

# THE EMERGENCE OF IMAGING SPECTROMETRY IN EUROPE

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## ABSTRACT:

In 1984 the European remote sensing research community became aware of Imaging Spectrometry. AIS, the Airborne Imaging Spectrometer of JPL had been tested from 1982 onwards and AVIRIS became operational in 1989. The paper describes how MONITEC with their FLI/PMI enabled first IS flight campaigns (EISAC-I) in Europe, which were followed by experiments with AVIRIS, CASI and later the GER-7915 called DAIS. Numerous flight campaigns were conducted by DLR, VITO, NERC, INTA and others. Commercial companies offered and are still offering flight opportunities with airborne instruments. Specim and NEO are successfully supplying commercial systems to the market. The satellite projects HIRIS, GEROS, HRIS, PRISM, SPECTRA and others resulted finally in MODIS and MERIS as well as CHRIS-PROBA and Hyperion. Future projects include among others ENMAP, PRISMA, FLEX and HypSIRI.

## 1. INTRODUCTION

In 1984 the European remote sensing research community at large became aware of Imaging Spectrometry at the ERIM Symposium in Paris. AIS, the Airborne Imaging Spectrometer of JPL had been tested from 1982 onwards and AVIRIS was in its development with first flights in 1986 and fully operational in 1989. This Paris conference set the pace for a high interest in IS in Europe.

My view on the emergence of imaging spectroscopy in Europe is based on early sensor deployment in Europe, sensor development and availability in Europe, and the development of the EARSeL SIG Imaging Spectroscopy in Europe. Emphasis is put on land applicable systems, air- and spaceborne.

## 2. THE PREPHASE IN THE US AND CANADA

AIS-1 and AIS-2 were the first operational airborne imaging spectrometers built by NASA JPL. Their spectral ranges revealed their prime operational interest, the detection of minerals. Famous became the investigations at the Cuprite test site. The somewhat limited spectral range and the number of across track pixels were enlarged with AVIRIS, a whiskbroom airborne imaging spectrometer with four spectrometer channels, initially planned for the range of 400 – 2450 nm. Its robust design was very successful and still as of today represents the best performing instrument worldwide. It has been improved over the years to offer today a range of 380 - 2500 nm, well calibrated data and an exceptionally good SNR over the total wavelength range. Any new instrument developer will have to measure up to this imaging spectrometer, that has now served over 20 years (Vane et al, 1984).

In Canada Monitec Ltd had developed its FLI/PMI in the mid-eighties, while CCRS

was developing SFSI. FLI/PMI and AVIRIS both had an enormous impact on the development of imaging spectroscopy in Europe.

Table 1. Early airborne imaging spectrometers

AIS-1 (NASA, JPL) 128 Bands, 900-2400 nm, 32 acr. track pixels AIS-2 (NASA, JPL) 128 Bands, 800-2400 nm, 64 acr. track pixels AVIRIS (NASA, JPL) 224 Bands, 400-2450nm, 614 acr. tr. pixels FLI/PMI (ITRES, CA) 8/288 Bands, 430-805 nm, 2.5 nm spectr. res. SFSI (CCRS, CA) 122 Bands, 1200-2400 nm, 10 nm spectr. res.
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### 3. SPILLOVER INTO EUROPE - the first airborne flight campaigns

FLI/PMI of Moniteq Ltd was flown in Europe in 1986 by DFVLR (DLR) on its Do-228. A fully fledged campaign called EISAC in 1989 covered the following test sites: Skagerak, Sylt, Helgoland, Venice, Sacca di Goro, Freiburg, Somerset, Almadén and Ardèche (Bodechtel et al 1994).

AVIRIS was deployed in the MacEurope campaign in 1991 (NASA-ARC, 1991). The system was flying on the NASA ER-2 and covered test sites in Germany, The Netherlands, France, Iceland, Italy, England, Spain, Austria, Wales and Switzerland.

These campaigns were the take-off for the European research in imaging spectroscopy. From ESA officials and the early user community a quest for further systematic campaigns for the development of a research capacity in Europe was fostered. It became however more and more difficult to get for instance AVIRIS over the Atlantic. Its deployment by the ER-2 was too complex and very costly as well. Therefore a strive for independence emerged, leading to the acquisition of commercial systems (CASI, DAIS), to plans for the German ROSIS, later also to the ESA PRODEX project APEX, and to initial commercial industrial plans.

At the same time basic research in spectroradiometry and field goniometry continued and set the scene for upcoming flight opportunities.

## 4. EUROPE ON ITS OWN, ACQUIRED SYSTEMS AND FIRST DEVELOPMENTS

DLR announced its plans for ROSIS in 1986. The push broom instrument offering 128 bands between 450-850 nm became operational in 1992 and was continuously upgraded until today (Holzwarth et al 2003). ITRES (CA) had developed its CASI suite of instruments based on the experience with FLI/PMI. It successfully sold several instruments to European research establishments and customers. Among others early customers were NERC, Prof. Fischer at University of Berlin, Mrs. Mücksch etc..

DARA/DLR ordered a GER-7915, later called DAIS at GER Corp. This instrument was offered in 1996 as large scale facility instrument to European researchers, and served as testbed in a big number of international flight campaigns. It was owned and operated by DLR until 2002 when higher SNR's were asked for (see Table 4).

With the experience from building multi-spectral scanners such as the TMS, Daedalus developed MIVIS and sold systems to Italy (CNR) and Spain (INTA). The latest member of that family is the AHS (one system operated by INTA)

Table 2. Early development and acquired systems

ROSIS (DLR-development) CASI-1 (ITRES) operated by NERC et al CASI-2 operated by NERC et al DAIS-7915 (GER) operated by DLR MIVIS (Daedalus) operated by CNR (I) and INTA (ES) AHS operated by INTA (ES)
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### 4.1 Rented airborne systems for campaigns and European industrial developments

Since 1998 DLR rented HyMap from Integrated Spectronics (AU) systematically for their flight campaigns. The system was

operated by HyVista and flown by DLR, often as an alternative and backup to DAIS.

A very big number of flights were executed in the years 2003 to 2007 in the so called HyEurope campaigns.

In Norway „Norsk Elektro Optikk (NEO)“ developed its HySpex suite of instruments while in Finland „Specim“ developed AISA (Eagle and Hawk). These rugged grism-based instruments were a tremendous commercial success with more than 50 units sold world-wide by early 2009.

Based on the early experience with FLI/PMI and especially AVIRIS, RSL of the University of Zurich in 1995 proposed the development of APEX to ESA as a future European simulator and testbed for planned spaceborne hyperspectral missions. In a joint Swiss-Belgian endeavour a consortium of Scientific Institutes (RSL and Vito) and industry (RUAG Aerospace, OIP, Netcetera) started the planning and development. In late 2008 the first testflights took place; the instrument shall be operational in 2009/2010. It allows to acquire 300 to 500 bands in the range of 380 – 2500 nm, and offers user programmable binning for optimized SNR.

In a strive to respond to users DLR has ordered ARES from Integrated Spectronics with enhanced performances in the thermal infrared. It will become operational in 2010 as well.

Table 3. Rented systems, orders and European industrial developments

HyMap (IS), rented / operated by HyVista flown by DLR 125 Bands, 16 nm spectral res.
HySpex (VNIR-1600) developed by NEO(NO), 160 Bds
AISA developed by Specim (FI)
-AISA Eagle
-AISA Hawk
APEX developed by RUAG/OIP/Netcetera (CH, BE) for ESA - first testflights in 2008
ARES devel. by Integrated Spectronics, ordered by DLR

## 4.2 Major airborne campaigns

As example we show here the big efforts of DLR in offering flight campaigns to the international user community.

Table 4. DLR airborne projects and campaigns 1996 - 2007

Large Scale Facility	1996 – 1998	DAIS	21 User Groups
DAISwiss	1996 – 1997	DAIS	8 Flightstrips
PROSMART	1998 – 1999	HyMap D + CH	
HyEurope	1999	HyMap	20 User Groups
		+ DAIS	
Sotiel	1999	DAIS	
DAISEX	1998 – 2000	DAIS	a.o. “Barrax”
			+ HyMap
Donana	1998 – 2000	DAIS	
HySens	2000 – 2002	DAIS	
		+ ROSIS	
HyEurope	2003-05/07	HyMap	59 Flights”

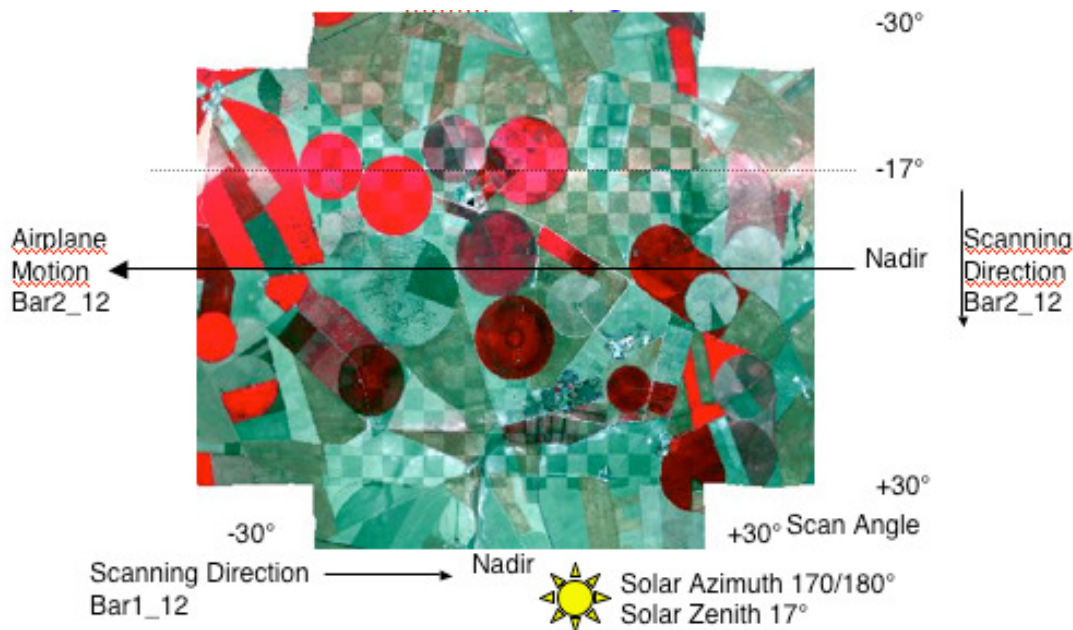


Figure 1. Example of the famous DAISEX “Barrax” Campaign, data from 1999 (Beisl,2001)

Systematic campaigns were also flown by Vito in 2002, 2003, 2004, 2005 and 2007) as well as yearly campaigns by NERC and by INTA.

(GER, US), HRIS-, PRISM-, Spectra (all ESA), SIMSA and SAND (DE). Especially HIRIS led to many ideas worldwide because it clearly set the scene for the big importance of imaging spectroscopy from space for studies of the earth ecosystems.

None of the above projects were realized, but out of these discussions the medium resolution systems MODIS and MERIS on Terra-1 and Envisat-1 emerged and Hyperion on EO-1 and CHRIS on PROBA were developed as testbeds for high spatial resolution imaging spectrometers.

Imaging Spectroscopy Flight Campaigns										
Flight	2002	2003	2004	2005	2007	Links				
Flight Campaign 2007 - Quicklooks										
AHS										
Acquisition Date	Scene Title (Click on Name for Quicklook)	Location	Acquisition time (UTC)	Coordinates Flightlines (UTM/WGS84)		Altitude (feet/m, AGL)	Nr of bands	Resolution		
02/06/2007	<a href="#">Kalmthout 1.8</a>	Kalmthoutse heide (B)	08:52	595447	5697258	604784	5688213	3300FT	80	2.7x2.7m
02/06/2007	<a href="#">Kalmthout 1.9</a>		09:02	595811	5697622	605148	5688576	3300FT		2.9x2.9m
02/06/2007	<a href="#">Kalmthout 1.20</a>		09:11	596177	5697987	605513	5688941	3300FT		2.6x2.6m
02/06/2007	<a href="#">Kalmthout 1.41</a>		09:21	596540	5698352	605877	5698307	3300FT		2.6x2.6m
02/06/2007	<a href="#">Kalmthout 1.54</a>		09:30	596905	5699670	606242	5698716	3300FT		2.3x2.3m
02/06/2007	<a href="#">Kalmthout 1.63</a>		09:39	597270	5699081	606608	5690035	3300FT		2.4x2.4m
08/06/2007	<a href="#">Hul 11</a>	Molse meren (B)	08:50	645121	5676541	657376	5677781	3300FT	80	7.3x7.3m
12/06/2007	<a href="#">IJzer 16</a>	IJzer Nieuwpoort (B)	15:08	479705	5665727	483532	5666882	3300FT	80	3.0x3.0m
12/06/2007	<a href="#">IJzer 17</a>		15:16	479857	5665223	483684	5666379	3300FT		3.0x3.0m
23/08/2007	<a href="#">Calabria 01(P01)</a>	Calabria (IT)	10:07	627067	4407503	627067	4399553	3400FT	80	2.0x2.0m
23/08/2007	<a href="#">Calabria 02(P02)</a>		10:14	625692	4407504	625693	4399552	3400FT		2.0x2.0m
23/08/2007	<a href="#">Calabria 03(P03)</a>		10:24	624319	4407754	624320	4399309	3400FT		2.0x2.0m
23/08/2007	<a href="#">Calabria 04(P04)</a>		10:33	622947	4408990	622947	4398562	3400FT		2.0x2.0m

Figure 2: example of Vito campaign quick-look access

## 5. SPACEBORNE SYSTEMS

The “early” spaceborne planning phase in the US and Europe comprised, among others, the following projects: HIRIS (NASA), GEROS

## 6. TODAY'S HYPERSPECTRAL SYSTEMS AVAILABLE IN EUROPE FOR RESEARCH AND DEVELOPMENT

In summary a great variety of airborne imaging spectrometers are available for flight campaigns in Europe. Either commercial companies offer services or national research establishments and universities operate their own systems. As outlined earlier the following instruments can be accessed:

Table 5. Available airborne instruments in Europe

ROSIS (DLR) CASI-1 / CASI-2 / CASI 1500 (NERC, U. Berlin, et al) AISA EAGLE / AISA HAWK (over 50 systems sold) HySpex (NEO) MIVIS (CNR, INTA) AHS (INTA) APEX (ESA, RSL, Vito) 2009/2010 operational ARES (IS, DLR) 2010 operational
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For spaceborne research and applications the international user community can easily access the current imaging spectroscopy data from MODIS, MERIS, Hyperion and CHRIS. An important development was the improved and eased access to data and products (especially from the MODIS and MERIS systems). Well defined and documented products are used worldwide by agencies, research establishments and organisations, which may not primarily be involved in remote sensing, but heavily depending on the results and products coming from those systems. The gap between the remote sensing specialists and a broader user community could therefore be well overcome or shortened.

## 7. SOME FUTURE SPACE PROJECTS

As national initiatives the German EnMAP project is currently in phase C/D and bound to be launched in 2012/13. With a similar timetable the Italian system PRISMA is currently under development.

ESA will launch the superspectral Sentinel-2 and later a MERIS follow-on imaging spectrometer mission Sentinel-3 which is currently planned for a launch in 2012.

NASA is discussing plans for HypIRI in continuing the efforts started with Hyperion.

## 8. THE EMERGENCE OF IMAGING SPECTROSCOPY IN EUROPE – an EARSeL perspective

EARSeL was founded in 1977. Based on the emergence and improved access and availability of imaging spectrometry data, as outlined in the chapters before, an EARSeL

Special Interest Group (SIG) „Imaging Spectroscopy“ was established in 1995. It efficiently serves as a scientific platform and brings together scientists in imaging spectroscopy in Europe, and serves also as advisory body to European institutions such as ESA and the EU. In 6 well attended workshops the research and user community gathered so far.

1998 Univ. of Zurich, Zurich, Switzerland

2000 ITC, Enschede, The Netherlands

2003 DLR, Herrsching, Germany

2005 Warsaw University, Warsaw, Poland

2007 Vito, Bruges, Belgium

2009 Tel-Aviv University, Tel-Aviv, Israel

The number of published pages and papers in the proceedings of these EARSeL SIG-IS workshops has increased steadily, with a small dip in 2007 when at the same time the ESA-Envisat Symposium in Montreux and the Bruges Workshop took place. It can be taken as an indicator of the increase in importance of imaging spectroscopy in Europe.

## 9. CONCLUSIONS

Initiated through the US and Canadian early developments, Europe has seen an outstanding growth of its hyperspectral research and its own developments. A few very active centers with their infrastructure enabled europe-wide access to hyperspectral data. Acquired and rented foreign systems allowed an excellent learning phase. European industrial developments and initiatives with non-european partners have increased the airborne system availability tremendously. European hyperspectral space developments in the direction of high spatial and temporal resolution have been slow ... as elsewhere ... but new exciting systems, airborne (ARES, APEX) and spaceborne (EnMap, PRISMA) are being introduced soon. The scientific research and publication record of european scientists has fully taken off, thanks to the early assistance of our overseas friends and the existence of our

Special Interest Group “Imaging Spectroscopy” at EARSeL.

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