

# APEX – Airborne Prism Experiment

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# APEX – Project Background

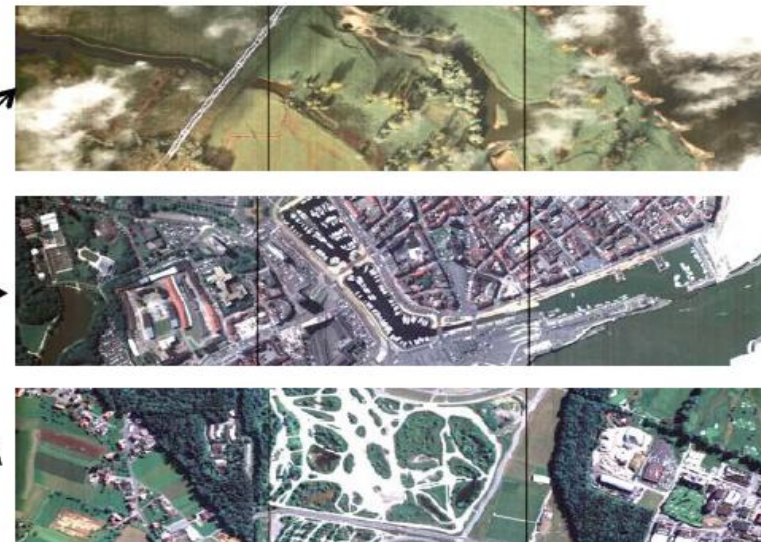
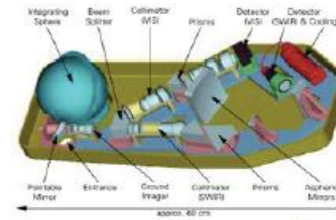


1. APEX is a joint Swiss/Belgian project funded under ESA-PRODEX with support from ESA Earth Observation.
2. APEX is an airborne pushbroom dispersive spectrometer for the support and development of future spaceborne Earth Observation systems, supported by a Processing and Archiving Facility (PAF) and 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.

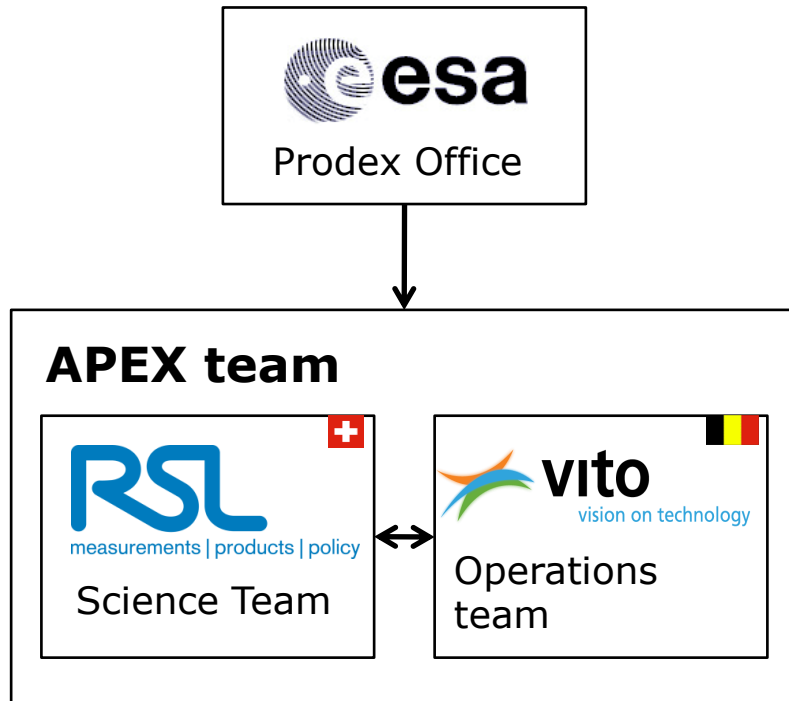
# APEX: from concept to acceptance



- 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, 1<sup>st</sup> test flight
- 2009 1<sup>st</sup> Acceptance flight campaign
- 2010 2<sup>nd</sup> Acceptance flight campaign
- Instrument accepted by ESA**
- 2011-2015 Exploitation Operations



# APEX team: organization

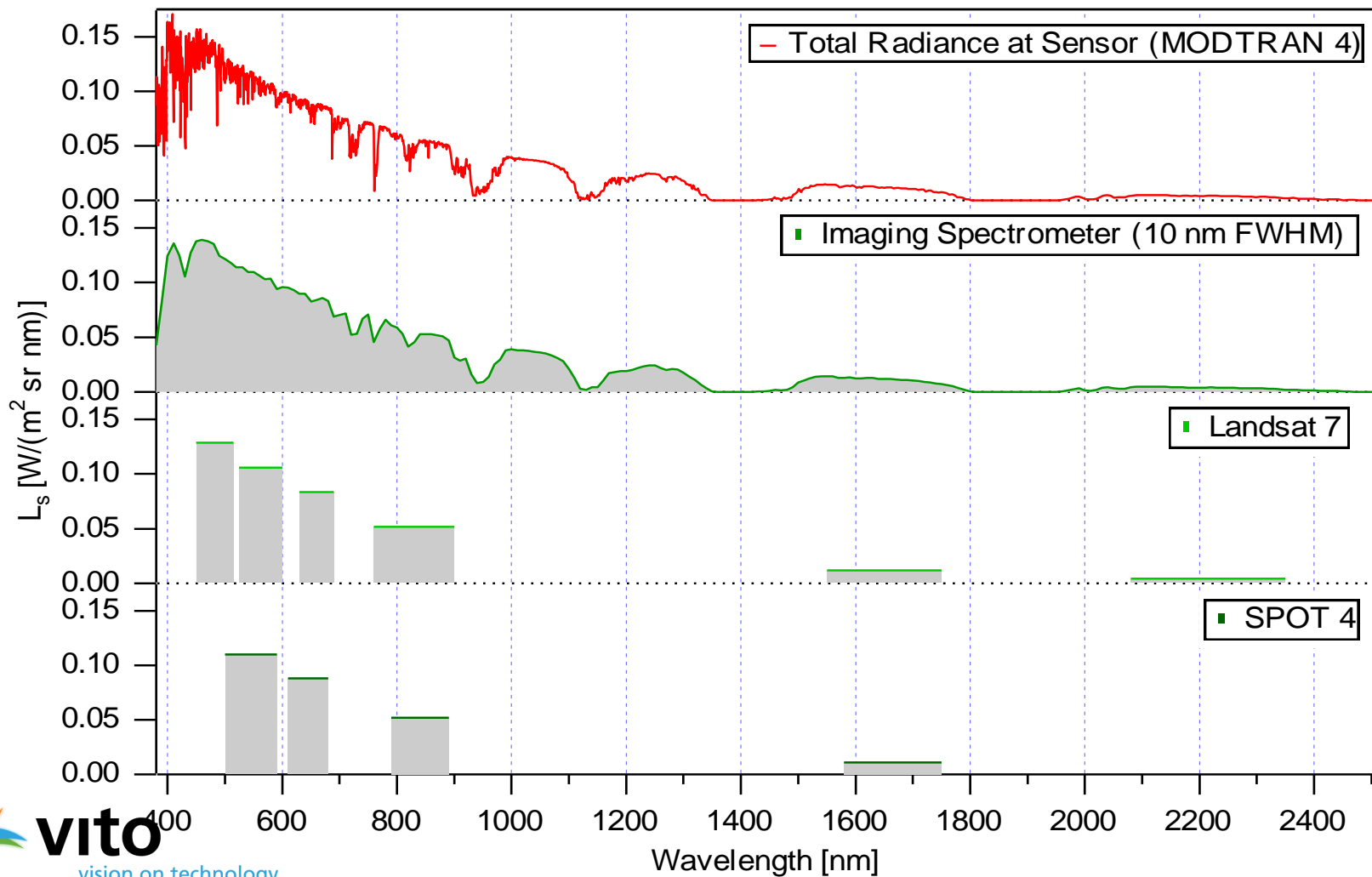


APEX Operations Team based at VITO, Mol,B

Team tasks:

- 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



# APEX Performance



## Spectral Performance

Spectral Range	<b>VNIR</b> 380.5 – 971.7 nm	<b>SWIR</b> 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

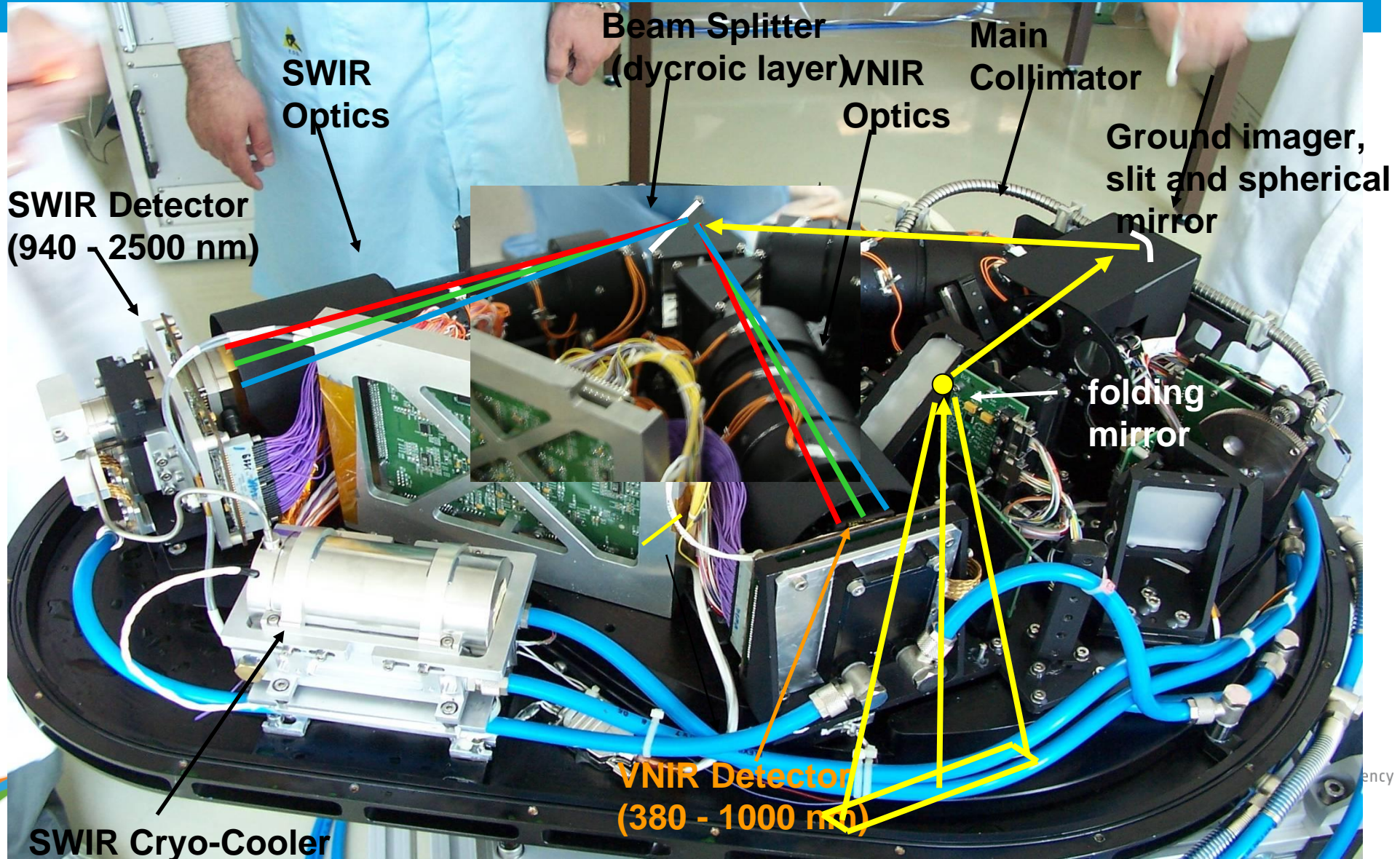
Type	CCD	CMOS
Dynamic Range	14 bit encoding	13 bit encoding
Pixel Size	22.5 µm x 22.5 µm	30 µm x 30 µm
Smile		0.35 pixel
Keystone (Frown)	Average, less than	0.35 pixel
Co-Registration		0.55 pixel

## Other Information

Data Capacity	500 GB on SSD
Data Transfer	Spectral frames Housekeeping Data
Data rate for default configuration	0.4 GB/km (1250 km max)
	30 MB/s via Optical Link 20 kB/s via Serial Cable



# APEX Optical Sub-Unit



# The Calibration Home Base @ DLR München\*



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

1.6 m Integrating Sphere

Relative radiometric calibration

Absolute radiometric calibration

0.5 m Integrating Sphere

APEX

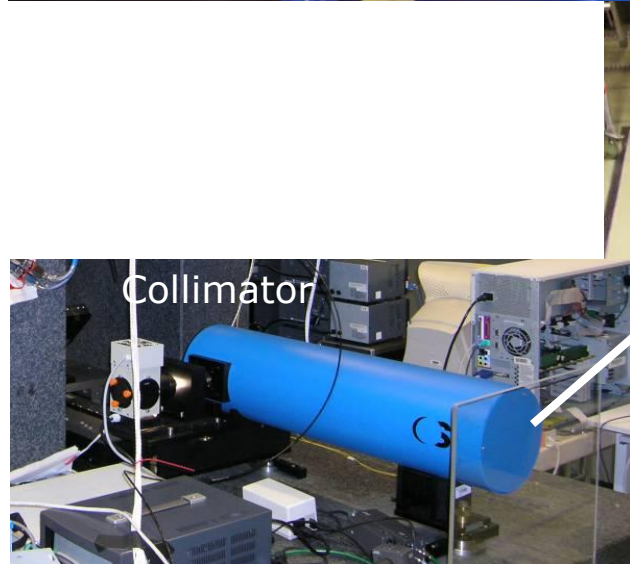
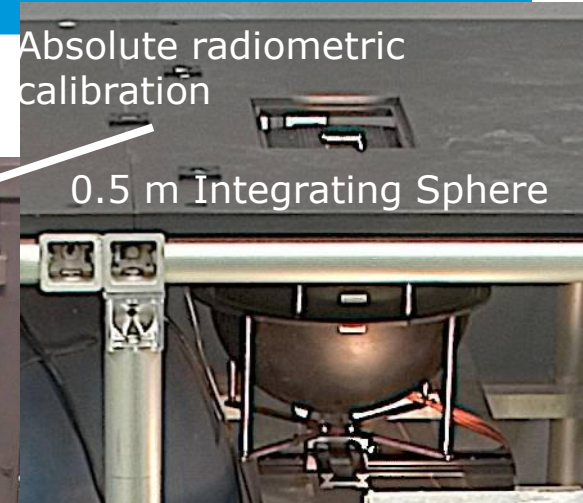
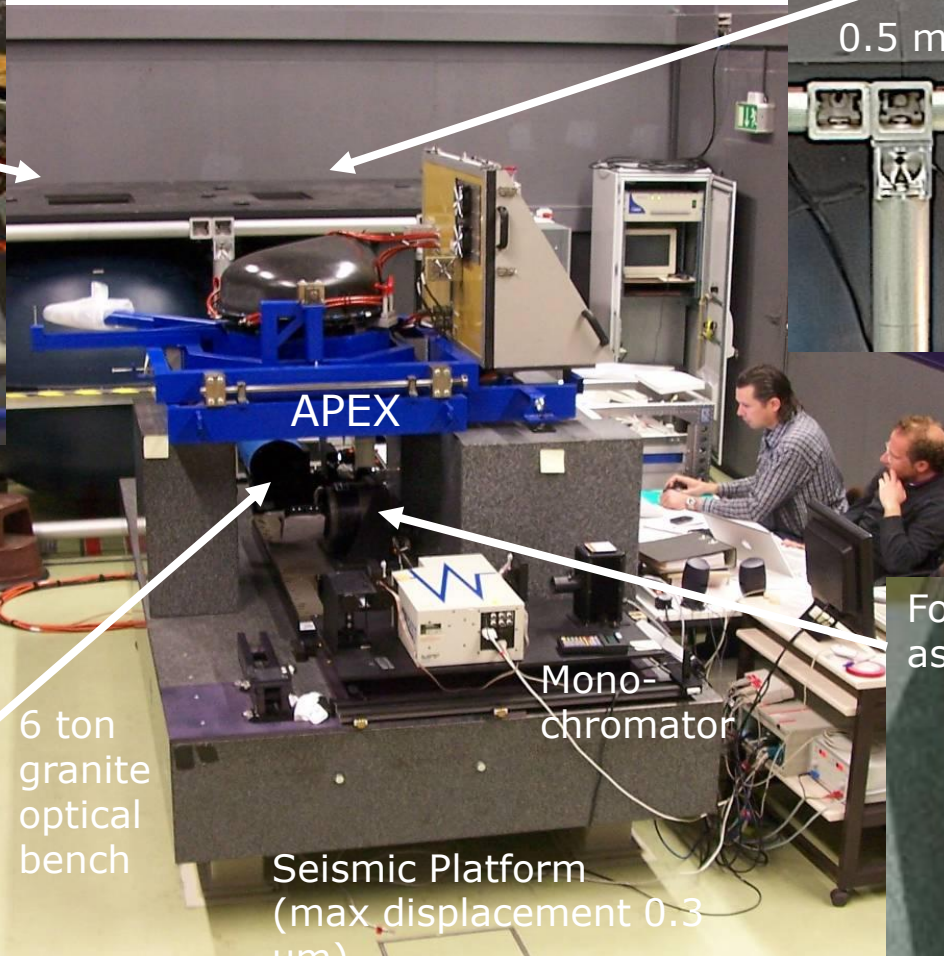
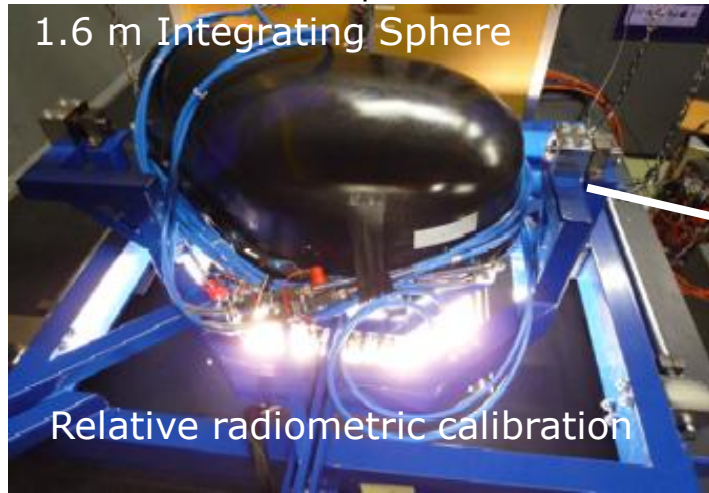
Folding mirror assembly

Collimator

6 ton granite optical bench

Mono-chromator

Seismic Platform  
(max displacement 0.3  $\mu\text{m}$ )

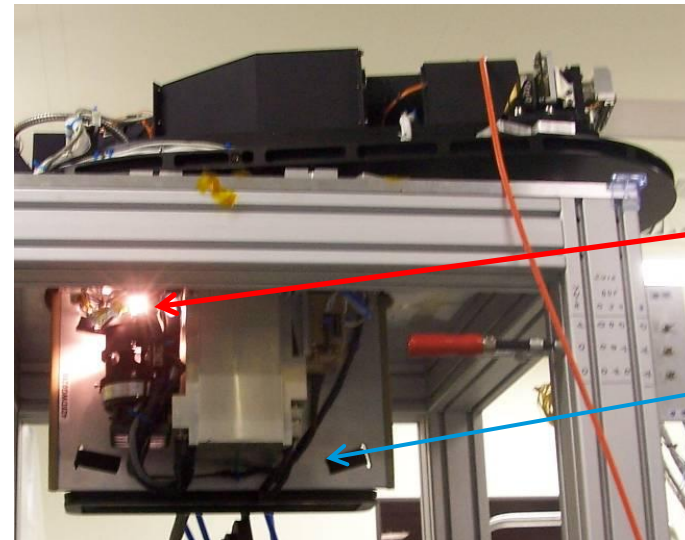




# In-Flight Characterization Facility

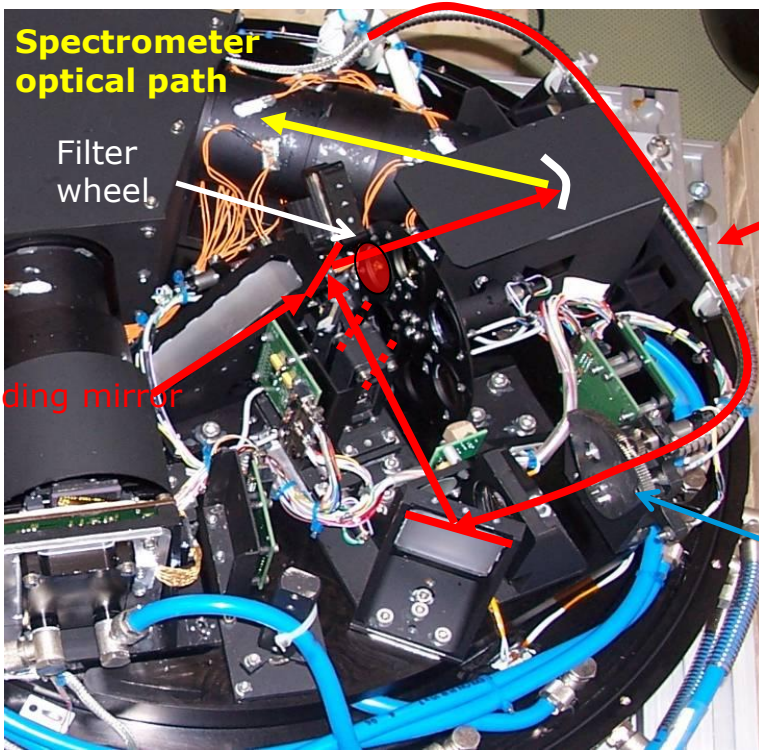


The **IFC** is a tool designed to **investigate** the overall instrument (radiometric, spectral, geometric) **stability** during flight.



Stabilised IFC QTH lamp  
Entrance Baffle

IFC light path (glass fiber)



Spectrometer optical path

Filter wheel

Shutter for standard imaging operations

## Spectral filters:

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

# APEX Operations - Flight organization and planning - Workflow



THE TRACKER - LICENSED TO VITO - [Schelde\_2009/Schelde\_2009]

1-File 2-Hide 3-Display 4-Config 5-Sub\_flight\_plans 6-Tools 8-Runs 9-Planning 10-Equipment 11-Help

PHOTO GPS Line 1 unselected

Copyright © 1994-2008 By Trackair b.v.

TIME 15:56  
 NR 000  
 ROLL 031110  
 RUN None  
 MSL 21 198  
 SCAL 0  
 DLAY 0  
 CORR 300  
 INTR 0.88  
 DONE 0  
 LEFT 64  
 IMOT na  
 SUN 1.8

CSU 1 No data  
 CSU 2 No data  
 CSU 3 No data  
 CSU 4 No data  
 CSU 5 No data  
 CSU 6 No data  
 CSU 7 No data  
 CSU 8 No data  
 CSU 9 No data

MCRS = 0000 288.6 = MTRK  
 XTRK = 0000 XCRS = > 000.0 <

5 287 288 289 290 291

R 150/22

L 150/22

DISP 1:151 K  
 GSPD 554.8kt  
 TTRK 288.5  
 MVAR W0.1  
 MTRK 288.6  
 MHDG 000.0  
 LAT N51.248  
 LONG E004.357  
 GALT 9 842 ft  
 DIST 2.2nm  
 MBRG 313.5  
 ETA 0:00:14  
 PDOP 0.9  
 SATS 9

POS AV DRIFT  
 DRFT Turning

5....):

yes	no
yes	no
yes	no
yes	no

MENU 3.1 nm - 5.7 km

250 200 150 100 050 000 050 100 150 200 250

start

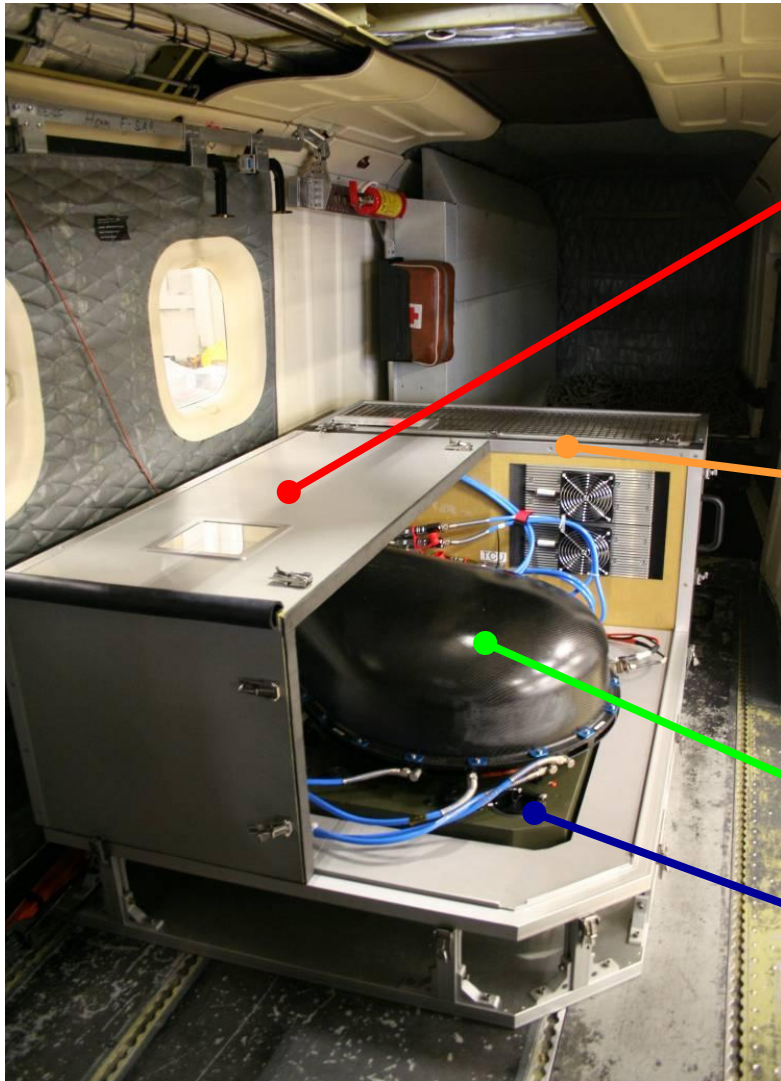
15:56



# APEX Operations - aircraft installation



# APEX Operations - aircraft installation

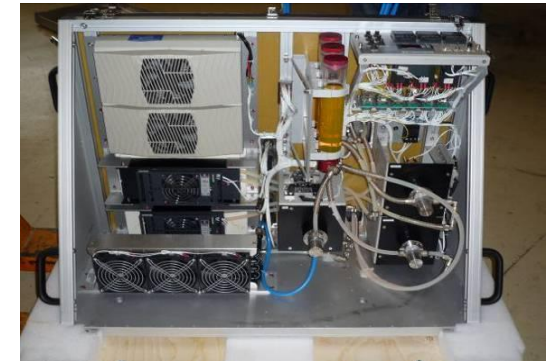


Environmental Thermal Control (ETC) Box

Thermal Control Unit (TCU)

Optical Subsystem Unit (OSU)

Stabilising Platform (Leica PAV30)

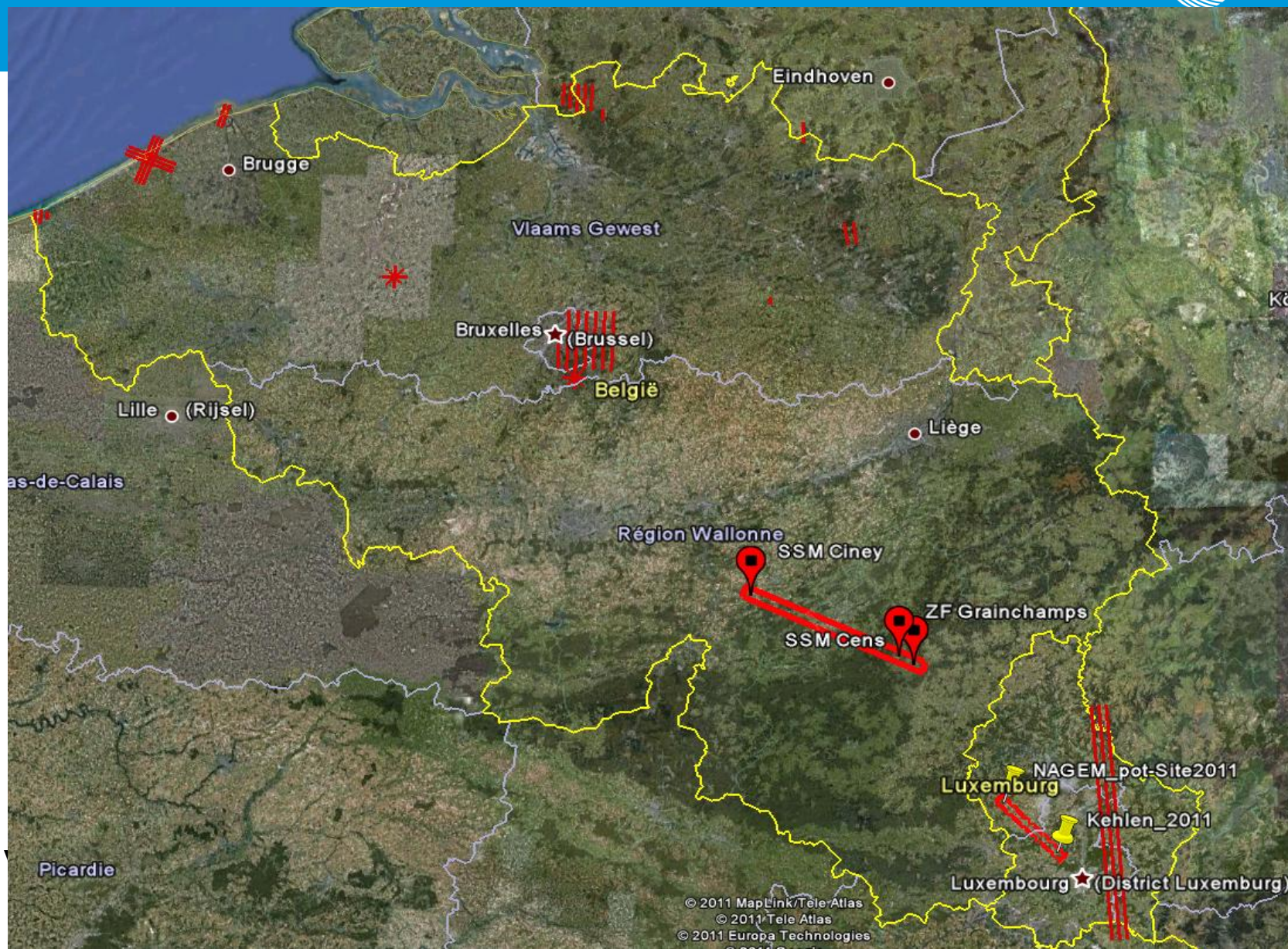


# APEX Operations - Aircraft

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](http://www.eufar.net)) offers aircraft + APEX within a EC FP7 project.**



# APEX flights 2011



# 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	MAIN	Rack 2 - Development	UPS	MAIN	Rack 3 - Development	UPS	MAIN	Rack 4 - Development	UPS	MAIN	Rack 5 - Operational	UPS	HP EVA
1			1	=SWITCH= DEVEL 1	1	1	=SWITCH= DEVEL 2	1	1			1			
2			2			2			2			2			
3			3			3			3			3			
4			4			4			4			4			
5	1	Development Node	5	1	File Server ARCHIEF 1	5	1	Development Node	5	1	File Server VTRAK	5			
6	1	Development Node	6	1	File Server ARCHIEF 2	6	1	File Server VTRAK	6	1	File Server VTRAK	6			
7	1	Development Node	7	1	MYSQL MASTER	7	1	Development Node	7	1	File Server VTRAK	7			
8	1	Development Node	8	1	MYSQL SLAVE	8	1	WORKFLOW MASTER	8	1	WORKFLOW WORKER	8			
9	1	Development Node	9	1	WEB	9	1	WORKFLOW MASTER	9	1	WORKFLOW WORKER	9			
10			10	1	WEBSERVICES	10	1	WORKFLOW WORKER	10	1	WORKFLOW WORKER	10			
11	1	WORKFLOW File Server 1	11	1	FTP	11	1	WORKFLOW WORKER	11	1	WORKFLOW WORKER	11			
12	1	WORKFLOW File Server 2	12			12	1	WORKFLOW WORKER	12	1	WORKFLOW WORKER	12			
13			13	1	ORACLE	13	1	WORKFLOW WORKER	13	1	WORKFLOW WORKER	13			
14	1	WORKFLOW WORKER1	14	1	POSTGRES	14	1	WORKFLOW WORKER	14	1	WORKFLOW WORKER	14			
15	1	WORKFLOW WORKER2	15			15	1	WORKFLOW WORKER	15	1	WORKFLOW WORKER	15			
16	1	WORKFLOW WORKER3	16			16	1	WORKFLOW WORKER	16			16			
17			17			17	1	WORKFLOW WORKER	17			17			
18	1	WORKFLOW MASTER	18			18			18			18			
19	1	File Server VTRAK	19			19			19			19			
20			20	2	KVM	20			20			20			
21	1	=SWITCH= DATA 1	21	1	=SWITCH= DATA 2	21	1	=SWITCH= DATA 3	21	1	=SWITCH= DATA 4	21			
22			22	1	=SWITCH= ISCSI 1	22			22			22			
23	1	Development Node	23	1	=SWITCH= ISCSI 2	23		=SWITCH= ISCSI 3	23	1		23			
24			24		VTRAK	24			24			24			
25			25		Archive Airborne	25			25			25			
26			26	1	VTRAK	26			26			26			
27		TAPE ROBOT LTO4 20 TB (RAW)	27		Archive Airborne	27			27			27			
28			28			28			28			28			
29			29	1	VTRAK	29			29			29			
30			30		Archive Airborne	30			30			30			
31			31			31			31			31			
32	1	VTRAK	32	1	VTRAK	32			32			32			
33			33		Archive Airborne	33			33			33			
34		Development Test Data	34			34			34			34			
35	1	VTRAK	35	1	VTRAK	35			35			35			
36			36		Archive Airborne	36			36			36			
37		Hyperspectral Test Data	37			37			37			37			
38	1	VTRAK	38	1	VTRAK	38	1	VTRAK	38	1		38			
39			39		Archive Airborne	39			39			39			
40		Hyperspectral Test Data	40			40		Development Test Data	40			40			
41	1	VTRAK	41	1	VTRAK	41	1	VTRAK	41	1		41			
42			42		FTP	42			42			42			
43		Development Test Data	43			43		Development Test Data	43			43			
44	1	VTRAK	44	1	VTRAK	44	1	VTRAK	44	1		44			
45		UNASSIGNED	45			45			45			45			
46			46		Development Test Data	46		Development Test Data	46			46			
19		12	20		16	17		7	12		0				





# APEX validation: geometric

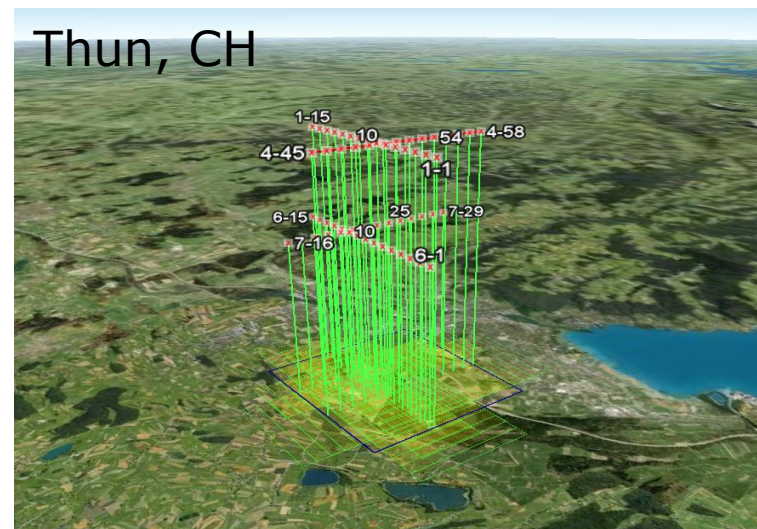


## Inputs:

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



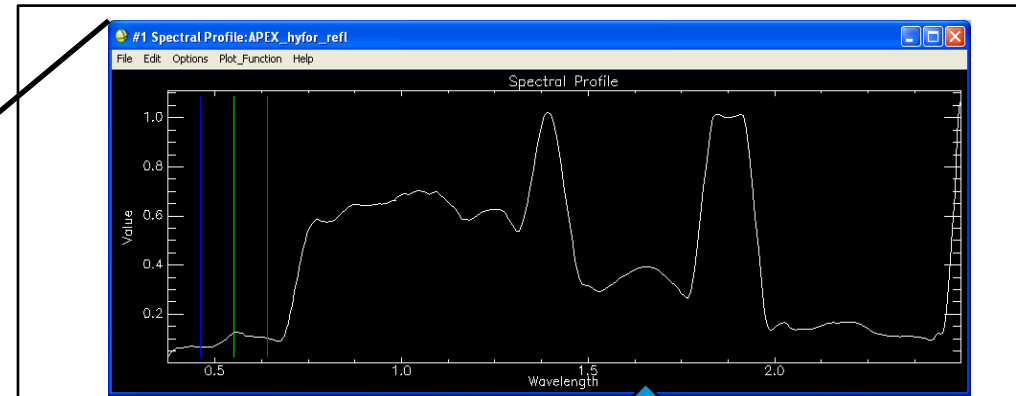
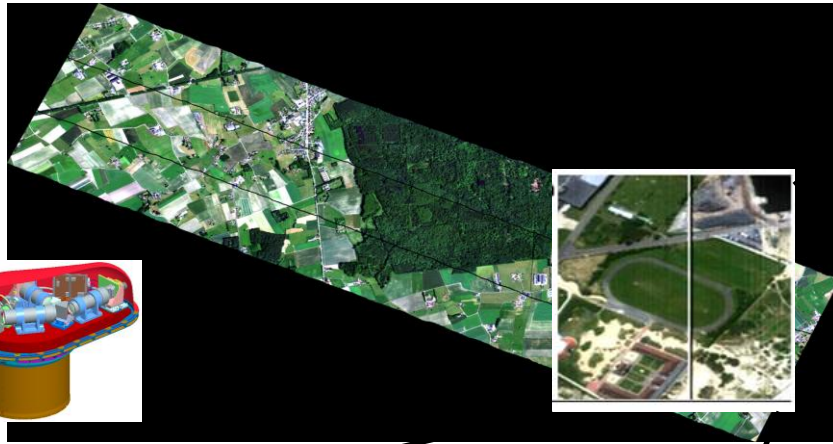
Residual boresight parameters  
(+/-1 pixel accuracy)



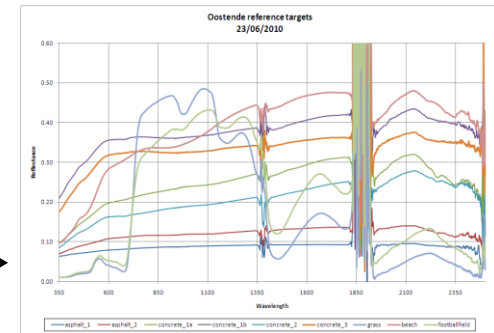
# APEX Validation: radiometric/spectral



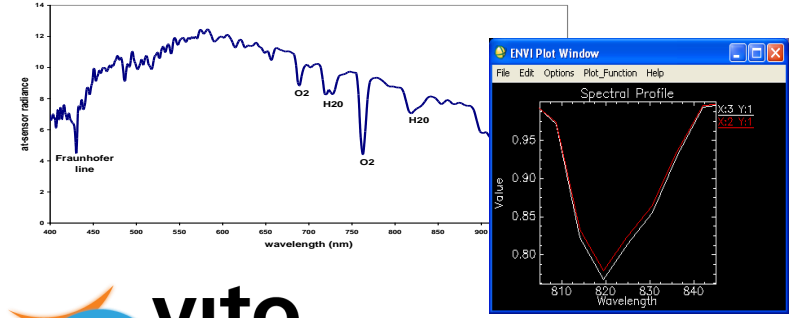
Monitoring spectral and radiometric performance



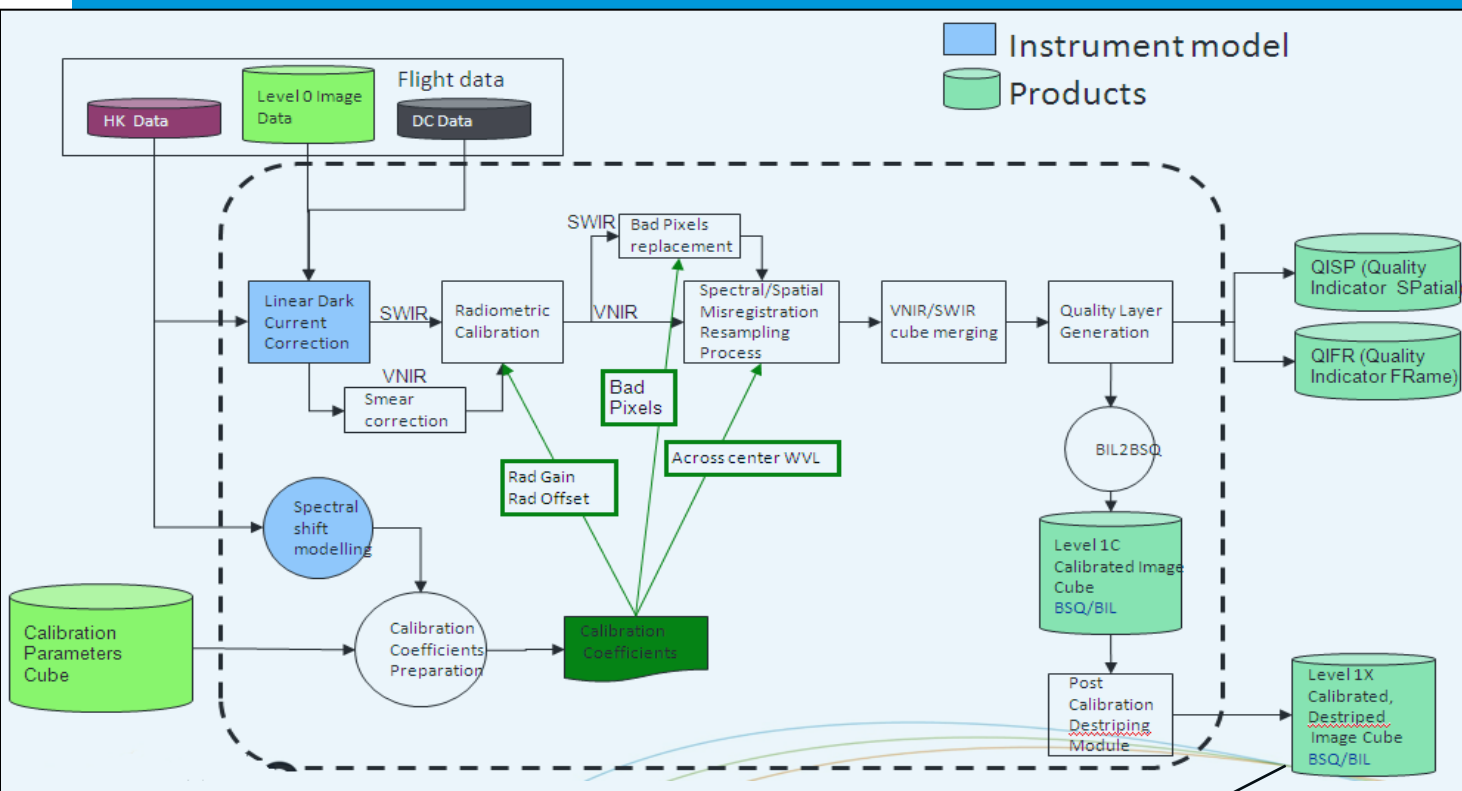
Radiometric



Spectral



# APEX PAF Archiving workflow level 0 -1 Processing



**RSL development**

**VITO development**

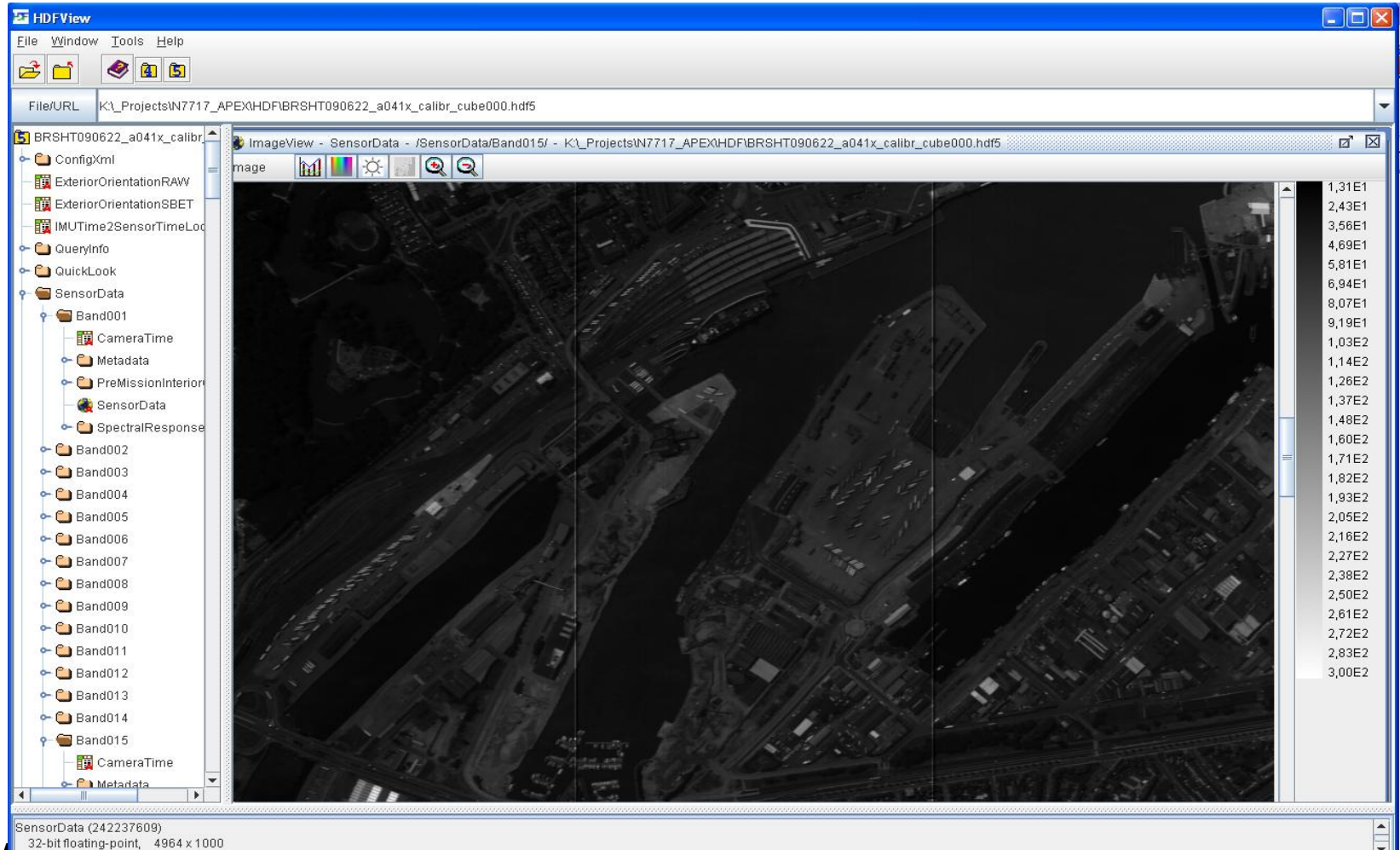
**PosPac Processing**

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

Archiving workflow

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

# APEX PAF - level 1 HDF5 product



# APEX PAF - level 1 – 2



APEX level 1  
HDF5

APEX  
Level 2 PAF

"Standard"  
Level 2  
product

- G**• **Direct Georeferencing** (ortho production through forward projection): custom VITO software, for better interfacing with MODTRAN4.
- E**• **Integration of Applanix POSPAC** for dGPS/IMU corrections.
- O**• **Smile correction module (optional)**
- A**• **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.
- T**• **Water vapor determination (user or image)**
- M**• **Visibility determination (user of image)**
- O**• 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
- S**
- R**
- E**
- S**

USER:  
APEX  
level 2  
HDF5:  
ftp,  
harddisk

# New APEX website online



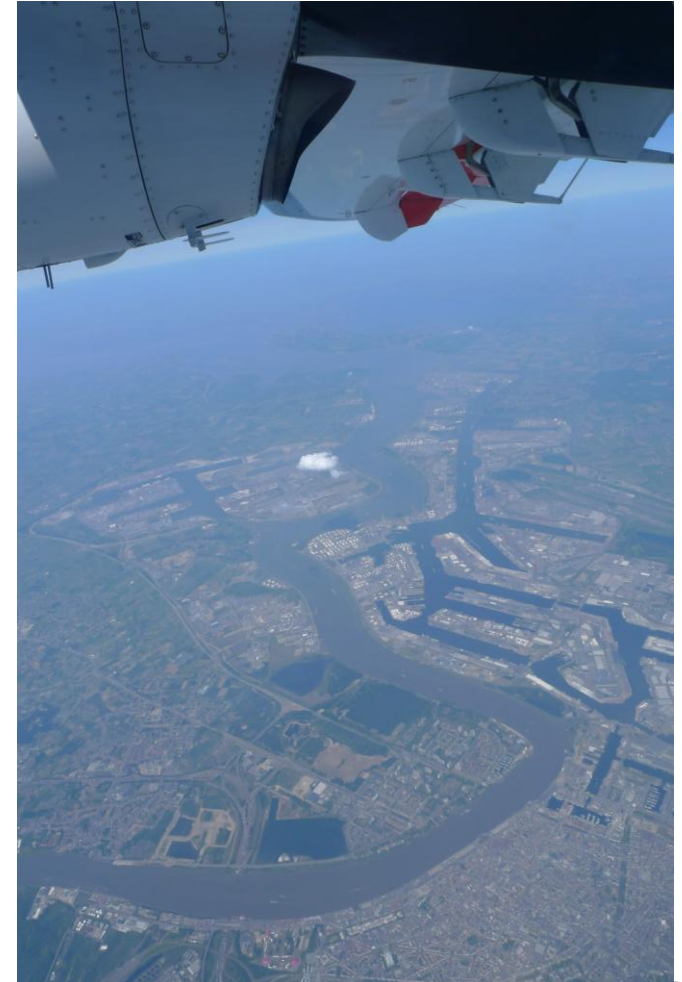
[www.apex-esa.org](http://www.apex-esa.org)

The screenshot shows a Windows Internet Explorer browser window displaying the APEX website. The address bar shows the URL <http://webnearlive.vgt.vito.be/apexnew/content/instrument>. The website header includes the APEX logo and the text "APEX - Airborne Prism EXperiment". Below the header is a navigation menu with buttons for APEX, DATA, DOCUMENTS, QUICKLOOKS, LINKS, STATUS, and CONTACT. The main content area features a large image of a mountain landscape with the text "APEX campaign 2010" and "CHAMP". Below this is a sub-menu with buttons for Objectives, Instrument, Imaging Spectroscopy, Data processing facility, and Applications. The "Instrument" section is active, displaying a list of technical specifications:

- airborne (dispersive pushbroom) imaging spectrometer with 1000 pixels across track (FOV  $\approx 14$  deg, FOV 0.48 mrad)
- ground resolution: 2 - 8 m at flight altitudes of 4 - 10 km
- spectral wave-length range covering 350 - 2500 nm (NIR and SWIR)
- > 115 spectral bands between 350 nm and 1000 nm (VNIR)
- > 190 resolution  $\times 1.5$  " spectral sampling interval
- radiometric accuracy  $\pm 2\%$ , traceable to international standards
- highest signal to noise ratio through advanced detector technology and pressure/temperature stabilization

On the right side of the page, there is a "USER LOGIN" section with fields for USERNAME and PASSWORD, a "Log In" button, and a link for "Request new password". A search box is also present above the login section. The Windows taskbar at the bottom shows the Start button, several open applications, and the system tray with the time 11:58.

# APEX – Airborne Prism Experiment



Thank you for your attention!

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[www.apex-esa.org](http://www.apex-esa.org)

