APEX – Airborne Prism Experiment

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RSL measurements | products | policy
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APEX – Project Background

1. APEX is a joint Swiss/Belgian project funded under ESA-PRODEX with support from ESA Earth Observation.

2. APEX is an airborne pushbroom dispersive spectrometer for the support and development of future spaceborne Earth Observation systems, supported by a Processing and Archiving Facility (PAF) and a Calibration Home Base (CHB).

3. APEX is able to simulate, calibrate, and validate existing and planned spaceborne optical missions.

4. APEX will foster the use of imaging spectrometer data and will support the application development for imaging spectroscopy products.

APEX: from concept to acceptance

1991 APEX is initiated by Klaus I. Itten

1994 ESA is identified as funding agency

1996 Belgium is asked to join

1998 First instrument concept identified

2001 Requirements, specifications, feasibility studies

2003 Breadboarding activities

...

2006 Critical Design Review

2007 Instrument prototype built

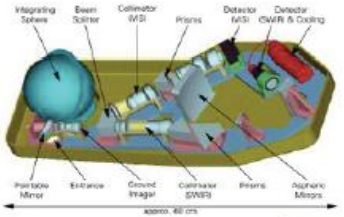
2008, 1st test flight

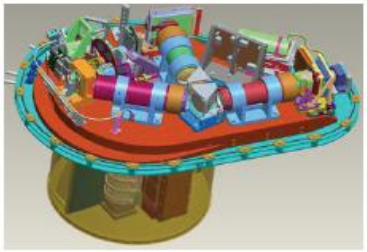
2009 1st Acceptance flight campaign

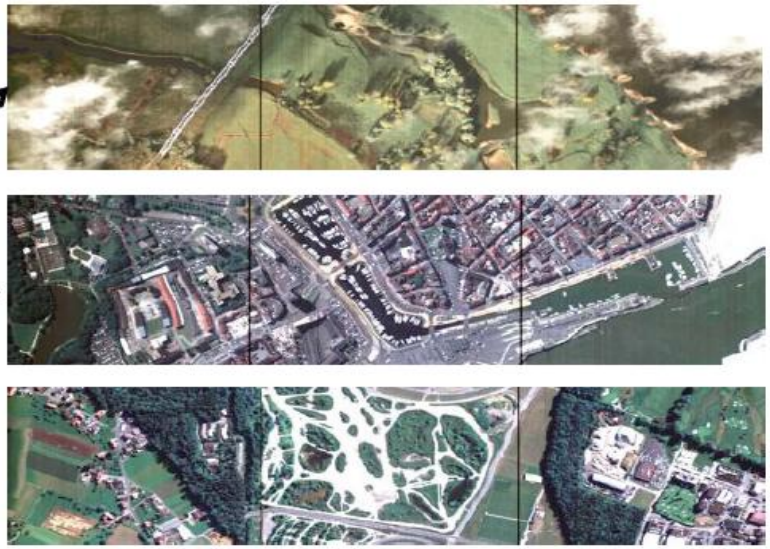
2010 2nd Acceptance flight campaign

Instrument accepted by ESA

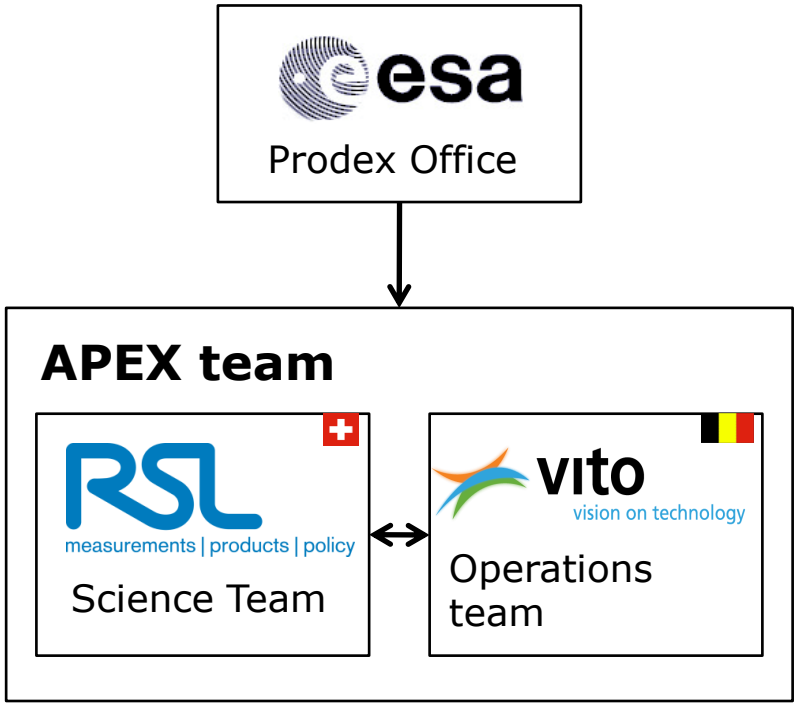
2011-2015 Exploitation Operations







APEX team: organization

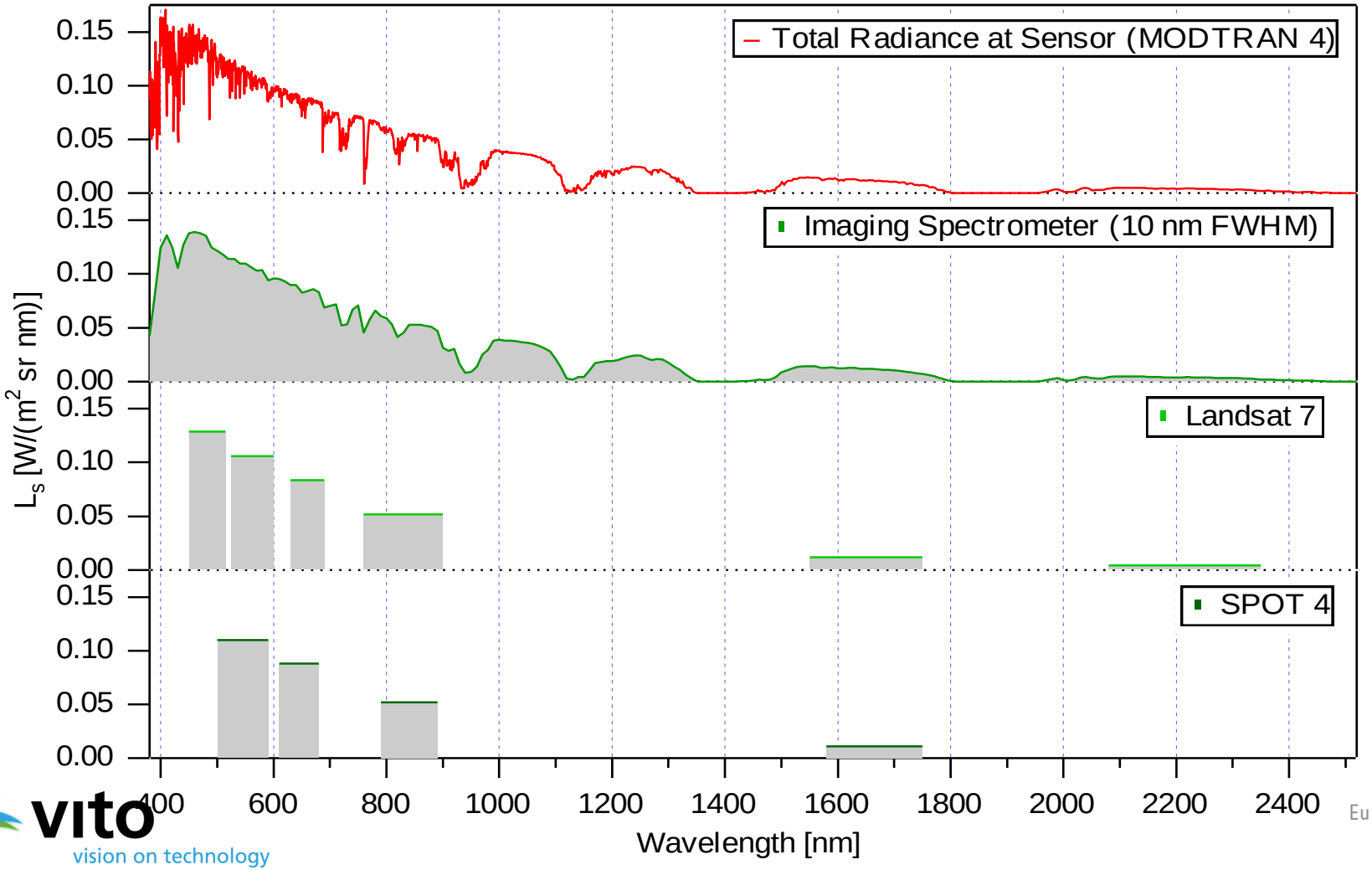


APEX Operations Team based at VITO, Mol,B

Team taks:

a. Flight planning and preparation
b. Aircraft and ATC planning and coordination
c. Instrument Operation and handling
d. APEX Processing and Archiving and Data dissemination
e. Laboratory calibration together with RSL
f. Website

Spectral Data Richness



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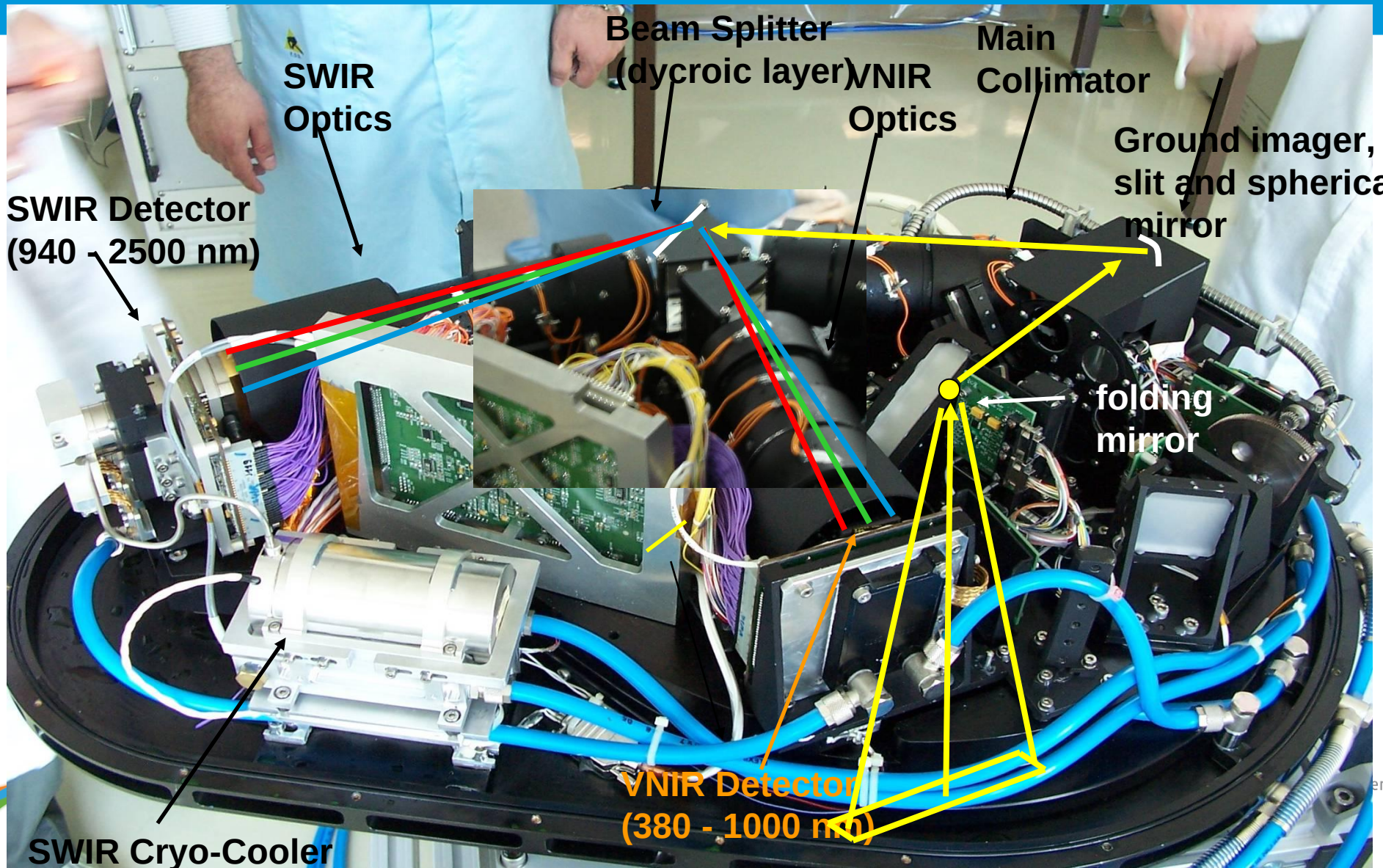
APEX Performance

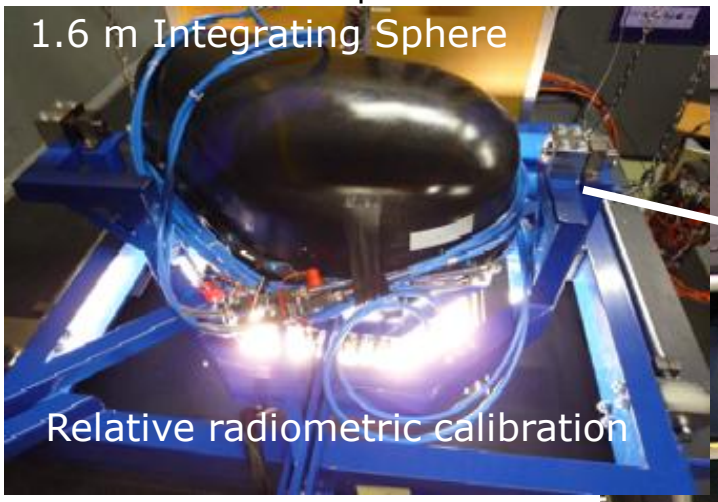
Spectral Performance	**VNIR**	**SWIR**
Spectral Range	380.5 – 971.7 nm	941.2 – 2501.5 nm
Spectral Bands	Up to 334 (default: 114) (number of VNIR spectral rows programmable via binning pattern upload)	198
Spectral Sampling Interval	0.5 ÷ 8 nm (default: 11 ÷ 8 nm)	5 ÷ 10 nm
Spectral Resolution (FWHM)	0.6 ÷ 6.3 nm	6.2 ÷ 11 nm
Spatial Performance		
Spatial Pixels (acrosstrack)	1000	
FOV	28°	
IFOV	0.028° (ca 0.5 mrad)	
Spatial Sampling Interval (across track)	1.75 m @ 3500 m AGL	
Sensor Characteristics		
Type	CCD	CMOS
Dynamic Range	14 bit encoding	13 bit encoding
Pixel Size	22.5 µm x 22.5 µm	30 µm x 30 µm
Smile		0.35 pixel
Keystone (Frown)	Average, less than	0.35 pixel
Co-Registration		0.55 pixel
Other Information		
Data Capacity	500 GB on SSD	
Data Transfer	Spectral frames	30 MB/s via Optical Link
	Housekeeping Data	20 kB/s via Serial Cable
Data rate for default configuration	0.4 GB/km (1250 km max)	

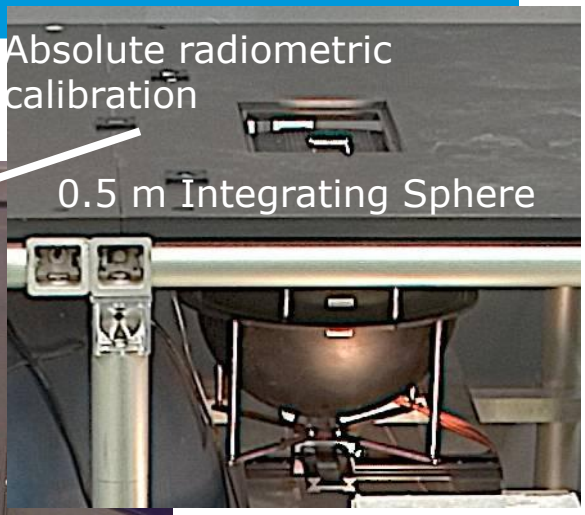
APEX Optical Sub-Unit

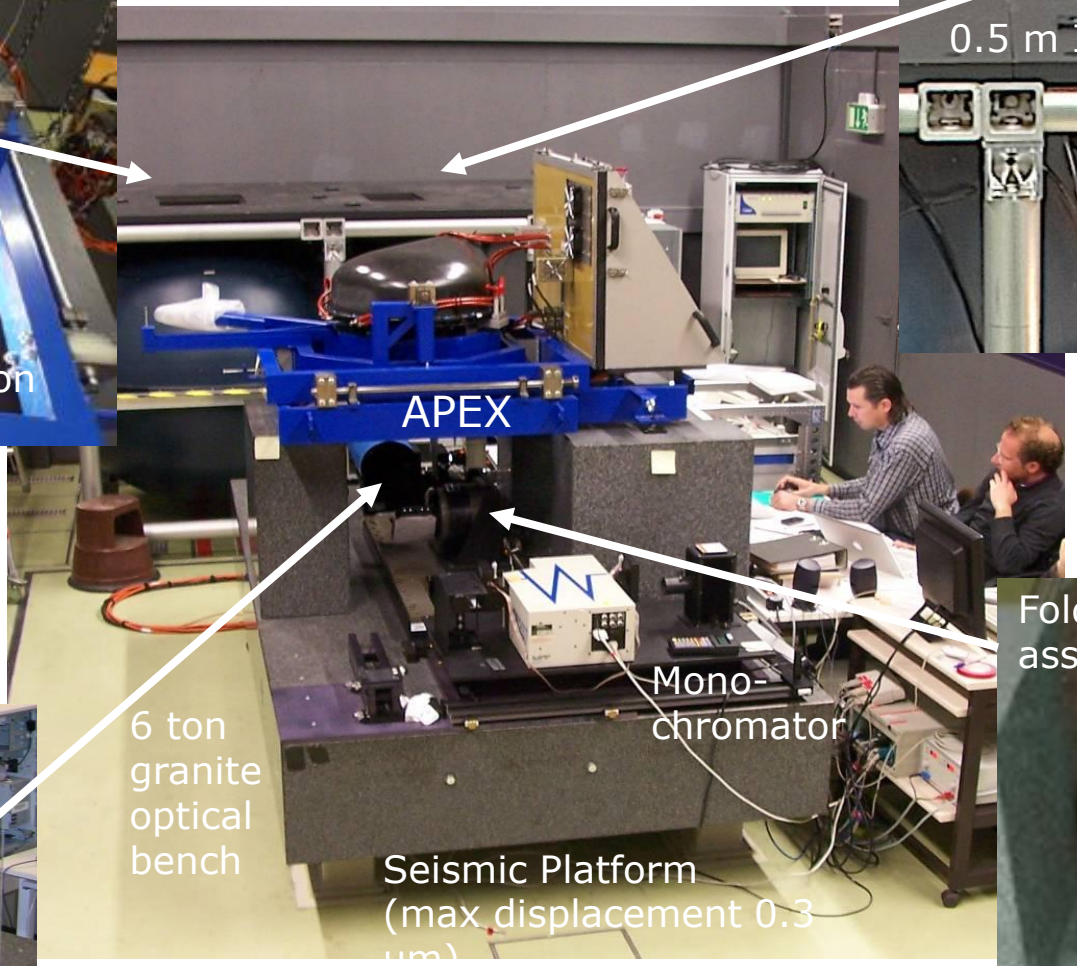


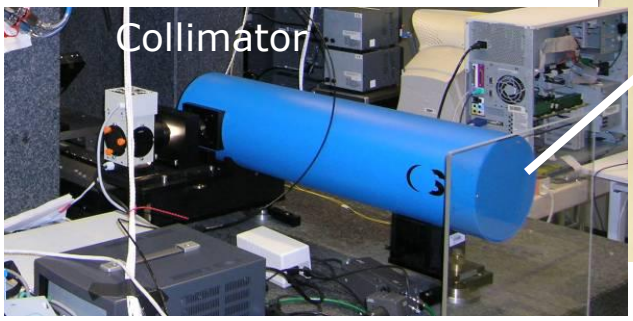
The Calibration Home Base @ DLR München*

* Developed under ESA-EOP Contract;
Status: Acceptance review successful in Jan. 2007



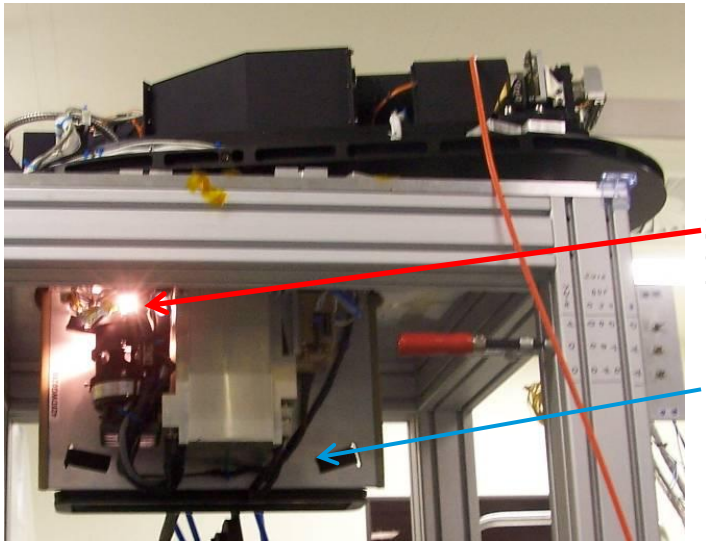


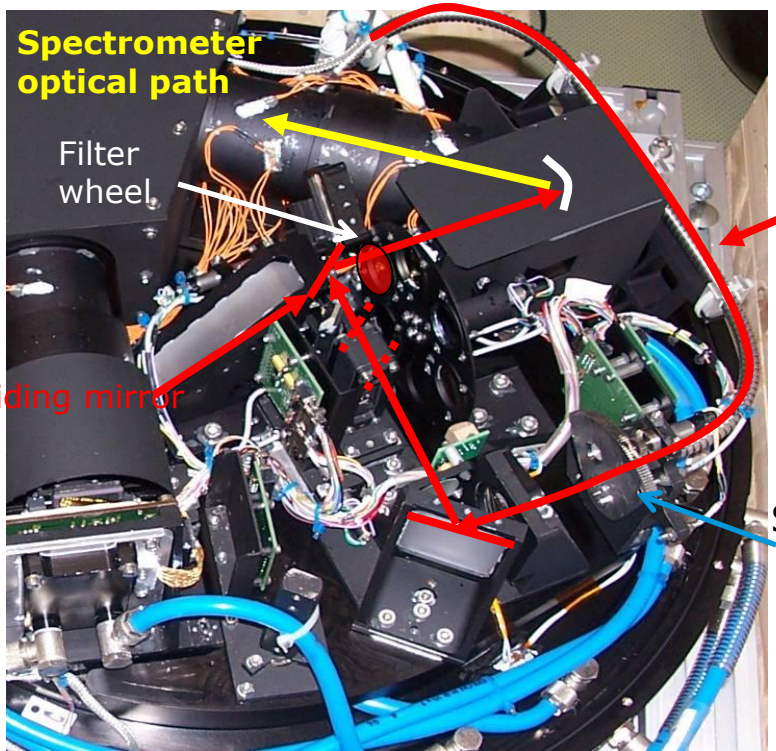




In-Flight Characterization Facility

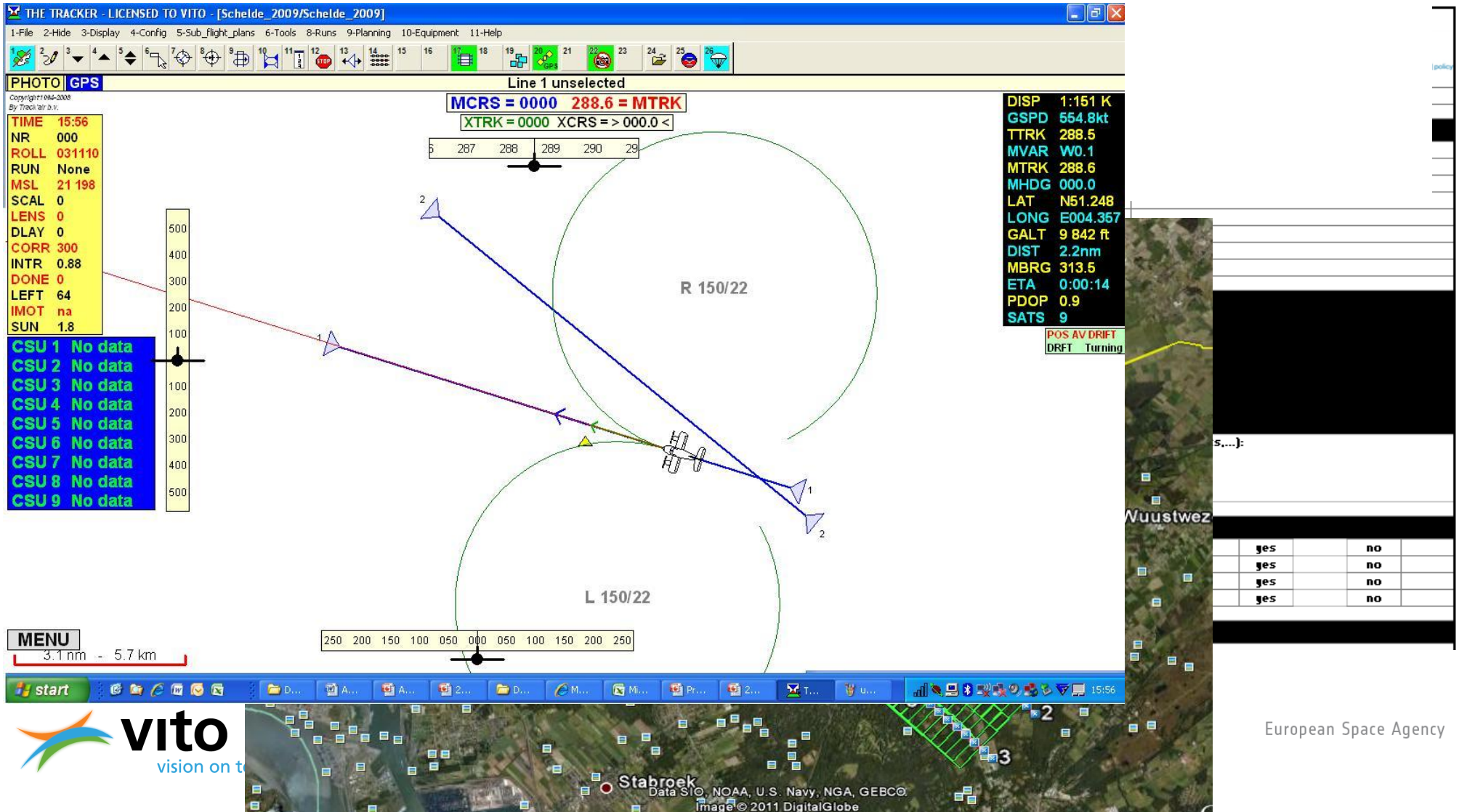
The **IFC** is a tool designed to **investigate** the overall instrument (radiometric, spectral, geometric) **stability** during flight.





Spectral filters:
- 3 Bandpass (color) filters
- 1 Rare Earth Material (NIST) filter
- 1 Neutral Density (grey) filter

APEX Operations - Flight organization and planning - Workflow



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APEX Operations - aircraft installation

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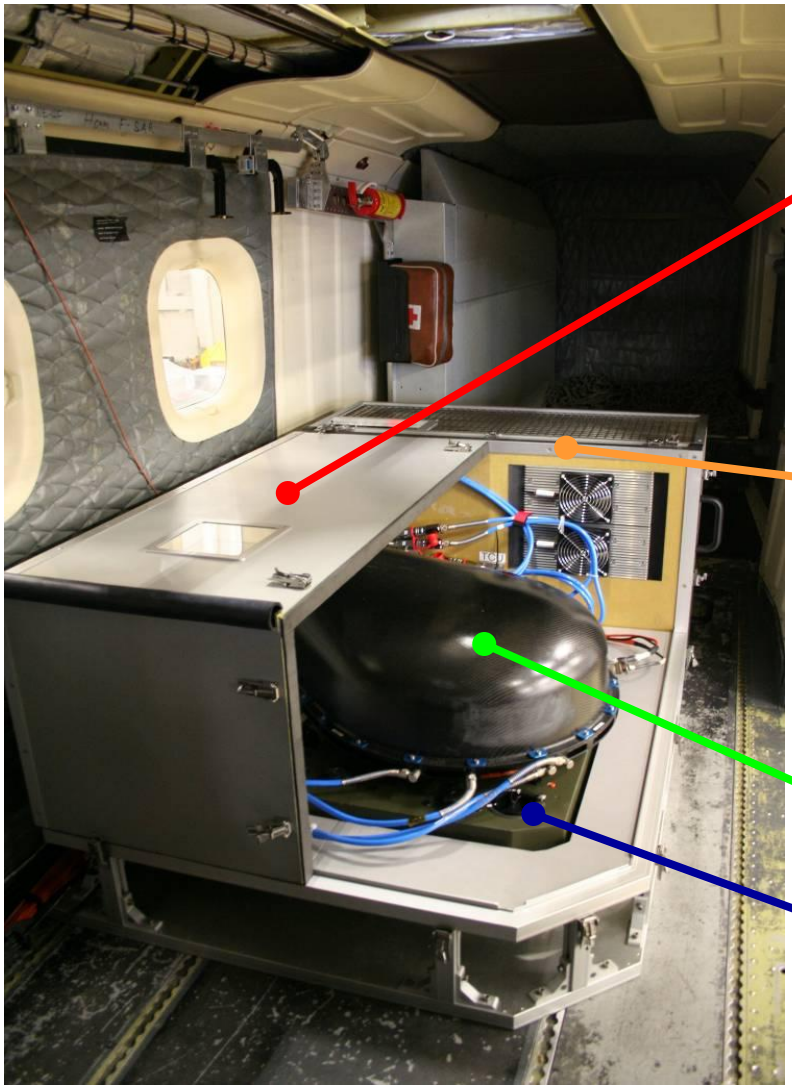
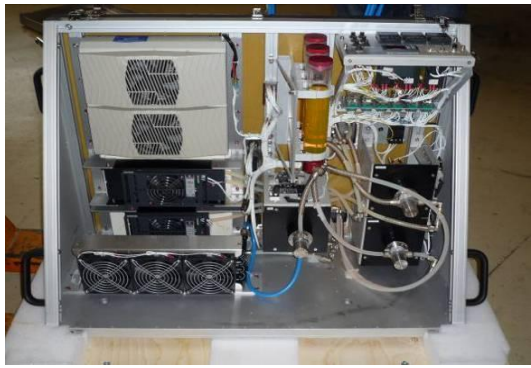
APEX Operations - aircraft installation





APEX Operations - Aircraft

1. APEX is currently certified to fly on DLR's DO-228 aircraft (D-CFFU, certification D-CODE ongoing) → 2 aircraft available
2. Ongoing activities to certify APEX on several other platforms (CAE Aviation – Cessna; DLR Halo – Gulfstream; RUAG – DO-228NG; etc.).
3. Airworthiness certification costs per aircraft range from approx. 40 -100 kEUR depending on type and rules.
4. Export license rules apply for the operation of APEX in certain countries.
5. **EUFAR – European Facility for Airborne Research (www.eufar.net) offers aircraft + APEX within a EC FP7 project.**

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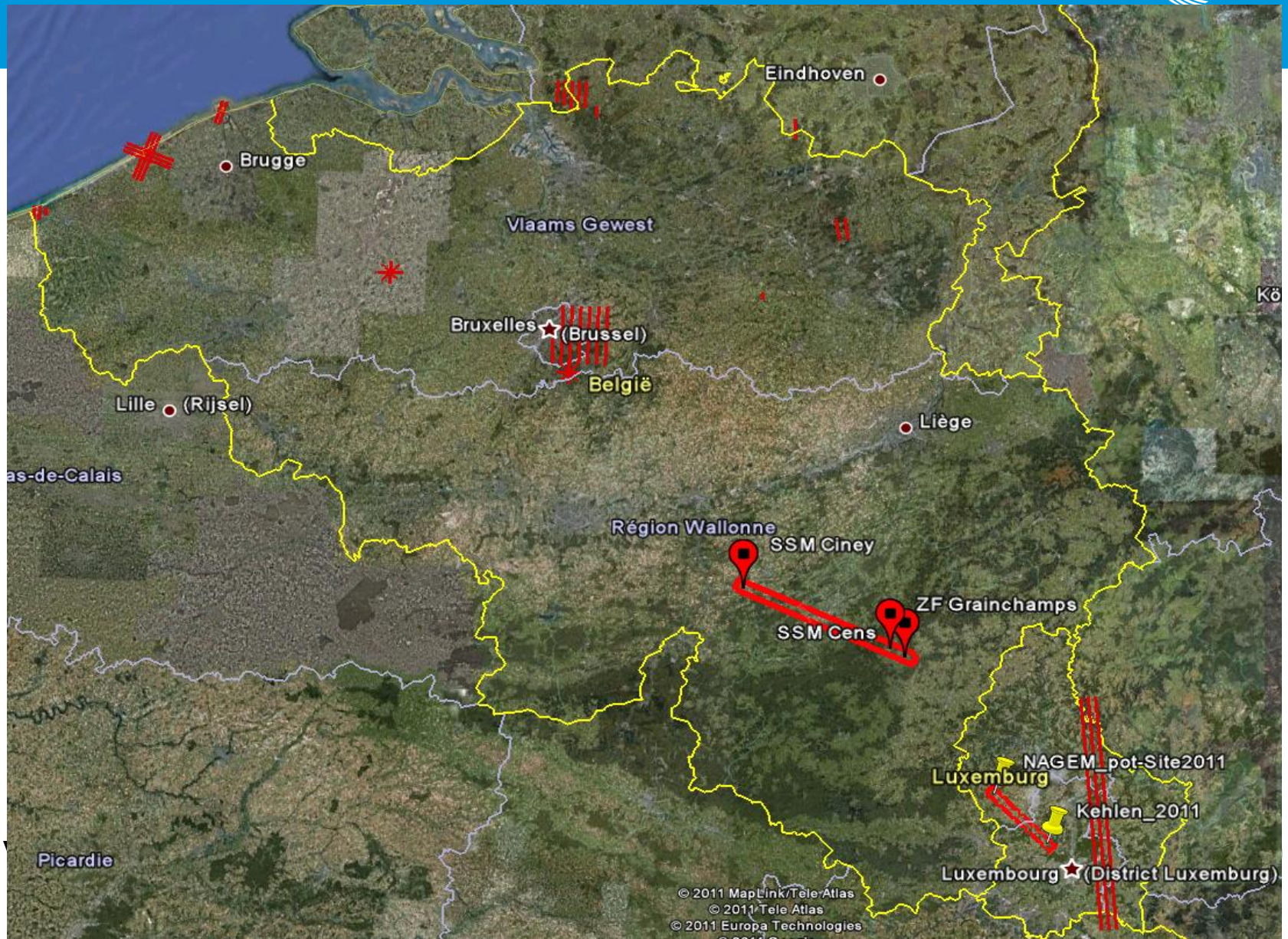
APEX flights 2011



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APEX Processing and Archiving Facility (PAF)

1. VITO is in charge of operational level 0-1 (RSL development) processing and additional level 2-3 processing
2. APEX PAF disposes of dedicated hardware and supports all levels of processing (Level 0-3)
3. Hardware concept is based on VITO's processing experience and various instruments and activities (Pegasus, Medusa, AGIV, CASI, Hymap, AHS, etc.)
4. Middleware based concept supporting parallel computing approaches: Master/Worker and Task/Data decomposition

Hardware: development + operational environment

	MAIN	Rack 1 - Development	UPS
1			
2		Fibre Panel	
3			
4			
5	1	Development Node	1
6	1	Development Node	
7	1	Development Node	
8	1	Development Node	
9	1	Development Node	
10			
11	1	WORKFLOW File Server 1	1
12	1	WORKFLOW File Server 2	1
13			
14	1	WORKFLOW WORKER1	
15	1	WORKFLOW WORKER2	
16	1	WORKFLOW WORKER3	
17			
18	1	WORKFLOW MASTER	1
19	1	File Server VTRAK	1
20			
21	1	=SWITCH= DATA 1	
22		=SWITCH= iSCSI 1	1
23	1	Development Node	1
24			
25			
26		TAPE ROBOT LTO4	
27		20 TB (RAW)	
28			
29			
30			
31			
32	1	VTRAK	1
33			
34		Development Test Data	
35	1	VTRAK	1
36			
37		Hyperspectral Test Data	
38	1	VTRAK	1
39			
40		Hyperspectral Test Data	
41	1	VTRAK	1
42			
43		Development Test Data	
44	1	VTRAK	1
45		UNASSIGNED	
46			
	19		12

	MAIN	Rack 2 - Development	UPS
1		=SWITCH= DEVEL 1	1
2			
3			
4			
5	1	File Server ARCHIEF 1	1
6	1	File Server ARCHIEF 2	1
7	1	MYSQL MASTER	1
8	1	MYSQL SLAVE	1
9	1	WEB	
10	1	WEBSERVICES	
11	1	FTP	
12			
13	1	ORACLE	1
14	1	POSTGRES	1
15			
16			
17			
18			
19			
20	2	KVM	
21	1	=SWITCH= DATA 2	
22		=SWITCH= iSCSI 2	1
23	1	VTRAK	1
24		Archive Airborne	
25			
26	1	VTRAK	1
27		Archive Airborne	
28			
29	1	VTRAK	1
30		Archive Airborne	
31			
32	1	VTRAK	1
33		Archive Airborne	
34			
35	1	VTRAK	1
36		Archive Airborne	
37			
38	1	VTRAK	1
39		Archive Airborne	
40			
41	1	VTRAK	1
42		FTP	
43			
44	1	VTRAK	1
45			
46		Development Test Data	
	20		16

	MAIN	Rack 3 - Development	UPS
1		=SWITCH= DEVEL 2	1
2			
3			
4			
5	1	Development Node	1
6	1	File Server VTRAK	1
7	1	Development Node	
8	1	WORKFLOW MASTER	
9	1	WORKFLOW MASTER	
10	1	WORKFLOW WORKER	
11	1	WORKFLOW WORKER	
12	1	WORKFLOW WORKER	
13	1	WORKFLOW WORKER	
14	1	WORKFLOW WORKER	
15	1	WORKFLOW WORKER	
16	1	WORKFLOW WORKER	
17	1	WORKFLOW WORKER	
18			
19			
20			
21	1	=SWITCH= DATA 3	
22		=SWITCH= iSCSI 3	1
23			
24			
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32			
33			
34			
35			
36			
37			
38	1	VTRAK	1
39			
40		Development Test Data	
41	1	VTRAK	1
42			
43		Development Test Data	
44	1	VTRAK	1
45			
46		Development Test Data	
	17		7

	MAIN	Rack 4 - Development	UPS
1			
2			
3			
4			
5	1	File Server VTRAK	
6	1	File Server VTRAK	
7	1	File Server VTRAK	
8	1	WORKFLOW WORKER	
9	1	WORKFLOW WORKER	
10	1	WORKFLOW WORKER	
11	1	WORKFLOW WORKER	
12	1	WORKFLOW WORKER	
13	1	WORKFLOW WORKER	
14	1	WORKFLOW WORKER	
15	1	WORKFLOW WORKER	
16			
17		WORKFLOW File Server1	
18		WORKFLOW File Server2	
19		WORKFLOW File Server3	
20			
21	1	=SWITCH= DATA 4	
22			
23		WORKFLOW File Server4	
24		WORKFLOW File Server5	
25		WORKFLOW WORKER	
26			
27		WORKFLOW WORKER	
28			
29			
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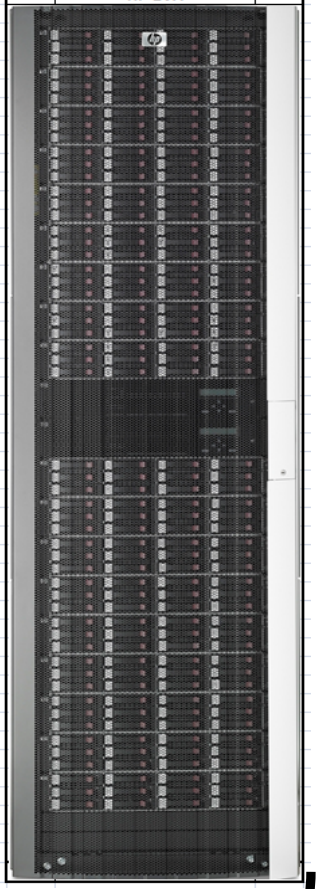
	12		0

MAIN	Rack 5 - Operational	UPS

HP EVA


Development Platform

Operational Platform

Total 172 cores on 19 machines

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APEX validation: geometric

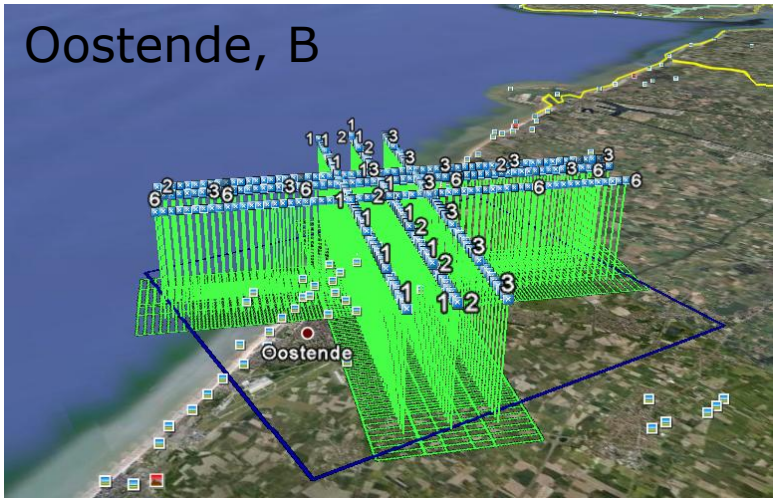
Inputs:

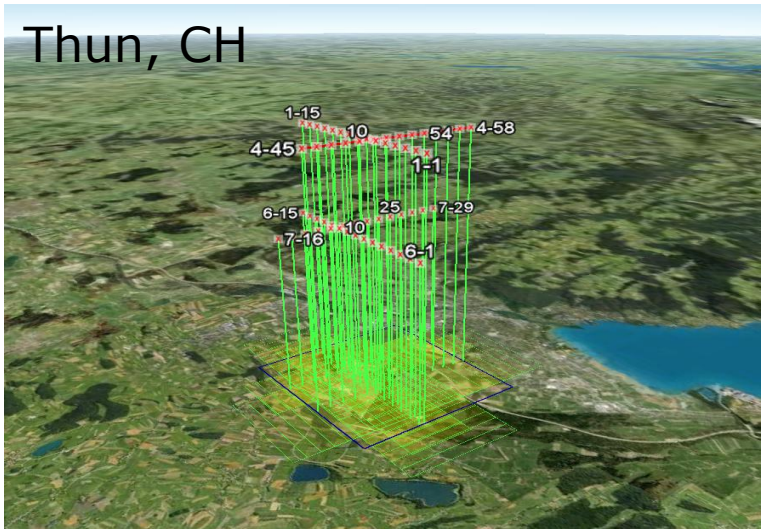
1. Specific flight pattern
2. GPS/IMU processing (lever arms, dGPS,)
3. GCP selection
4. APEX sensor model (FOV, IFOV, CCD size,...)

↓

Residual boresight parameters

(+/-1 pixel accuracy)





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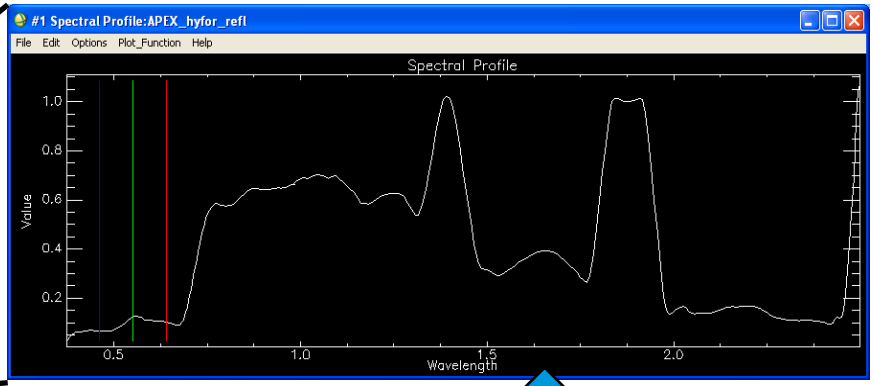
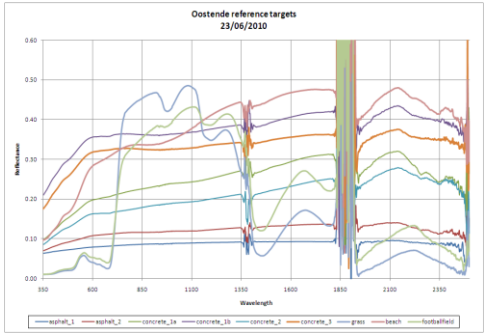
APEX Validation: radiometric/spectral

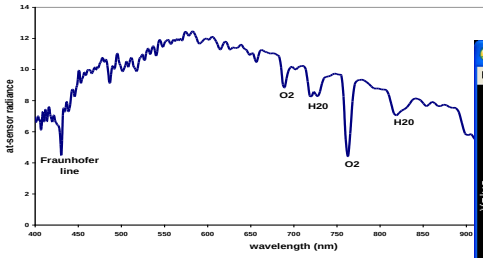
Monitoring spectral and radiometric performance

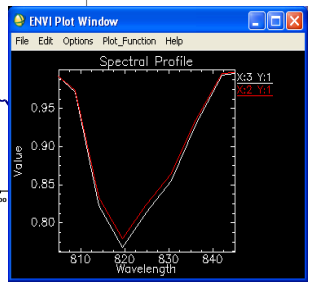


Radiometric



Spectral





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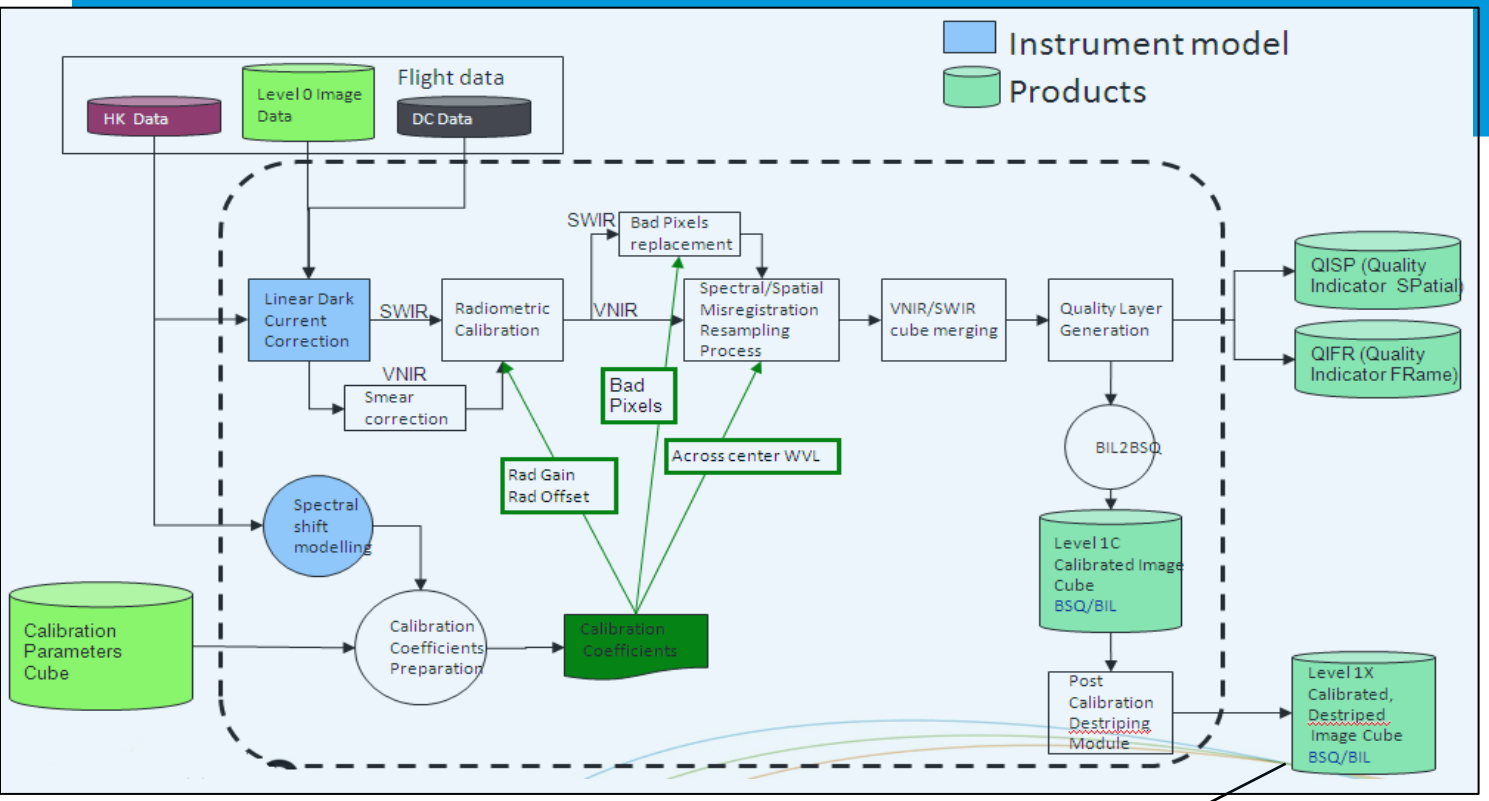
APEX PAF Archiving workflow level 0 -1 Processing



RSL development

VITO development

PosPac Processing

-) Level 1 X data
-) Applanix data
-) XML's

Archiving workflow

APEX level 1 standard product (HDF5)
Can be delivered to the users (ftp, harddisk)

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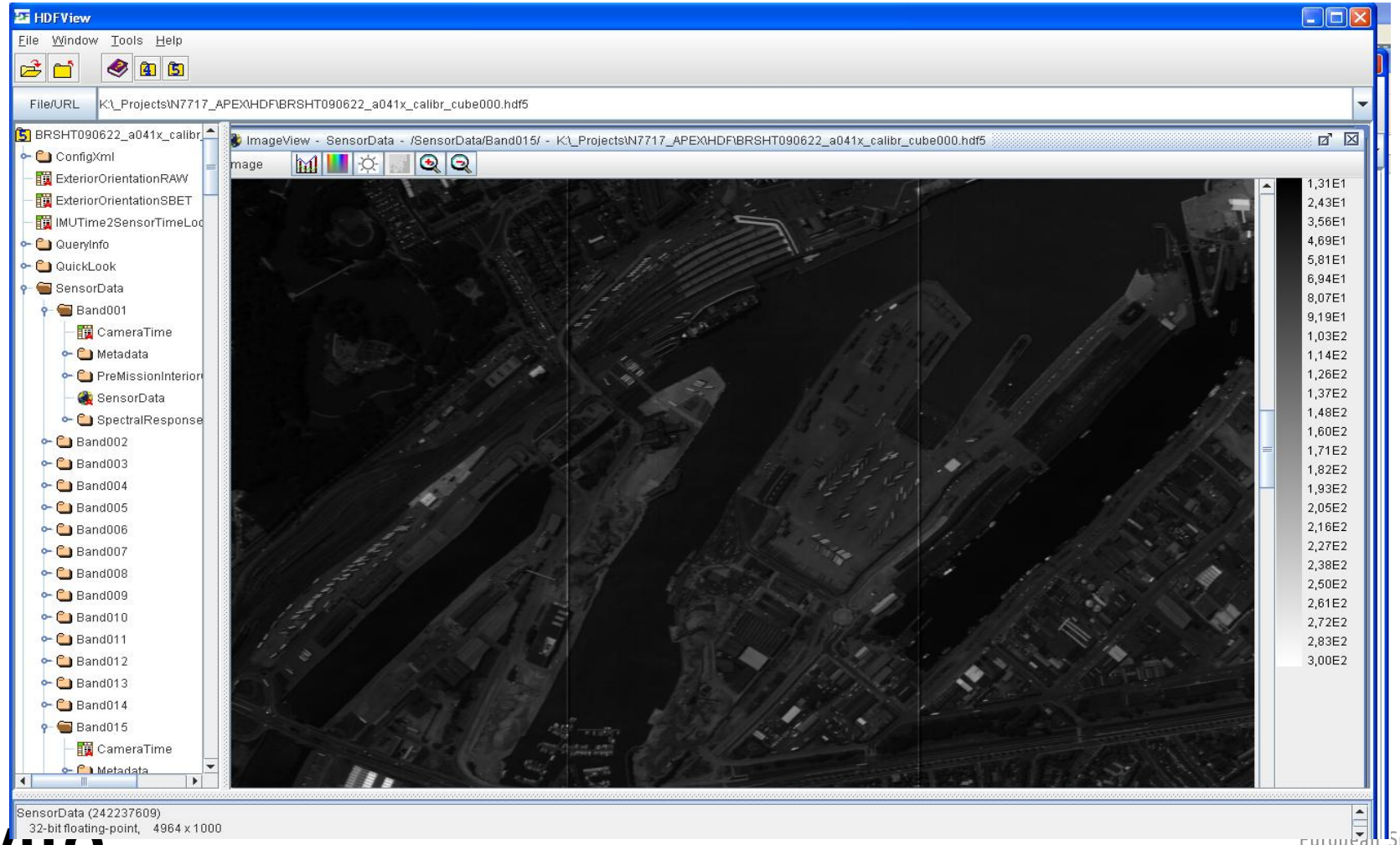
APEX PAF - level 1 HDF5 product



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APEX PAF - level 1 – 2

APEX level 1 HDF5

APEX Level 2 PAF

"*Standard*" Level 2 product

GEO

- **Direct Georeferencing** (ortho production through forward projection): custom VITO software, for better interfacing with MODTRAN4.
- **Integration of Applanix POSPAC** for dGPS/IMU corrections.

ATMOS

- ***Smile correction module (optional)***
- **VITO has its own C++ implementation of the ATCOR4 model.** No pre-compiled LUTs needed, MODTRAN4 is used "on-the-fly": all 176 MODTRAN4 parameters become available for AC.
- **Water vapor determination (user or image)**
- **Visibility determination (user of image)**

RES

- All algorithms in an optimal workflow perform their work on the raw scene geometry and **image resampling** to a certain projection system and projection datum is done at the very end

USER:
APEX level 2 HDF5: ftp, harddisk

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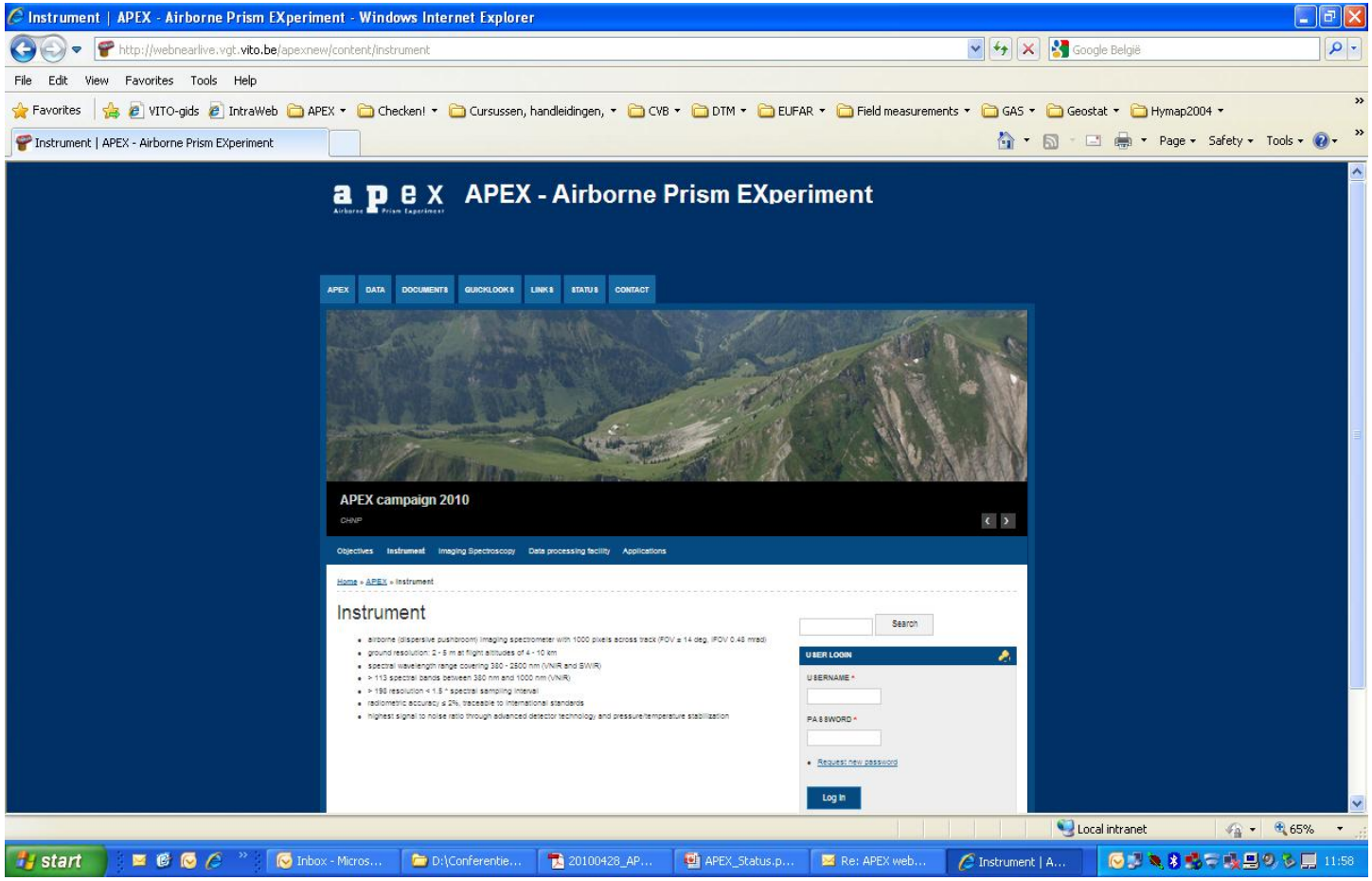
New APEX website online

www.apex-esa.org



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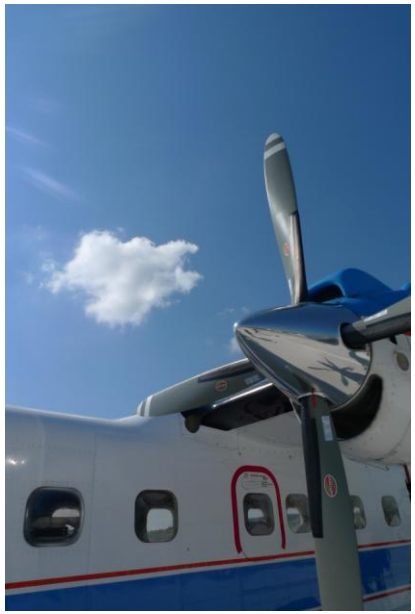

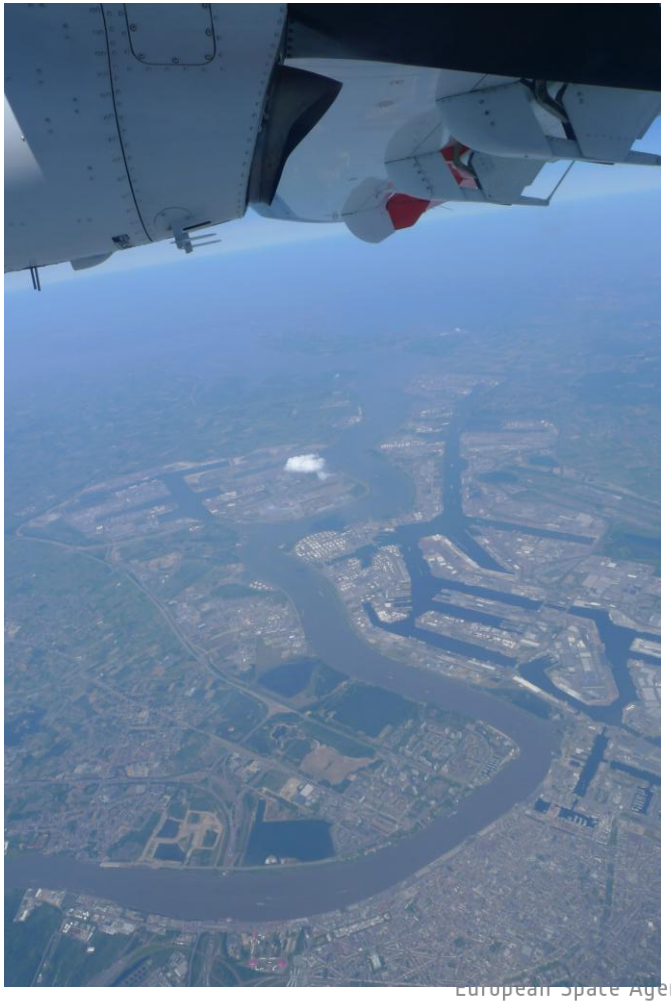

Thank you for your attention!

koen.meuleman@vito.be

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