SUMMARY OF CURRENT AND FUTURE TERRESTRIAL CIVILIAN HYPERSPECTRAL SPACEBORNE SYSTEMS

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ABSTRACT

This paper provides an overview of current and future civilian hyperspectral spaceborne systems for terrestrial applications. For this purpose, a brief history of hyperspectral mission initiatives is given together with the spectral and spatial characteristic of current systems in orbit today. Future sensor systems are divided into missions, which are under development and in a planning stage. The latter category provides a good cross section of sensor systems to come, but is probably not a complete list of hyperspectral instruments considered by the various space agencies.

Index Terms— Hyperspectral, past hyperspectral initiatives, current and future spaceborne missions, spectral and spatial characteristics.

1. INTRODUCTION

Terrestrial hyperspectral spaceborne mission application initiatives started in the early 1990's with NASA's High Resolution Imaging Spectrometer (HIRIS) [1] and ESA's High Resolution Imaging Spectrometer (HRIS) [2], followed by the Australian Resource Information and Environment Satellite (ARIES) [3]. Unfortunately, these missions did not make it out off the design phase (Phase A) into the detailed design and building phases. Other never-built initiatives included missions such as the Process Research by an Imaging Space Mission (PRISM) and Surface Process and Ecosystem Changes Through Response Analysis (SPECTRA) from ESA [4, 5], Hyperspectral Environment and Resource Observer (HERO) from the Canadian Space Agency (CSA) [6], Hyperspectral Earth Observer (HypSEO) from the Italian Space Agency (ASI) [7], and FLORA (not an acronym) from NASA [8]. Only two initiatives led to successful missions, which were built and successfully launched: NASA's Hyperion [9] and ESA's Compact High Resolution Imaging Spectrometer (CHRIS) [10] in 2000 and 2001, respectively. The success of these technology demonstrators led to more sophisticated sensor initiatives, such as the Environmental Mapping Program (EnMAP) from the Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences and German Aerospace Centre [11], Hyperspectral Precursor of the Application Mission (PRISMA) from ASI [12], and the Hyperspectral Infra-Red Imager (HyspIRI) from NASA [13]. Some of these are still in a Phase A stage, but, for example, EnMAP and PRISMA have progressed into the detail design and building stages. These new initiatives for land and water applications will be reviewed in this paper together with hyperspectral spaceborne missions currently operating in space. Moreover, an outlook will be given about possible civilian hyperspectral missions operating in space in the 2015/16 and 2020 time frames.

2. CURRENT MISSIONS

Major spectral and spatial characteristics of the terrestrial hyperspectral mission operating in space today are summarized in Table 1. With the exception of the Chinese HJ-1A [14], these missions were all designed to demonstrate the hyperspectral technology from space and as such have a limited data acquisition capability. Even with data quality issues, both Hyperion and CHRIS have contributed significantly to the development of space-based hyperspectral technologies and advanced hyperspectral applications in areas such as geology, agriculture, forestry and coastal/inland waters. In 2012, these missions are now well beyond their expected life time and a replacement is urgently needed. Although launched in 2008, HJ-1A and the Indian HySI are not really replacements for Hyperion and CHRIS because their spatial ground sampling distance (GSD) is larger (≥ 100 m) and, therefore, focus on different applications. The latest imaging spectrometer instrument in space is NASA/Office of Naval Research's (ONR's) Hyperspectral Imager for the Coastal Ocean (HICO) on the International Space Station [15]. With a 90-m GSD it is mainly focused on coastal applications. Table 1 does not include the ESA's Medium Resolution Imaging Spectrometer (MERIS) [16]. Although MERIS was

Table 1: Current hyperspectral spaceborne missions.

Sensor	**Hyperion**	**CHRIS**	**HySI**	**HJ-1A**	**HICO**
Country and Organization	USA NASA	UK ESA	India ISRO	China CAST	USA NASA/ONR
GSD (m)	30	17/34	506	100	90
Swath at Nadir (km)	7.65	13 (nominal)	129.5	≥50	42
Wavelength Coverage (nm)	357-2576	400-1050	400 - 950	450 - 950	353 - 1081
Number of Bands	242	18/37/6	64	110 - 128	128
Spectral Res. (nm @ FWHM)	10	5.6-32.9	~ 10	5	5.7
Launch Date	2000	2001	2008	2008	2009

technically an imaging spectrometer, it collected only a number of pre-defined bands scattered across the wavelength range from 390 nm to 1040 nm.

3. FUTURE MISSIONS

Future missions can be divided into the *fully funded* and *planned* categories. The former category includes missions which are fully approved and are in the design (Phase B) or building phases (Phase C/D), while the latter category refers to missions which are only in the design (Phase 0/A) stage.

Table 2 summarizes the missions which are currently in funded development or are ready for launch. EnMAP and PRISMA have fundamentally similar spectral and spatial sensor characteristics to those of Hyperion, but will have superior data quality and increased data acquisition capacity. The difference between the former two is that PRSIMA has in addition to the hyperspectral sensor a panchromatic instrument onboard. Although the Multi-Sensor Microsatellite Imager (MSMI) sensor [17] is built and ready for launch, the launch situation is not clear because the mission has been de-scoped.

There are several hyperspectral space missions in the planning stage in many countries, and only examples are listed in Table 3. HyspIRI [13] is a global mission and is listed in the NASA's Tier-2 Decadal Survey Mission, planned for implementation in 2013 – 2016. Unlike HyspIRI, the Japanese Hyperspectral Imager Suite (HISUI) [18] and the French HYPXIM [19, 20] sensors are targeting missions with spectral characteristics like those of Hyperion. HISUI will be on onboard the ALOS-3 platform together with a panchromatic camera and will be launched in 2015 or beyond. The same combination of sensors is also planned for HYPXIM-C (Challenging), while the 8-m HYPXIM-P (Performance) will have a thermal hyperspectral sensor added to the hyperspectral / panchromatic instrumentation suite. A third concept studied by CNES is the HYPXIM-CA (Challenging Advanced), an advanced sensor with 15-m GSD and 30-km swath width compared to HYPXIM-C with a 15-m GSD and 15-km swath width. These three HYPXIM instrumentation concepts are studied by CNES for use on micro-satellite platforms. Another proposed mission with a hyperspectral VNIR instrument on board is the FLuorescence EXplorer (FLEX), which was selected by ESA towards the end of 2010 for further study (Phase A/B1) [21]. Its main goal is to provide global coverage of chlorophyll fluorescence of vegetation canopies. Moreover, the Indian Space Research Organization (ISRO) has recently launched a 5-year hyperspectral program with the development of hyperspectral space technologies. They proposed a few hyperspectral instrument concepts, such as the HYSI-VNIR with 150 bands in the 750-nm to 1300-nm wavelength region and HYSI-SWIR with 60 bands in the 1300-nm to 3000-nm range [22]. The spatial resolution with 192 m for the VNIR and 320 m for the SWIR sensors is similar to FLEX and is coarser than for the other planned hyperspectral instruments. Other missions worth mentioning include EnMAP-2 and a hyperspectral instrument on KOMPSAT-6.

4. MISSION SCENARIOS

2015/16: EnMAP and PRISMA should be in orbit and acquire data on an on-going basis. In addition, India (ISRO) should have launched a hyperspectral instrument within that time frame as an outcome of its hyperspectral program. China has also an active hyperspectral program and a second Chinese hyperspectral mission could emerge towards 2015/16. Accordingly, three to four hyperspectral missions could be in space to replace the current aging systems and deliver data, which are desperately needed by the remote sensing community to cover its data demand.

2020: Several next-generation hyperspectral instruments such as HYPXIM (expected launch: 2019), EnMAP-2 (1919/20), HyspIRI (> 2015), HISUI-ALOS-3 (> 2015) and FLEX (2018) could be in space at that time. It is important that some of these or other initiatives in the planning stage today or in the future have to be realized to guarantee continued hyperspectral data coverage in 2020 and beyond.

With these hyperspectral mission developments, a specific emphasis has to be put on the processing and analysis of data. A significant increase in the data processing capacity needs to happen for an efficient analysis of the huge data volume generated from those systems. Such an

Table 2: Hyperspectral missions currently under construction or ready for launch.

Sensor	**EnMAP**	**PRISMA**	**MSMI**
Country and Organization	Germany GFZ/DLR	Italy ASI	S. Africa SunSpace
GSD (m)	30	30	~15
Swath at Nadir (km)	30	30	~ 15
Wavelength Coverage (nm)	420 - 2450	400 - 2500	440 - 2350
Number of Bands	218	237	200
Spectral Res. (nm @ FWHM)	5/10 VNIR 10 SWIR	~12	10
Launch Date	2015	2013/14	?

Table 3: Examples of hyperspectral missions in the planning stage.

Sensor	**HyspIRI**	**HISUI-ALOS-3**	**HYPXIM CA**
Country and Organization	USA JPL, NASA	Japan METI	France CNES
GSD (m)	60	30	15
Swath at nadir (km)	145	15	30
Wavelength Coverage (nm)	380 – 2500	400 - 2500	400 - 2500
Number of bands	> 200	185	> 200
Spectral Res. (nm @ FWHM)	10	10 VNIR 12 SWIR	≤ 14 VIS ≤ 10 NIR/SWIR
Launch Date	> 2015	≥ 2015	~ 2019

initiative has to come or be at least heavily supported from/by the government agencies, which generally develop and launch hyperspectral missions and distribute the data acquired with those missions.

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