Open Satellite Data for the area of Serbia

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Abstract— **This paper aims to introduce open access satellite data for the area of Serbia. We describe different satellite platforms which collect images with different spatial and spectral resolution, access and practical utility of historical data and the data that are being collected today. Radar platforms with different bands are introduced as well. We also discuss applicability of these data in different governmental institutions. The paper also indentifies the need to semantically describe such data and proposes introduction of semantic metadata.**

I. Introduction

The Global Open Data Initiative (GODI), The Open Data Foundation (ODaF), Open Gov Partnership (OGP) are just some of the organizations which define what open data are and how should they be treated by governmental institutions and non-governmental institutions. The definition of open data "Open data and content can be freely used, modified, and shared by anyone for any purpose" [1] is the most common and the most frequently used definition of open data. The Government of the Republic of Serbia in its action plan for OGP implementation initiative for 2014 and 2015 year [2] developed a strategy with 13 planned measures. In the part related to information access, measure 10 refers to new technology introduction to improve services provided to citizens. In that measure, the plan describes necessary actions which would facilitate the access to open data for common citizens. Although, these measures are primarily related to administration authorities, they can refer to spatial data.

The importance of spatial data in the 21 century is increasing exponentially, mainly because of growing availability and usability in everyday life, and because of the vast data quantity which are being collected, processed and analyzed in different ways and by different profit or non-profit institutions. The objective of this paper is to introduce open access remote sensing satellite data for the territory of Serbia which can be good starting point for all those who are in position to use and to analyze remote sensing data.

Usage of this satellite images can significantly improve the efficiency of state organizations dealing with spatial planning, agriculture, environmental protection, waters, floods and other areas in which remote sensing data can be used. These data can be used in educative purposes, in high school and faculty education. Satellite data importance and their open availability can have a significant influence on the mindset of future generations that are now being educated.

This paper is organized as follows: the next section presents what is open access satellite data, what is current international and domestic strategy, and also focuses on historical, current and future remote sensing data. Section three gives an explanation about data applicability in Serbia, and how open access data can be used. Also this section describes the necessity of educating users of remotely sensed data. Next section explains the semantic metadata of satellite images. Paper concludes with an outlook on new technologies in the future.

II. Open Access Satellite Data

A. International and domestic strategy

Land cover monitoring, land cover change detection, large cities expansion and their affect on environment, weather disasters, floods, fires, and other occurrences, are all informations that are being monitored and collected on a daily basis. These informations present satellite images with different spatial, spectral, temporal and radiometric resolutions. Property and access to this informations present an important step towards understanding the environment in which we live in and how do we influence on our environment.

Landsat program for Earth observation lasts from 1972 when the first Landsat was launched. Since 1982 Landsat 4 satellite platform began to deliver satellite images with 30 meters spatial resolution in visible, near-infrared and short-wave-infrared wavelengths, which enabled first severe Earth land cover monitoring [3]. A big step forward in information access was in 2008 when the US Geological Survey issued a decision that enabled all of the Landsat images free and open access to anyone [4]. They continued this practice with the launch of new platform Landsat 8 which monitors the Earth with spatial resolution from 15 to 100 meters in visible and infrared (including thermal) wavelengths. Landsat 8 from its launch and until the moment of writing this paper has already made over 450000 images of Earth and all of them are open access. The benefits of open access demonstrated by the Landsat program justify and encourage efforts for much more open access satellite data. Governments and the remote-sensing community should now seize the opportunity to develop a unified strategy for land monitoring [4].

European Space Agency (ESA) within the Copernicus program is constantly developing and planning new Sentinel satellite platforms. On the April 2014 year, the first Sentinel-1 was launched, and more of them are planned to be launched. Sentinel-2 and Sentinel-3 are planned to be launched in 2015. Apart from the different properties of these satellite platforms, common to all of them is the fact that the images that they deliver will be free open access.

Satellite platforms launch into space is not a rarity any more. In the 70's there were only 2 launches by decade, and today that number is more than 10 platforms in one year. Thanks to Google Earth and Bing maps, we now have more and more people who observe the Earth surface. Within the book that Committee on Earth Observation Satellite's (CEOS) published it can be found that "CEOS agencies are operating or planning around 260 satellites with an Earth observation mission over the next 15 years. These satellites will carry around 400 different instruments" [5].

In [6] the authors identified 197 satellite platforms which were used for the analysis of Earth surface until 2014 year. Furthermore, authors [6] propose the classification of satellite images based on spatial resolution on 5 classes: 0.5-4.9 m (very high resolution), 5-9.9 m (high resolution), 10-39.9 m (medium resolution), 40-249.9 m (moderate resolution) and 250 m-1.5 km (low resolution) and they point out that the images with medium and moderate spatial resolution are generally free through 'free and open' data policies. Images with high and very high spatial resolution are commercial.

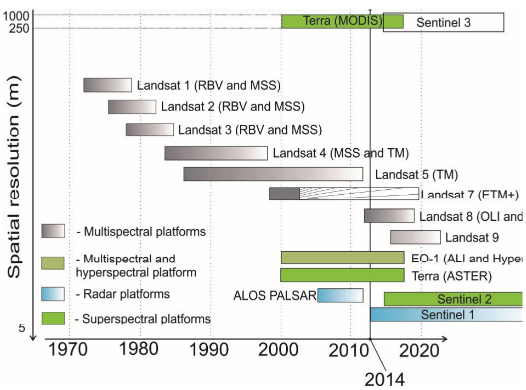

Figure 1. Historical, current and future open access satellite data

If we discuss about satellite images and platforms, Serbia's position does not differ from other countries with similar size and population. Serbia does not possess any satellite platform and does not share the possession of any platform with other countries. If we look at similar countries, members of EU, we can conclude the lack of Serbia's involvement in important EU institutions such as ESA and consequently the lack of involvement in projects such is ongoing Copernicus. Participation in this institutions and programs would certainly have a significant effect on consciousness development regarding the use of satellite images and surely an effect on awareness of open access data. Serbia in its action plan for OGP implementation initiative for 2014 and 2015 year [2] did not predict any measures that would refer to geospatial data access generally, and specially in the light of satellite images open availability. The Republican Geodetic Institution (RGI) as the responsible institution, opened the access to some data that are in their possession (data regarding real estate cadastre and similar) but did not open the access to data that are related to Earth surface on the territory of Serbia. This, remote sensing data refers to satellite images that RGI purchases for own needs, and also to aerial imagery which is used by RGI for different products (ortophotos, terrain models and similar).

B. Historical Data

Figure 1 Historical, current and future open access satellite data, shows all satellite platforms which imaged and still image the territory of Serbia. Spatial resolution of these platforms range from 5 to 1000 meters. Figure 1 also depicts that the platforms are of different spectral characteristics, that is, there are multispectral, hyperspectral and radar images that cover the whole territory of Serbia. Different, open access data with proper systematic treatment, analysis and interpretation would surely help in creating a new, different perspective on the state of Serbia itself.

If we inspect different historical multispectral images which include visible and infrared parts of the electromagnetic spectrum, we can conclude that they present a meaningful information resource for historical land cover reconstruction. Land cover can include: urban area, water area, forests, agricultural land, etc. That is, we can monitor deforestation, floods, expansion of Belgrade, Novi Sad, Nis, and also we can monitor the health of crops, we can simulate crop yield, pollution of water areas can also be monitored, snow cover, determination of soil moisture with active sensors, monitoring the environment and more. Satellite which monitored Earth the most and therefore photographed the territory of Serbia more than every other satellite was Landsat 5. Launched in March 1984, and decommissioned in June 2013, Landsat 5 entered the Guinness book of records as the longest operating Earth observing satellite mission in history. During its mission Landsat 5 collected more than 2.5 million images [7]. Landsat 4 stopped to collect images in December 1993 but was decommissioned in 2001. Combination of multispectral images from Landsat 5 and from Landsat 4 provide a powerful open access archive which can be used together with Landsat 7 and Landsat 8 images in order to monitor Serbia landscape behavior dating from 1982 until now.

Besides historical multispectral images, historical radar images (ALOS PALSAR) are also available for the territory of Serbia for the years: 2007,2008,2009 and 2010. These data are also open access and free. The data include forest and non-forest products as well as the original radar images with two polarizations. The images can be used to monitor forests for mentioned years and for the whole territory of Serbia. Moreover this data can be combined with other images not necessarily radar in order to track changes. The creators of ALOS PALSAR images recommend that images be used for forest monitoring but of course this is not necessary and we can use original radar images to monitor, for example water. The historical data present a significant factor in understanding the ecological changes on Earth during the past decades.

TABLE I.
HISTORICAL DECOMMISSIONED SENSORS WHICH OBSERVED SERBIA

Sensor	Decommissioned	Where to find images
ALOS PALSAR	May 2011	http://www.eorc.jaxa.jp/ALOS/en
Landsat 4	June 2001	http://glovis.usgs.gov http://earthexplorer.usgs.gov
Landsat 5	June 2013	http://glovis.usgs.gov http://earthexplorer.usgs.gov

Table 1 shows the dates when the sensors which cover territory of Serbia have begun to collect images and also the locations on the internet where these images can be found and ordered free of charge. It is necessary only to register as a user and then the images can be downloaded.

C. *Current Data*

Figure 1 also shows that in the moment of writing this paper, there are 6 satellite platforms which currently observe Serbia and provide open access, that is they are still active and will be. Active platforms image the Earth in visible, near-infrared, middle-infrared, thermal infrared and in the microwave part (Sentinel-1) of the electromagnetic spectrum. Main difference in comparison with historical images is in spatial resolution, which is much higher, with trend towards medium and higher spatial resolutions if the platforms are launched in the last few years. This fact, is maybe the best depiction of technology development in the last 30 years, because it was unimaginable that the images with 5 m spatial resolution can be downloaded free of charge.

TABLE II.
SENSORS WHICH MONITOR TERRITORY OF SERBIA

Sensor	Collecting since	Where to find images
ASTER	February 2000	http://glovis.usgs.gov http://reverb.echo.nasa.gov/reverb
EO-1 ALI, Hyperion	November 2000	http://glovis.usgs.gov http://earthexplorer.usgs.gov
Landsat 7	April 1999	http://glovis.usgs.gov http://earthexplorer.usgs.gov
Landsat 8	May 2013	http://glovis.usgs.gov http://earthexplorer.usgs.gov
MODIS	December 1999, May 2002	http://glovis.usgs.gov http://reverb.echo.nasa.gov/reverb http://nsidc.org/data/modis
Sentinel-1	April 2014	https://sentinel.esa.int

Table 2 displays the date when the platforms became active and where to find images for territory of Serbia from these platforms. As mentioned before, it is only required to register on the internet and the images can be downloaded.

If the tables 1 and 2 are closely analyzed, it can be seen that all of these datasets, except data from 2 satellite platforms, are controlled by the United States Geological Survey (USGS). Also, all satellite platforms except ALOS and Sentinel-1 are in US property. This information leads to a conclusion that the USGS as one of the most important institution in field of remote sensing, has recognized the significance of making images free and open access to all interested institutions and people. Information that more than 1 million images were downloaded since the Landsat images became free in just one year, whereby the number of bought images were 25000 yearly, speaks in favor of importance of open data access. The second interesting information is that until March 2008 only 7.7% of all Landsat 7 scenes which are stored in the archive were ordered/purchased. After the USGS decision in 2008 to make Landsat images free and open access this percent changed to 65.1% by December of the same year 2008 [8].

Newest satellite platform with open data, Sentinel-1, property of ESA, presents a new breakthrough in the era of free satellite images which EU proclaimed with Copernicus program. Copernicus is the most ambitious Earth observation program to date. It will provide accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

D. *Future Data*

Landsat 7 fuel-based end of life is 2017, Landsat 8 fuel ending life is until 2023. Plans for Landsat 9 are still developing, he is planned for December 2018, but the resources from the Congress are not approved yet, neither the goals for the new platform are defined [8].

The Sentinel mission which is conducted by European Commission (EC) in cooperation with ESA, should launch 5 more platforms in order to complete the Copernicus program. First one of 5 is Sentinel-2 with its 13 spectral bands and spatial resolutions which range from 10 to 30 meters. Sentinel-2 is indented to monitor changes in climatic conditions, land cover and in special cases to help in critical situations. If we look at technical characteristics, this platform will be very similar to Landsat platforms under USGS property. The launch is planned for May 2015. Sentinel-3, which will serve in mapping sea surface topography and will monitor sea and land surface temperature with spatial resolutions from 300 to 1000 meters, will be launched in mid of 2015 year, that is the first platform (3A) of 3 will be first launched. The second one, 3B is planned for 2017 and the last one 3C will not be launched before 2020.

We conclude that the Copernicus program is somehow a response from EC to US Landsat program and even more than that. It will be shown in the near future how more.

III. DATA APPLICABILITY

Figure 2 shows some of the results that can be obtained from the open access satellite data for the area of Republic of Serbia. Landsat satellite images can be used for generation of land cover maps, or maps of different vegetation indices that can be used in area of agriculture (quality of agricultural cultivated plants or condition of other types of crops and fruit fields) or in environmental applications. Also, Landsat satellite images can be used

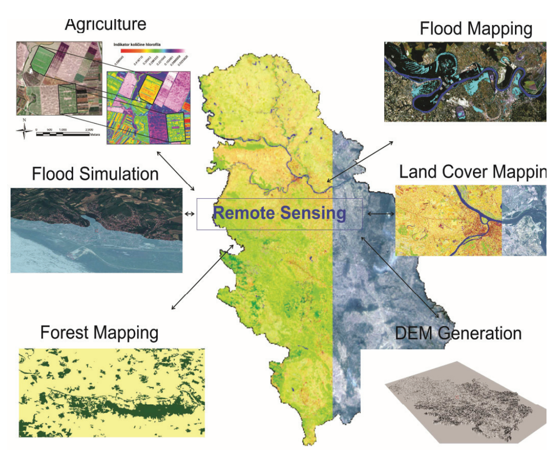

Figure 2. Examples of products obtained from the processing of open access satellite data for the area of Republic of Serbia

for mapping of flooded areas and flood simulations. Figure 2 also illustrates forest map for the area of Fruška Gora National Park, obtained from radar PALSAR images, while Aster images, among other applications, can be also useful for Digital Elevation Model (DEM) generation.

Free satellite images trend lead to increased number of of public and scientific communities which are involved in researching, analyzing and distributing satellite images and products derived from images. This increasing number of users applies to all countries as well as Serbia. This means that more and more people are somehow involved in spatial data processing. Therefore, the necessity of remote sensing education is a must. People need to understand image processing and their potential. Tomorrow these people will work in governmental or public institutions and knowledge of spatial data will surely have a benefit. We are now witnesses of Copernicus ambitious program which will have six platforms in space until 2023 and these data will be free to process and to gain the most from images.

Historical remote sensing images can be used in various applications, in the next paragraph we will mention some of the areas where satellite data for Serbia can be useful.

ALOS PALSAR radar images can be used to map forests for previous years (Figure 2). Mapping forests allows us to monitor deforestation. The effects of vast fires can also be mapped. Also, radar images (Sentinel-1) can be very useful in monitoring water or floods or for DEM generation. That is, today we have flood, and shortly after that we can have maps of flooded areas on the whole territory of Serbia. Historical multispectral images can also monitor any kind of land cover. Popular parameter that can be derived from thermal bands is land surface temperature (LST). Therefore, we can monitor the temperature on any part of Serbia now and in the past. Application in agriculture is constantly increasing. Crop status can be analyzed with infrared bands, soil moisture also, and soil drought. MODIS has special bands that effectively monitor floods and fires, with spatial resolutions from 250 to 1000 m. We hope that Sentinel-3 will also serve in similar purposes. Natural disasters in Serbia are unfortunately increasing and therefore it is necessary to increase the importance of spatial data which can help in monitoring, mapping and better overcoming these disasters.

Authors of this paper can confirm that the bachelor and master theses from remote sensing are very popular among students, and the number of theses is increasing constantly. With new platforms that offer open access, this number will increase even more. That is, people are very interested to work with satellite images. This interest can eventually represent Serbia as a recognized country in satellite image processing.

IV. Open Data Metadata

Effective use of spatial data requires easy access to their documents, or metadata that describes lineage, ownership, quality, maintenance, etc. Considering many different sources of open data it is necessary to describe that data in standardized way using available metadata standards, and make it accessible through metadata catalogues. In this paper we analyze standards that are suitable for describing open geospatial data and propose shift toward the semantic level of metadata in order to make open data more accessible to non expert users.

Currently, the most significant metadata standard for geospatial data is ISO 19115 (ISO 19115-2 is its extension for describing imagery and gridded data) [9]. ISO 19115 classifies metadata standards into categories which include: identification information for data identification, constraint information about access rights, data quality information, information about maintenance of data, spatial representation information, reference system information, information about the content of the dataset and a feature catalogue, distribution information etc. Part 2 of ISO 19115 also introduces imagery identification, such as acquisition information, instrument identification, platform identification, mission identification, processing information etc.

```
MD_Metadata
...
+spatialRepresentationInfo (digital
representation of spatial data)
        MD_Georectefied (descendent of
        MD_GridSpatialRepresentation)
        numberOfDimensions: 2
        axisDimensionsProperties:
                MD_Dimension
                dimensionName: 001 (code for
the ordinate y)
                dimensionSize: 9449 (cell-
pixel)
                resolution:
                        Measure (documented in
ISO 19103)
                dimensionName: 002 (code for
the abscissa x)
                dimensionSize: 14173
                resolution:
                        Measure (documented in
ISO 19103)
        cellGeometry:002 (cell represent
area)
        transformationParameterAvailability:
        1 (transformation parameters are
        available)
        checkPointAvailability: 0 (check
        points for testing accuracy of
        georeferenced data)
        cornerPoints: (geographical
        coordinates of the corners of an
        image)
                GM_Point (documented in ISO
        19107)
        pointInPixel: 001 (center)
...
+identificationInfo (basic information about
data)
        MD_DataIdentification
                …
        spatialRepresentationType: 002 (code
        for grid data)
        spatialResolution: (scale 1:1000)
                MD_Resolution
                equivalentScale:

        MD_ReprezentativeFraction
                        denominator:1000
        …
        geographicBox:
                EX_GeographicBoundingBox
                (bounding box of data in
                degrees)
                …
...
```

Listing 1. Metadata description of raster data

An example of satellite imagery description using ISO 19115 is shown in listing 1. It shows the spatial representation information which includes grid spatial representation and can be divided in georectified and georeferencable grid. Georectified grid is a grid whose cells are regularly spaced in a geographic or map coordinate system defined in the spatial referencing system so that any cell in the grid can be geolocated given its grid coordinate and the grid origin, cell spacing, and orientation. Georeferencable grid is a grid with cells irregularly spaced in any given geographic or map projection coordinate system, whose individual cells can be geolocated using geolocation information supplied with the data but cannot be geolocated from the grid properties alone. Spatial representation information includes properties of the grid such as number of dimensions, axis properties, cell geometry, availability of check points and transformation parameters, etc. The following listing shows extract of metadata for gridded data in ISO 19115, including information about reference system, bounding box, distribution and spatial representation information which gives details of the grid.

This sort of information enables discovery and retrieval of data according to title, abstract, keywords, spatial and temporal extent, categories, themes, etc. It answers the "what, where, when, why, who, and how" questions about geospatial resources. ISO 19115 also specifies Core metadata set which is a basic minimum number of metadata elements that should be maintained for a dataset in order to identify a dataset for catalogue purposes. It includes mandatory metadata elements as well as recommended optional elements which will increase interoperability, allowing users to understand the geographic data and the related metadata provided by either the producer or the distributor. Metadata is stored and accessed through metadata catalogues [10] that are usually implemented according to OGC Catalogue Services (CAT) specification [11] by OpenGIS consortium. This specification can be implemented using different information models among which is ISO 19115 (OpenGIS Catalogue Services ISO Metadata Application Profile [12]).

Spatial metadata can also be expressed using OASIS ebXML Registry Information Model [13]. In order to support this information model OGC has developed ebRIM profile of CAT [14] which uses ebRIM as catalogue information model over standard OGC CAT interface (ebRIM profile for Earth Observation Products is specified in [15]). This information model specifies how catalogue content is structured and interrelated. It constitutes a public schema for discovery and publication purposes. The ebXML Registry is capable of storing any type of electronic content such as XML documents, text documents, images, sounds and videos. The ebRIM uses several standard classification schemes as a mechanism to provide extensible enumeration types which are used to create classifications or ontologies for the catalogue content. The ebRIM information model is a general and flexible one with several extensibility points. A set of extensions that address the needs of a particular application domain or community of practice may be defined. The ebRIM is more generic and flexible than ISO 19115 and may contain various contents which is not specifically indented for geospatial data, and in that way the relationship between GIS and non-GIS systems is provided. For this reason, OGC has proclaimed it for the recommended application profile. An example of metadata in ebRIM format, namely ebRIM profile for Earth Observation (EO) Products is shown in Listing 2.

```
<adsHeader><!--Information that applies
to the entire data set-->
    <missionId>S1A</missionId> <!--
Information about sensor. Sentinel 1-->
    <productType>GRD</productType><!--
Ground Range Detected product type-->
    <polarisation>VH</polarisation>
       <!—Radar  polarisation-->
    <mode>IW</mode>   Interferometric <!-
-Wide Swath mode-->
    <swath>IW</swath>
    <startTime>2014-10-
05T16:33:15.005782</startTime><!--
Beginning of acquisition-->
    <stopTime>2014-10-
05T16:33:40.004681</stopTime><!--End of
acquisition-->
<absoluteOrbitNumber>2697</absoluteOrbitN
umber><!--Absolute orbit number considers
the orbits elapsed since the first
ascending node crossing after launch. -->
<missionDataTakeId>12340</missionDataTake
Id><!-- Mission ID-->
    <imageNumber>002</imageNumber><!--
Delivered image number. 001 is for other
image with VV polarisation (VV-VH,dual
polarisation). -->
</adsHeader>
```

Listing 2. Metadata describing Sentinel data according to ebRIM profile for EO

The difference between ISO 19115 and ebRIM metadata can be summarized as the choice between generality and simplicity. ISO 19115 defines a detailed structure of the content of metadata for geospatial data and services. This allows better interoperability, but limits metadata to what can fit inside the ISO model. On the other hand, ebRIM allows the description and storage of the various content and data structures. ebRIM is more powerful in terms of flexibility, but is less strong as the data model specification, given that the use of ebRIM model is not sufficient to agree on the representation of metadata and achieve interoperability. Therefore, the choice between ISO and ebRIM model is a choice between simplicity and consistency on the one hand, and the expressiveness and flexibility on the other. This generality and flexibility is the reason why ebRIM is recommended by OGC for storing metadata.

Metadata catalogues may facilitate retrieval of the open data. However, the retrieval of the data is only based on keyword-based search, and the part concerning the semantics of the data is still missing and the user is not able to see the details about underlying data model. Retrieval of the data should consider feature attributes which can be spatial, thematic, qualitative and temporal. Although application schema may be referenced in metadata set, the problems of heterogeneity of formats for its representation, as well the meaning of schema elements persist and therefore it is not suitable for the any kind of automatic processing.

Record orientation of catalogues as in ISO 19115, is a clear user / client paradigm but it is hard to maintain and limited for complex metadata relationships. A registry model makes catalogs easier and more flexible to maintain, but it is rather complex when exposed to the clients. ebRIM allows the classification of data and services into categories which only partially solves the problem of semantics by introducing taxonomy, but non-taxonomic relationships are hard to maintain. Possible solution for the problem is the introduction of formal ontologies, namely OWL, a semantic markup language for the web [16]. OWL is also proposed by OGC as the information model for CAT in OWL Application Profile of CAT [17]. An example OWL class `SentinelPlatform` representing Sentinel platform, a subclass of SatelitePlatform is shown in Listing 3. It contains many properties including, stripmap, interferometric wide swath, wave mode, extra wide swath, etc.

```
eo:SentinelPlatform
  a owl:Class ;
  rdfs:subClassOf eo: SatellitePlatform;
  rdfs:subClassOf
    [ a owl:Restriction ;
      owl:allValuesFrom eo:WaveMode;
      owl:onProperty eo:hasWaveMode
    ] ;
  rdfs:subClassOf
   [ a owl:Restriction ;
     owl:onProperty eo:hasWaveMode;
     owl:someValuesFrom eo:WaveMode
   ]
rdfs:subClassOf
    [ a owl:Restriction;
      owl:allValuesFrom eo: Stripmap;
      owl:onProperty eo:hasStripmap
    ] ;
  rdfs:subClassOf
   [ a owl:Restriction;
     owl:someValuesFrom eo: hasStripmap;
     owl:onProperty eo: hasStripmap
   ] ...
```

Listing 3. OWL class SentinelPlatform

V. CONCLUSION

New technologies provide construction of smaller platforms and therefore the price of construction is decreasing. Furthermore, competition in space is also one of the parameters that can lower the price of commercial images. RapidEye constellation of five platforms is one example of light and cheaper platform that was sent to space. It is also possible in the future that the constellation will have much more satellites, more than 5. One platform can carry more sensors with different spatial, radiometric, spectral and temporal resolution. Example is Terra platform (NASA) which carries 5 sensors with different properties. Future work of scientist from this field is 'smaller and cheaper' and they strive towards developing such platforms (Skybox, Planet Labs) [18]. It is planned that data from these platforms be free for academic and non-profit researches.

One of the conclusion is that the EC decided to send significant number of remote sensing satellites in space. The data which will be delivered free of charge will be different (products, multispectral images, radar images) and will often be combined with other platforms such are USGS platforms.

Increasing number of sensors in space means more and more data to process, analyze and use in different fields. People need to be educated for this.

In this paper we have introduced the meaning of semantic metadata for EO products. Future work will be to clearly and fully describe, display and analyze the semantic metadata for Earth Observation products.

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