the extended and revised BoK available for users (through different applications) will contain the accepted / endorsed concepts (after revision and decision by the Editorial Board). This platform and tools will certainly be based on an ontology environment using Linked Data technology. The tools to manage the consolidated BoK will be either the (improved) BoKWiKi or the (improved) LTB, or towards the end of the project a new tool with similar functionality.

For each of the templates and tools, some guidance documents exist on how to use them, or will be provided, most probably in the form of video's showcasing how they should be used in the process of addition or maintenance of concepts.

6. Conclusions, discussion and next steps

This report aimed at looking into the revision of the ontology-based approach by refining the ways in which the development and management of the Body of Knowledge was done in the LLP-Erasmus project *"GI-N2K – Geographic Information Need to Know".* During this project an approach was developed based on concepts (theories, methods, technologies …) and five potential relationships amongst them: super- and sub-concepts, pre- and post-requisites and similarities. After an analysis and discussion within the EO4GEO consortium it was decided to stick to these five relationships although the Living Text Book platform allows to add other relationships and even define new ones. It was also decided that the content of the BoK should be structured according to some key information elements: a 1 sentence description, an abstract of around ½ to 1 page, relationships with other concepts, learning outcomes and a bibliography.

The current version of the BoK which was developed in the same GI-N2K project was analysed from two perspectives. First, a critical analysis was made on the correct application of the ontology and its completeness in terms of non-homogeneous descriptions and missing information. It was found that currently 18% of the concepts in the BoK are disconnected from the rest of the BoK. Moreover, it was also observed that at the most detailed level descriptions were missing (59%), and often also learning outcomes and source documents. Second the current BoK was analysed from the perspective of its usage in the context of EO and RS topics, or Copernicus. Besides some explicit concepts related EO/RS, also certain learning objectives were found to be relevant in this context. From there already 9 new concepts were proposed for discussion.

Finally, the report describes the procedures for developing the BoK in detail. The roles for the BoK revision were outlined and 7 Working Groups have been defined to organise the work (their naming should still be confirme). Second two awarding mechanisms have been proposed: not only listing contributors in publications and on portals, but also trying the set-up collaborative ways of preparing joint publications on one or more concepts developed for the BoK. Third, a detailed step-by-step approach for the development of the BoK was defined, including the definition of 3 big rounds of development, spread over three years. An intermediate development round at the end of 2019 would support the design of the curricula for the 3 scenarios for the chosen sub-sectors: smart cities, integrated applications and climate change. Also the potential tools for maintaining the BoK are discussed in the report. It should be stressed that this document is a living document. Based on the first experiences, the procedures might need some fine-tuning, or new Working Groups might be put in place.

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Annex 1: structure of the current BoK

The existing structure is listed in a following word document (please feel free to use it): https://docs.google.com/document/d/1zfF6hibBLgr_j0C0mgcpKAWKYYbaLliKYd0vOff8vLg/edit?usp=sharing

Where an example of a concept should be placed? A concept should consist of following information.
Example of a concept

1. Code
2. Name
3. Abstract/description of a concept (approx.. ½ page)
4. Relationships (super- and sub-concepts, post- and pre-requisites, similar concepts)
5. Learning outcomes
6. References


GI-N2K
Home What's New *Propose New Concept* Graph Interface

Satellite and shipboard remote sensing

concept created 2006-09-01 by GIS&T BoK 2006ed.

Should this be part of the Body of Knowledge?
- true

Proposed short codes:
- GD11

Proposed names:
- Satellite and shipboard remote sensing

Proposed descriptions:
- Satellite-based sensors enable frequent mapping and analysis of very large areas. Many sensing instruments are able to measure electromagnetic energy at multiple wavelengths, including those beyond the visible band. Satellite remote sensing is a key source for regional- and global-scale land use and land cover mapping, environmental resource management, mineral exploration, and global change research. Shipboard sensors employ acoustic energy to determine seafloor depth or to create imagery of the seafloor or water column. The topics included in this unit do not comprise an exhaustive treatment of remote sensing, but they are aspects of the field about which all geospatial professionals should be knowledgeable.

This is proposed as a sub-concept of:
- Remote sensing

Proposed subconcepts:
- Algorithms and processing
- Nature of multispectral image data
- Platforms and sensors
- Ground verification and accuracy assessment
- Applications and settings

Proposed similar concepts:

Proposed prerequisite/preceding concepts:

Proposed postrequisite/subsequent concepts:

Proposed demonstrable skills/competencies:

Proposed source documents:
- Jensen, J. R. (2005). Introductory digital image processing: a remote sensing perspective (3rd ed.). Upper Saddle River, N.J.: Prentice Hall.
- Lillesand, T. and Kiefer, R. (2003). Remote sensing and image interpretation (5th Ed.), New York: Wiley.

Figure 6: Example of a concept in the current BoK

Co-funded by the Erasmus+ Programme of the European Union

Annex 2: template for the revision of the current BoK

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Q
SIMPLIFIED WIKI			BOKWIKI							EO4GEO BOK (example)					
Short co	Type	Name	Short co	Type	Name	Description Y/N	documents Y/N	outcomes Y/N	Notes	Short code	Type	Name	Source documents (for new concepts)	1-line description (for new concepts)	
CV	WG	Cartography and visualization	CV	WG	Cartography and visualization			N/A		CV	WG	Cartography and visualization			
CV1	Unit	History and Trends	CV1	Unit	History and trends			N/A		CV1	Unit	History and trends			
CV1-1	Topic	History of Cartography	CV1-1	Topic	History of cartography					CV1-1	Topic	History of cartography			OK
CV1-2	Topic	Historical Maps	CV1-2		not in use										Inconsistency
CV1-3	Topic	Paradigm and technology shifts	CV1-3	Topic	Paradigm and technology shifts					CV1-3	Topic	Paradigm and technology shifts			Not applicable
CV1-4	Topic	Art and geo-data visualisation	CV1-4	Topic	Art and geo-data visualisation										not in use
			CV1-5	Topic	Historical Maps										new for EO4GEO
										CV1-6	Topic	I love EO4GEO	Vandenbroucke, D. ; Vancauwenberghe, G. Towards a New Body of Knowledge for GIS&T. Micro, Macro & Mezzo Geoinformation 6, 7-19, 2016	blbalblablalalblbaldas lblala	
CV2	Unit	Data considerations	CV2	Unit	Data considerations			N/A							
CV2-1	Topic	Data sources for 'mapping'	CV2-1	Topic	Data sources for mapping										
CV2-2	Topic	Data processing	CV2-2	Topic	Data processing										
CV2-3	Topic	Mathematical base	CV2-3	Topic	Mathematical base										
CV3	Unit	Design principles	CV3	Unit	Design principles			N/A							
CV3-1	Topic	Map design fundamentals	CV3-1	Topic	Map design fundamentals										
CV3-10	Topic	Geo-Gaming	CV3-2	Topic	Basic concepts of symbolization				Inherited from UCGIS Bok						
CV3-2	Topic	Symbols and icons	CV3-3	Topic	Color for cartography and visualization				Inherited from UCGIS Bok						
CV3-3	Topic	Colour	CV3-4	Topic	Typography for cartography and visualization				Inherited from UCGIS Bok						
CV3-4	Topic	Typography													
CV3-5	Topic	Photos													
CV3-6	Topic	Animation													
CV3-7	Topic	Sound													
CV3-8	Topic	Storytelling													
CV3-9	Topic	Info-graphics													
CV4	Unit	Graphic presentation techniques	CV4	Unit	Graphic representation techniques			N/A							
CV4-1	Topic	Thematic mapping	CV4-1	Topic	Thematic mapping										
CV4-10	Topic	Visualisation of uncertainty	CV4-10	Topic	Visualization of uncertainty										
CV4-2	Topic	Representing terrain	CV4-2	Topic	Representing terrain										
CV4-3	Topic	Multivariate displays	CV4-3	Topic	Multivariate displays										
CV4-4	Topic	Visualisation of temporal geo-data	CV4-4	Topic	Visualization of temporal geographic data										
CV4-5	Topic	Dynamic and interactive displays	CV4-5	Topic	Dynamic and interactive displays										
CV4-6	Topic	Webmapping	CV4-6	Topic	Web mapping										
CV4-7	Topic	Virtual and immersive environments	CV4-7	Topic	Virtual and immersive environments										
CV4-8	Topic	Augmented environments	CV4-8	Topic	Augmented environments										
CV4-9	Topic	Spatialization	CV4-9	Topic	Spatialization										
CV5	Unit	"Map" production	CV5	Unit	Map production			N/A							
CV5-1	Topic	Computational demands	CV5-1	Topic	Computational demands										
CV5-2	Topic	Web"map" making	CV5-2	Topic	Web map making										
CV5-3	Topic	"Traditional" Map making	CV5-3	Topic	Traditional map making										
CV5-4	Topic	"Map" reproduction	CV5-4	Topic	Map reproduction										
CV6	Unit	Usability	CV6	Unit	Usability			N/A							
CV6-1	Topic	The power of maps	CV6-1	Topic	The power of maps										

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