CDF-IDA Summary Report

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CHANGE RECORDS

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1. INTRODUCTION

This report is the summary of the work done in the *Space Instrument Design Modelling in a Concurrent Engineering approach* study and presents its main results: the Space instruments database, review of design methods and tools and developed CDF-IDA model architecture for Passive Optical Instruments.

This study has spanned around 16 months, featuring:

- a phase 1 dedicated to the implementation of a space instrument database and the review of the space instruments design methods and tools. This first phase has covered the following instruments categories:
    - optical instruments (passive and active),
    - micro-wave instruments (passive and active).

This phase has led to the development of the space instrument database and the delivery of a comprehensive document addressing the design methods and tools for imagers, imaging-spectrometers, Fourier Transform Spectrometers, Lidars, Synthetic Aperture Radars, Altimeters, radar sounders, scatterometers and rain radars.

- a phase 2 dedicated to the development and implementation of generic modelling tools for passive optical instruments and integration of these tools in the IDA model.

This phase has led to the creation, in the IDA model, of geometric performance tools addressing scene acquisition sizing, MTF estimation, IPSF and ISRF estimation for imagers and imaging spectrometers, OPD, Dwell time IFOV and contrast budget estimation for Fourier transform spectrometers. Radiometric performance tools have also been integrated addressing quantum detectors, µ-bolometers detectors and a specific dynamic FTS radiometric model and finally a detectors database has been added to the CDF-IDA.

- a phase 3 dedicated to the validation of the model, first in the CDF facilities at Thales Alenia Space and second in the CDF environment at ESTEC.

~~2.1~~2. TEAM STRUCTURE

During the CDF-IDA study, Thales Alenia Space was supported by:

- Jotne EP Technology (Norway),
- J-CDS (The Netherlands).

Responsibilities of each team member are mentioned in the following table:

Table 2-1 Responsibilities were shared according to the excellence field of each team member

Team member	Main responsibilities
THALES ALENIA SPACE	Prime contractor, responsible for project management, instrument design methods, modelling tool development, validation.
Jotne EPM Technology	Instrument database development and COTS interfacing
J-CDS	Concurrent Design expertise, CDF IDA model enhancement and software component integration

3. THE CDF-IDA MODEL

The CDF-IDA model allows to perform a pre-feasibility study (i.e. pre-phase A/0) related to a space instrument design activity .

Its objectives are also:

- to increase the engineers team communication,
- to improve the team's understanding of instrument design concepts,
- to improve the system design introducing a consistent approach,
- to reduce the design cycle by decreasing the iterations delays.

In order to achieve this, the model utilizes dedicated instrument MS Excel® workbooks, Domain Specific Databases and Domain Specific Tools as COTS (Commercial of the shelf software).

The workbooks can exchange key instrument parameters with the Domain Specific Databases (DSD) and the Domain Specific Tools (DST). Each workbook is composed of:

- presentation sheets,
- calculation sheets,
- outputs sheets,
- inputs sheets.

The global IDA architecture is illustrated in the following figure:

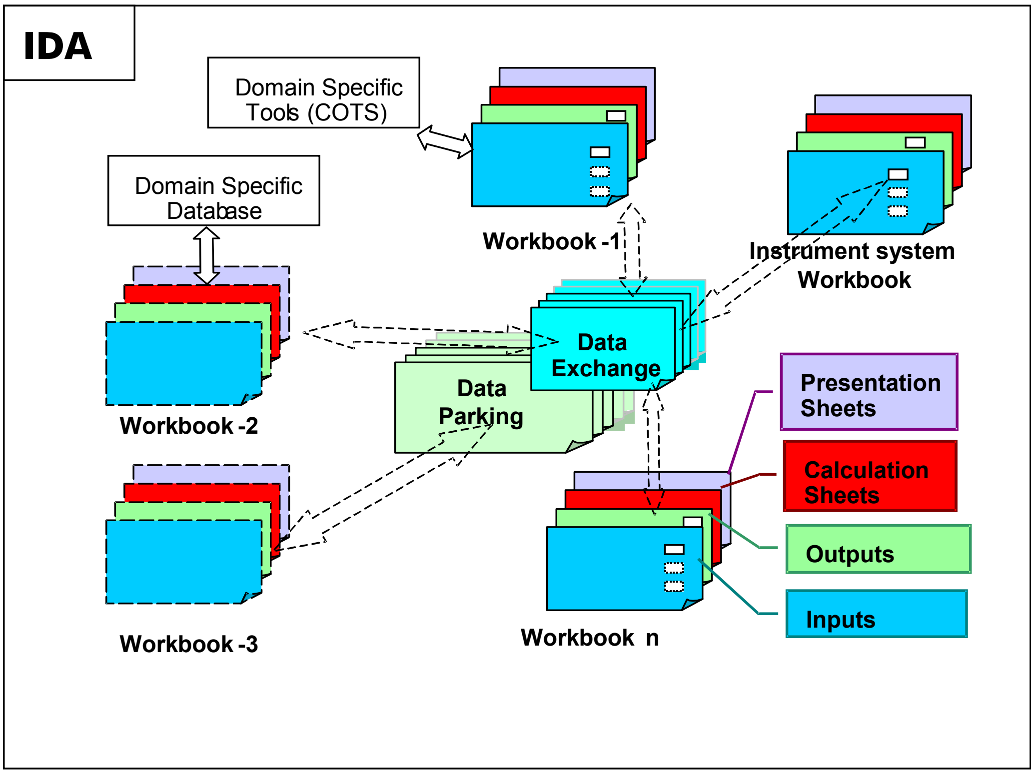


Figure 3-1 IDA model is self content and stand alone. The workbooks can exchange Key instrument parameters with the Domain Specific Databases (DSD) and the Domain Specific Tools (DST)

4. STUDY OUTPUTS

This study was shared between a review phase addressing the design methods and tools and an implementation phase during which several tools have been developed. The following sections gives an overview of these two phases outcomes.

4.1 Space instrument database

This database is of high interest at the beginning of a new phase 0/phase A study. It helps as a starting point, not to start from scratch when initiating preliminary conception. It allows to search for existing instruments corresponding to a particular specification (instrument type, mass, power budget …).
As a starting point, it contains existing instruments (past, operational or being developed), it can also be further populated by successive results from instrument design CDF sessions.
As a consequence, the objectives of the database have driven its main characteristics. The instrument database:

- identifies key parameters for the instrument design,
- displays directly main parameters and gives access to more detailed ones,
- allows easy queries through drop-down menu or equivalent,
- permits also easy updates (instrument to create, modify or cancel).

Depending on the instrument type (e.g. passive optical or active microwave instruments), the conception logic is quite different. As a consequence, key parameters can be different from one instrument type to another. Thus the database population covers passive and active, microwave and optical instruments (see Figure 4-1).

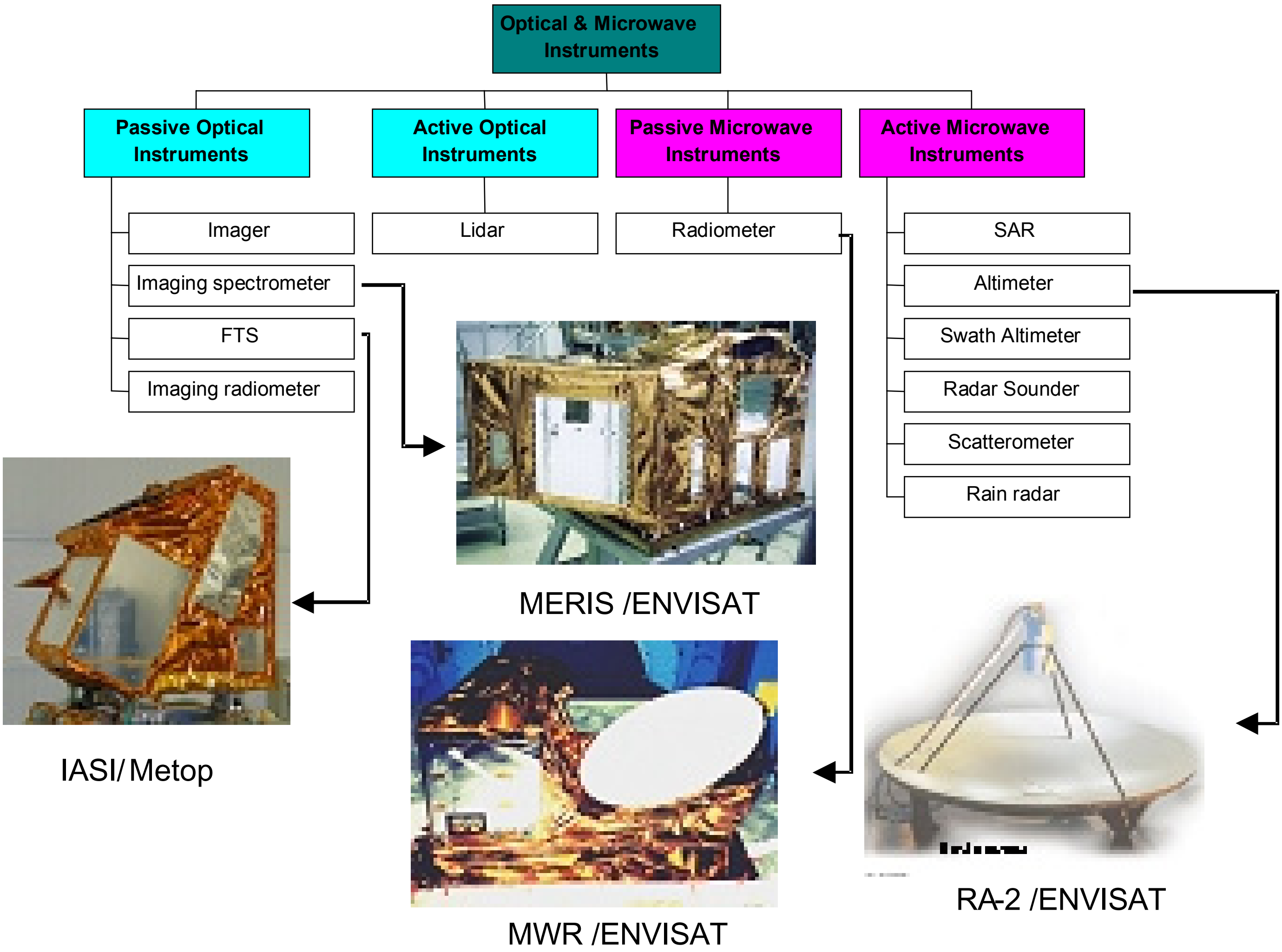


Figure 4-1 Proposed instrument families for the Space Instrument design modelling activity

The database has been implemented using PostgreSQL, a free database management system and it is published as Web services using available free source toolkits:

- Apache TOMCAT,
- Apache AXIS.

The database architecture is illustrated in Figure 4-2.

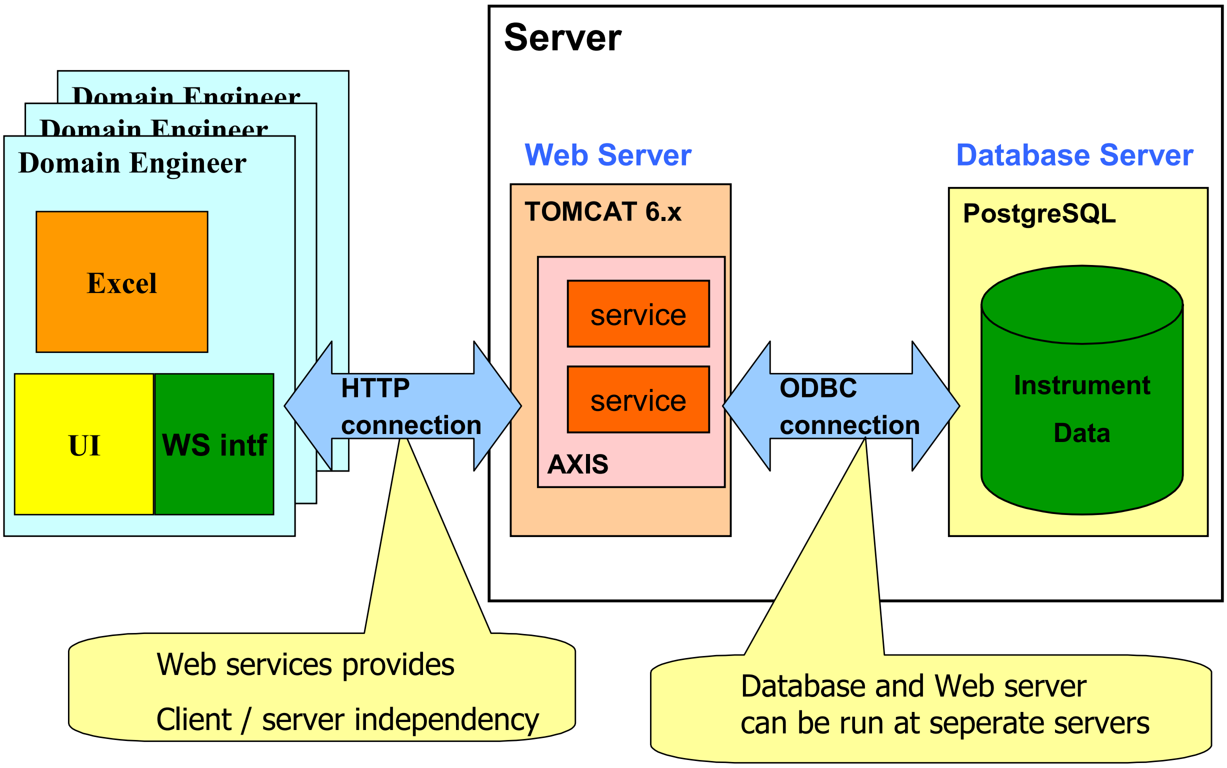


Figure 4-2 Space Instruments database architecture

A Graphical User Interface has been developed under Microsoft .Net v2 that authorizes the following actions:

- browse and search instruments:
    - tree based and form based,
- add instruments,
- edit instrument parameters descriptions:
    - define instrument groups,
    - define instrument types within a group,
    - define parameter types for instruments.

Database GUI snapshots are given in Figure 4-3

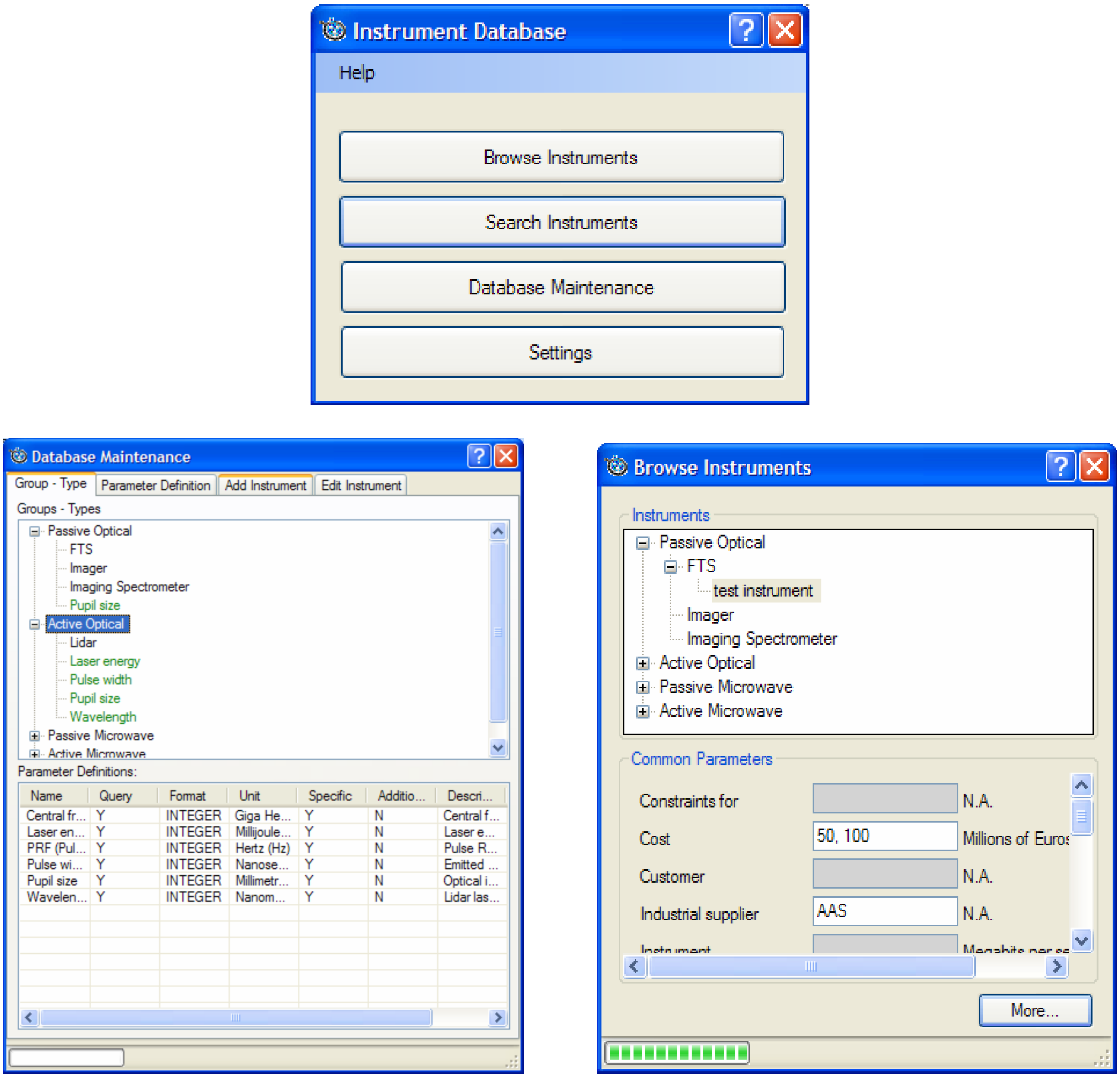


Figure 4-3 Snapshot view of space instruments database graphical user interface

<u>This architecture makes the database very flexible for new instruments.</u>

4.2 Review of design methods and tools

The review of design methods and tools has covered the four previously identified categories: optical instruments (passive and active), and microwave instruments (passive and active) (see Figure 4-1).

The approach followed to perform the design methods and tools review is given hereafter, it is valid for each instrument type:

- define top level instruments requirements and constraints from Satellite and mission,
- produce a functional diagram identifying
  - required sub-systems,
  - parameters/constraints defining them,
  - options or trade-offs to be performed,
  - outputs constraining other sub-systems or participating to the performance and instrument budgets,
- identify the methods, tools, needed to define the required parameters,
- organize the design sequence and tools in a design method flowchart.

4.2.1 Identification of requirements and constraints for passive instruments

The first step in the instrument design logic consists in the analysis of the requirements. They can be gathered in several categories, representative of their origin. The analysis of these requirements permits to identify the instrument design drivers. Taking the example of an imaging spectrometer, the following drivers can be identified:

- from mission analysis:
  - satellite altitude,
  - field of view,
  - lifetime,
  - orbit type,
- from mission objectives:
  - wavelengths, spectral range, number of bands and resolution,
  - temporal and spatial sampling,
  - image quality (MTF, SNR, registration, polarization),
  - calibration,
- from observed scene:
  - radiance, dynamic range, non uniform scenes,
- constraints from satellite:
  - available space, mass and power
  - constraint on CoG (agility),
- cost.

All these requirements define the instrument class to be designed and give inputs for the instrument design logic and more precisely for the tools used during this activity and introduced later, after the functional description of the instrument.

~~3.3.3~~4.2.2 *Instrument functional description*

The main functions of an imager and a FTS instrument are given in the following diagrams.

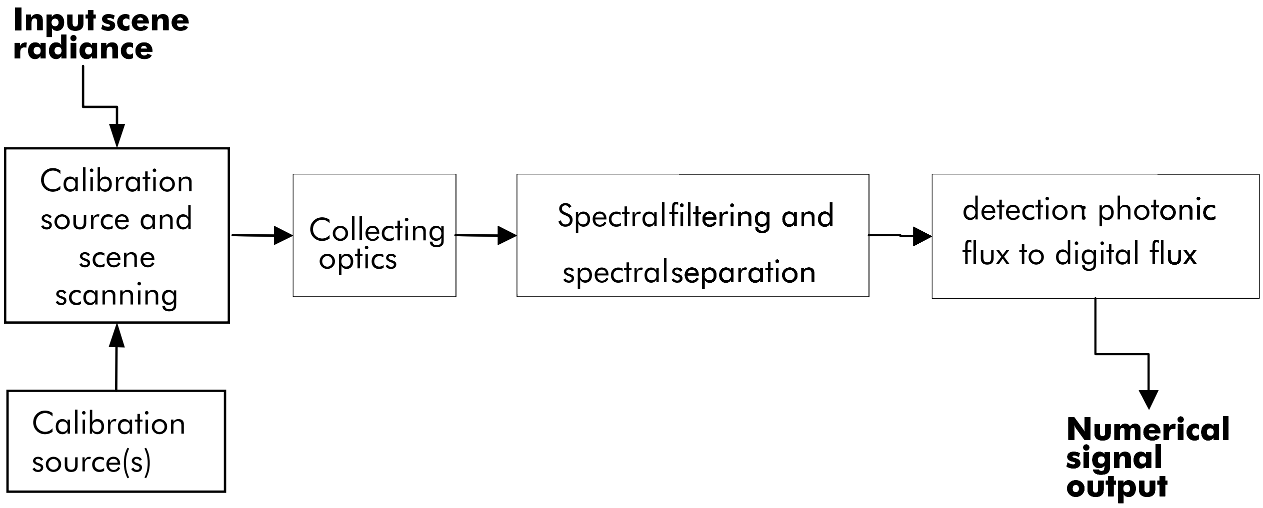


Figure 4-4 Imagers and imaging spectrometers functional diagram

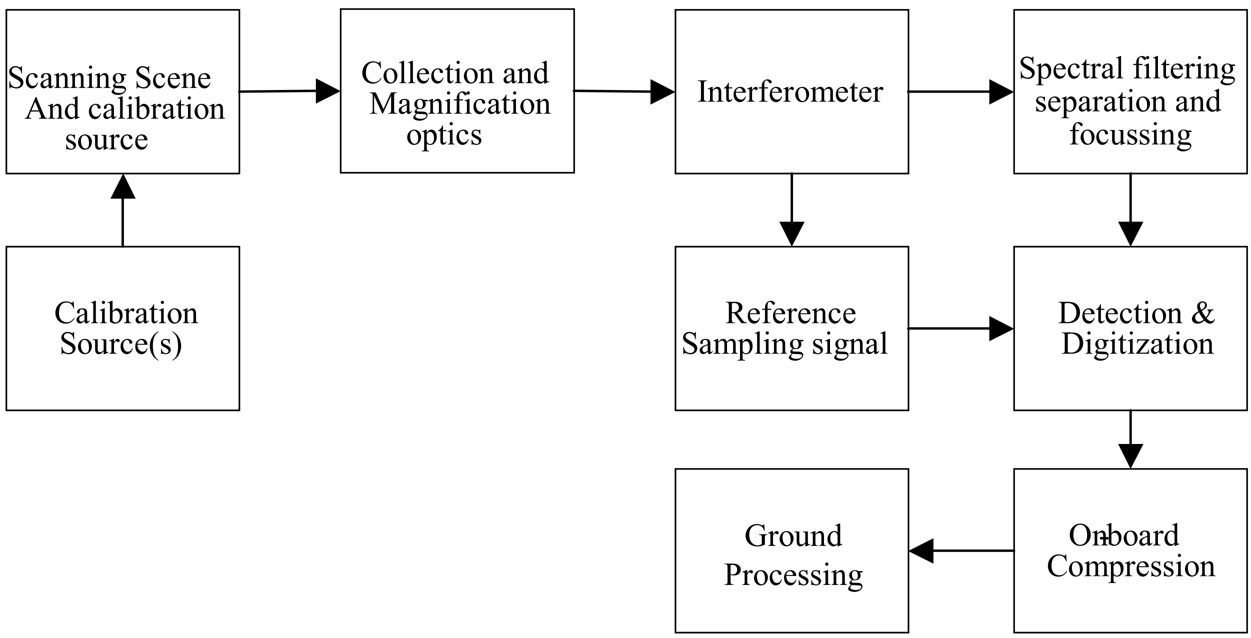


Figure 4-5 Fourier Transform Spectrometers functional diagram

Each identified sub-system is characterized by its function, the parameters and constraints that are used for the dimensioning activity and output parameters and constraints that affect the other instrument subsystems.

An illustration of collecting optics and detectors design options is given in Figure 4-7 and Figure 4-8.

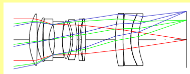
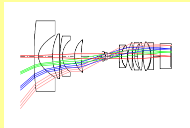
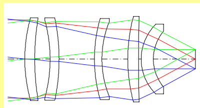
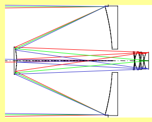
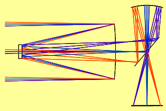
Collecting optics				
Function: Collects the light and forms an image				
Input parameters and constraints	**Output parameters and constraints**	**Options**	**Examples** Dioptric	 Catadioptric
Physical parameters Pupil dimensions Pupil location Exit pupil location Focal length Backfocus Field of view Spectral domains Operational temperature Sensitivity. to therm. variations Radiation environment Max. dimensions Max. mass **Performance** Image quality Distortion Throughput Straylight rejection Polarisation	**Design** Optical Mechanical Thermal **Interfaces** Dimensions Mass Temperature stability **Performance** Image quality Distortion Throughput Straylight rejection Polarisation	High resolution optics Wide field of view optics Large spectral range optics	  	 

Figure 4-6 Collecting optics sub-system design options

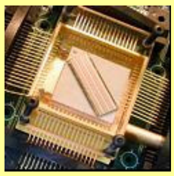
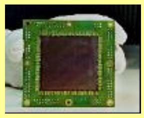
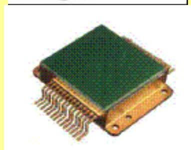
Detection				
Function: Transforms photonic flux into digital flux Include detectors and video electronics				
Input parameters and constraints	**Output parameters and constraints**	**Options**	**Examples** Linear	 Matrix
Physical parameters Spectral bands Optical fluxes Integration time Pixel pitch & size range Total number of pixels Number of TDI lines Radiation environment Max. power **Performance** SNR MTF Max. charge capacity	**Design** Mechanical Thermal **Interfaces** Dimensions Mass Power Temperature Temperature stability Number of video outputs ROIC readout mode Number of pixels per module Number of modules Pixel pitch & size Data rate Power **Performance** SNR MTF Max. charge capacity	**Visible** CCD CMOS **Infrared** HgCdTe QWIPs InSb InGaAs Microbolometer	  	  

Figure 4-7 Detection sub-system design options

During the first phase of the study, such a review has been done for each instrument type and sub-system. Sizing and performance parameters have been collected, grouped per domain and formatted to prepare the implementation of the CDF-IDA model in the second phase of the study (see section 4.3).

4.2.3 Identified tools and cots

Each type of instrument necessitates the use of a given set of tools and COTS. For imagers, image quality mainly translates into MTF, SNR, distortion requirements which are estimated using geometrical and radiometric performance tools.

Geometrical, spectral and radiometric performance are first estimated using dedicated tools for MTF & SNR estimation (or other expressed requirements such as IPSF, ISRF,…).These tools will give inputs for the selection of the optical configuration and its sizing.
COTS are also used in the design process to consolidate the selected concept:

- optical concept
    - Architecture selection, performance analysis, sensitivity analysis (Zemax)
- mechanical and thermal concept
    - mechanical and thermal architecture,
    - selection of structures, optics, asses eigen frequencies,
    - mechanical and thermal design performance,
- validation of the selected concept
    - Catia v5,
    - Patran/Nastran,
    - Esarad, ThermXl.

4.2.4 Tools application to Concurrent Engineering:

During the review, Concurrent Engineering applicability criteria for instrument design methods and tools have been established. These criteria are listed hereafter:

- Quasi real-time preparation and calculation
    - Leads to limited time impact on team
    - High preparation time -> ‘fast use during sessions
- Limited number of inputs
    - Relative total amount of I/O parameters in model
    - High number of input leads to pressure on other domains
- Level of Design Detail
    - System -> Subsystem-> Unit
- Documentation
    - Support to new users
    - Low learning curve -> efficient use of experts
- Ease of Use
    - Low learning curve -> efficient use of experts
- Programmatic interface
    - Scripting capabilities
    - Data exchange via open standards
- Platform Independent
    - Webservices -> interoperability
- Ease of installation/Licensing
    - Preparation time
- ESA CDF compatibility
    - MS Excel Environment – VBA scripting
    - MS Windows 2003 / MS Terminal Services /Citrix Metaframe XP

All identified COTS and TOOLS have been traded-off with respect to the previous criteria. As a result of this analysis, a list of compliant tools and COTS have been established. The list of tools presented here applies to optical and microwave instruments:

- COTS tools:
  - OPTICS
    - Zemax
    - Code V
  - Microwave Instruments
    - GRASP
    - HFSS
  - CAD
    - Catia V5
  - Mechanical Analysis
    - PATRAN
    - NASTRAN
  - Thermal Analysis
    - ThermXL

- In-house developed tools:
  - Imagers, spectro-imagers and FTS
    - Radiometric performance estimation tool
    - Geometric performance estimation tool
    - Spectral performance estimation tool
  - LIDARS
    - Spectral performance estimation tool
    - Radiometric performance estimation tool

This tools review and selection phase have been completed for each instrument type, by a description of analytical methods to be integrate in the in-house tools.

4.2.5 Design approach

Designing an instrument needs to trade-off between several options for each sub-system (see Figure 4-6 and Figure 4-7). In order to start analyzing optical configuration and identifying focal plane solutions, which will be optimized during the study, a first estimation of the sizing parameters values is performed using specific tools as identified in the previous section.

The main requirements from which are derived the space instruments design drivers are linked to performance quality, trough mission objectives and given foreseen image or signal processing. Image or signal processing is to be considered at an early stage since it will relax the instrument requirements.

The following flowcharts illustrates the design logic identified for Fourier Transform Spectrometers and Radiometers. They show the interactions between the main sizing tasks, as well as the required tools.

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It has to be noted that the design logics illustrated by the flowcharts do not describe a pure sequential activity. Several options can be explored and several loops have to be done before converging towards a satisfying solution.

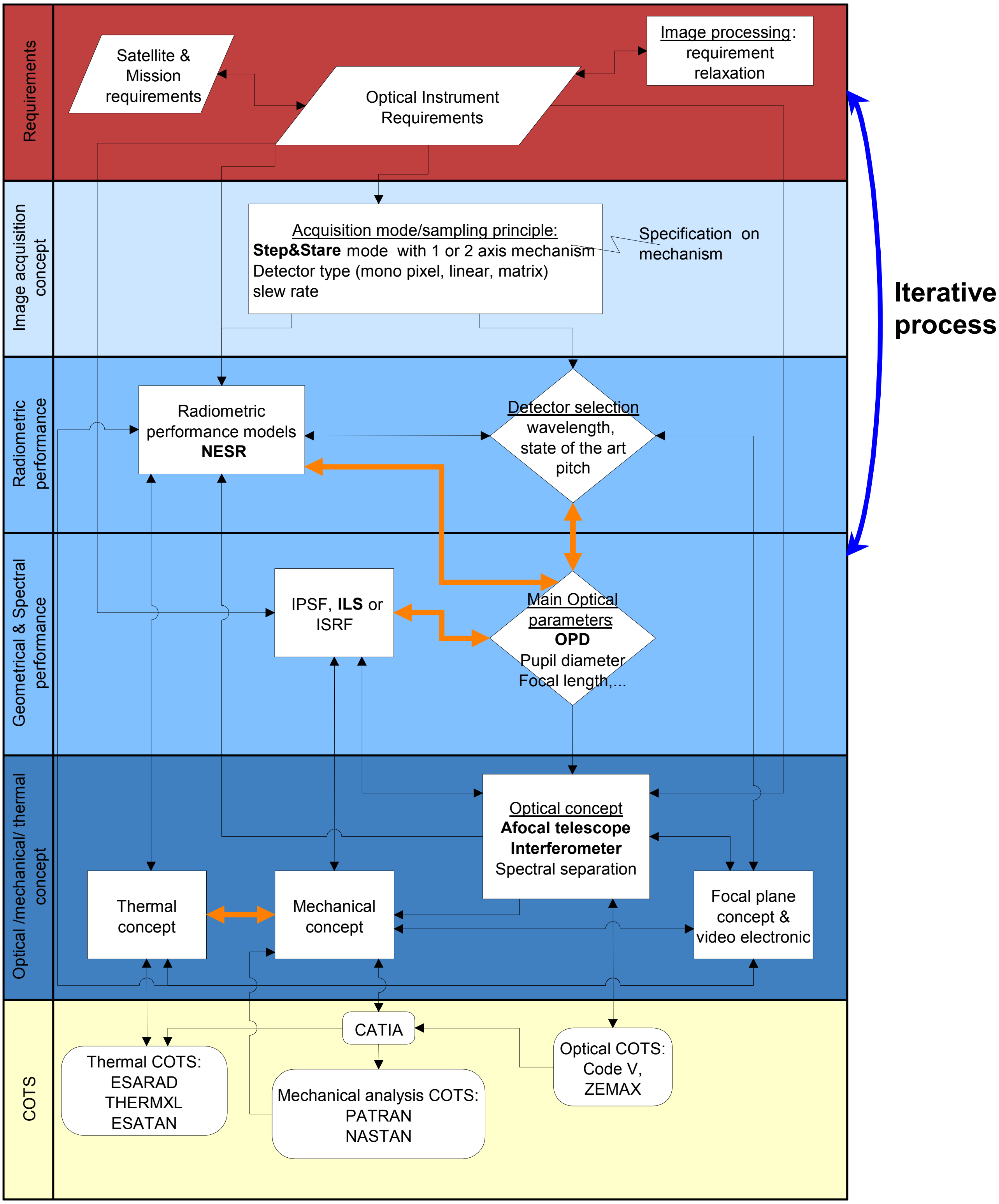

Figure 4-8 Fourier Transform design method flowchart

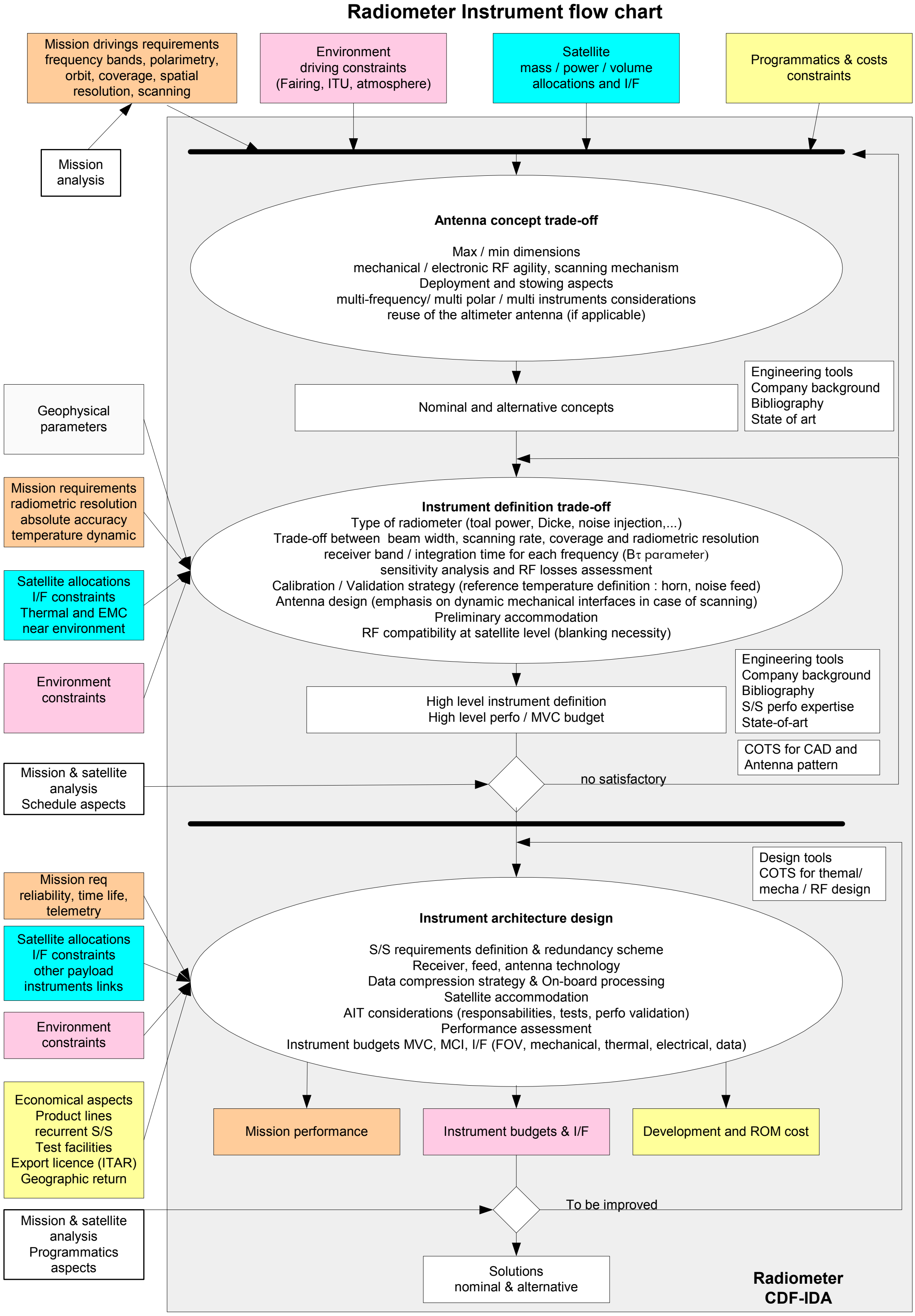

Figure 4-9 passive µ-wave instruments: radiometer design method flowchart

4.3 CDF-IDA model architecture for Passive Optical Instruments

After reviewing the design methods and tools for the four identified categories, a CDF-IDA model has been developed for the passive optical instruments starting from the ESA IDM. The proposed model is generic and flexible enough to be adapted to specific needs either for Earth observation or Exploration missions. Its architecture is detailed in the following section.

4.3.1 CDF-IDA workbooks architecture

The IDA architecture reflects the team of experts to be involved in the design activity:

- instrument system engineer
  - in charge of instrument requirements synthesis, pre-sizing activities, performance synthesis, global coherence of the instrument architecture,
- detection chain engineer
  - in charge of radiometric performance calculations and detection chain architecture,
- optical engineer
  - in charge of optical configuration selection, optimization and sensitivity analysis,
- structure engineer
  - in charge of instrument structure design and optimization, thermal and mechanical allocations and budgets linked to instrument stability, mass budgets, instrument stability synthesis (line of sight), mechanical analysis synthesis,
- thermal engineer
  - in charge of instrument thermal control architecture design,
- mechanisms engineer
  - in charge of mechanisms design.

To each of these expert corresponds a domain or workbook in the CDF-IDA that completes the workbooks already identified in the ESA IDM. Each of these workbooks are interfaced with needed tools, COTS and databases.
The proposed IDA workbook architecture, applied to imager/spectrometer model is illustrated in Figure 4-10.
The software links between COTS and major databases are pointed out. The IDA data exchange supports the parameter exchange protocol between workbooks and guarantees a unique technical configuration of the design during the study.

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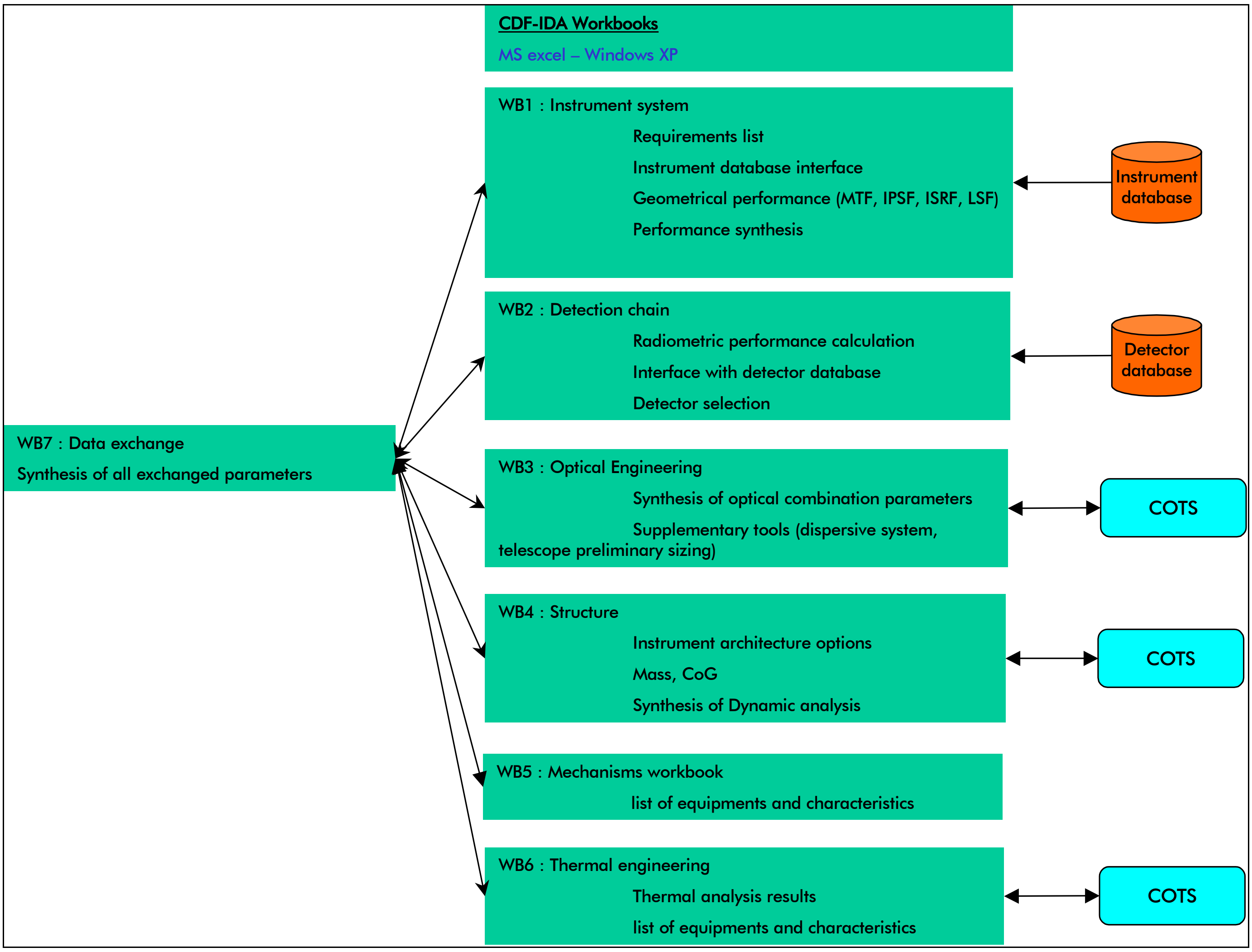

Figure 4-10 CDF-IDA architecture for passive optical instruments. In addition to the workbook already identified in the IDM, it integrates an Instruments_system workbook, detection_chain workbook and instrument database and a detector database

Specific tools addressing the passive optical instruments design activity have been developed and integrated in the CDF-IDA. Some domains, already existing in the IDM had already their modelling tools (like for structure, thermal, CAD) required not to be modified. Within the CDF-IDA project, models development activity has concentrate on the missing tools (e.g. detector and optical performance tools) to assure the ability of the Model to perform conceptual design of instruments.

The following sections focus on the tools developed for imagers and FTS instruments.

4.3.2 Focus on Imagers and imaging spectrometers:

4.3.2.1 Instrument system workbook

In order to performs instrument pre-sizing activities, the instrument system workbook integrates, besides a sheet dedicated to the requirements synthesis, several sheets, each of them containing a specific tool:

- Acquisition mode selection tool
- MTF performance estimation tool
- IPSF/ISRF calculation tool
- Mass and volume estimation tool

The use of these tools gives the possibility to the expert to determine, given the instrument requirements, the more adapted scene acquisition mode (push-broom, snapshot, scene scanning), to produce MTF reduction factors allocation and to estimate a pupil diameter that is sent, through the data exchange workbook, to detection_chain and optics workbooks.

When the sizing activity is sufficiently advanced, instrument performances are also gathered in this workbook to be compared to the requirements. Figure 4-11 gives an illustration of the IPSF/ISRF calculation tool:

Parameter	Value	Unit	
Requirements			
Spatial width ACT	#VALEUR!	[m]	
Spatial width ALT	#VALEUR!	[m]	
Spectral width	#VALEUR!	[nm]	
Mission			
Satellite altitude	35786	[km]	
Roll	0	[deg]	
Yaw	0	[deg]	
Pitch	0	[deg]	
Latitude	0	[deg]	
Satellite incidence	0	[deg]	
Ground incidence	0	[deg]	
Optics			
Central wavelength	-	[µm]	
Instrument Pupil diameter	#VALEUR!	[m]	
Telescope obscuration ratio	0		
Instrument Focal length	#VALEUR!	[m]	
Telescope aberration enlargement	-	[x DL]	
Telescope RMS error	-	[lambda/]	
Spectrometer aberration enlargement	-	[x DL]	
Spectrometer RMS error	-	[lambda/]	
Slit size (ALT)	-	[µm]	
Slit size (ALT), on ground	#VALEUR!	[m]	
Focal plane			
Detector pitch, ACT	-	[µm]	
Detector pitch, ALT	-	[µm]	
Actual Detector size, ACT	#VALEUR!	[µm]	
Actual Detector size, ALT	#VALEUR!	[µm]	
Detector Nyquist MTF, ACT	-		
Detector Nyquist MTF, ALT	-		
Smearing / ALT sampling			
ALT sampling period on ground	#VALEUR!	[m]	
Sampling time (not accounting slow down)	#VALEUR!	[ms]	Calculated
Integration gate, on ground	-	[m]	
Integration time (not accounting slow down)	#VALEUR!	[ms]	Calculated
PSF sampling			
PSF on ground or at FPA ?	FPA		
PSF range, +/-	-	[µm]	
PSF step	#VALEUR!	[µm]	
MTF sampling			
MTF range, +/-	#VALEUR!	[mm-1]	
MTF step	#VALEUR!	[mm-1]	
Pixel enlargement			
ACT enlargement	1		
ALT enlargement	1		
Others			
Nyquist ACT & ALT	#VALEUR!	[mm-1]	
Number of points	256		
F number	#VALEUR!		
Imaging spectrometer ?	True		
INSERT ROWS ABOVE THIS ROW IF YOU NEED TO ADD PARAMETERS			

Figure 4-11 Snapshot view of the IPSF/ISRF calculation tool

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4.3.2.2 Detection chain workbook

The detection chain expert is in charge of focal plane architecture determination and radiometric performance estimation. To perform these activities, dedicated sheets are implemented:

- Focal Plane sizing sheet
- SNR sheet

The detection_chain expert receives from the instrument system and the optics all the information required to perform its activities (radiometric performance requirements, orbit characteristics, scene characteristics, instrument characteristics).
The SNR sheet gives the possibility to address either quantum detectors or µ-bolometers detectors and to work either with radiance data or temperature data. Once the detector characteristics are selected and the calculations done, the radiometric performance estimation is accessible to the instrument_system expert through the data-exchange workbook.

The following figure gives an illustration of the SNR sheet:

Parameter	Values	Units	List of choices	Cell Name
	Spectral band number 1			
	-	[N.A]		
Model Selection				
selected model	Photonic Noise	[N.A.]		
Published Output Values choice			Quantum detector	
SNR				
NeDL				
NeDT				
Input Values and Manual Values				
Estimated Pupil Diameter	-	[mm]		Det_EstimPupilDiam
Optimised Pupil Diameter	-	[mm]		Det_OptimPupilDiam
Pupil Diameter used for work	-		Optimised value	Det_PupilDiameter
Estimated Focal Length	-	[mm]		Det_EstimFocalLenght
Optimised Focal Length	-	[mm]		Det_OptimFocalLenght
Focal length used for work	-		Optimised value	Det_FocalLength
Scene TOA min radiance for spectral band number 1 (E1)	-	[W/m2/µm/sr]		Det_Ls_Lambda_E1_band
Scene TOA typical radiance for spectral band number 1 (E2)	-	[W/m2/µm/sr]		Det_Ls_Lambda_E2_band
Scene TOA max radiance for spectral band number 1 (E3)	-	[W/m2/µm/sr]		Det_Ls_Lambda_E3_band
Scene TOA saturation radiance for spectral band number 1 (E4)	-	[W/m2/µm/sr]		Det_Ls_Lambda_E4_band
Scene min temperature for spectral band number 1 (T1)	-	[K]		Det_Temp_E1_band
Scene typical temperature for spectral band number 1 (T2)	-	[K]		Det_Temp_E2_band
Scene max temperature for spectral band number 1 (T3)	-	[K]		Det_Temp_E3_band
Scene saturation temperature for spectral band number 1 (T4)	-	[K]		Det_Temp_E4_band
Calculated radiance for IR channels @ E1	#VALEUR!	[W/m2/µm/sr]		Det_Ls_Temp_E1_band
Calculated radiance for IR channels @ E2	#VALEUR!	[W/m2/µm/sr]		Det_Ls_Temp_E2_band
Calculated radiance for IR channels @ E3	#VALEUR!	[W/m2/µm/sr]		Det_Ls_Temp_E3_band
Calculated radiance for IR channels @ E4	#VALEUR!	[W/m2/µm/sr]		Det_Ls_Temp_E4_band
Kind of radiance used for work			Radiance value	
Source radiance E1 used for work	-	[W/m2/µm/sr]		Det_Ls_E1_band
Source radiance E2 used for work	-	[W/m2/µm/sr]		Det_Ls_E2_band
Source radiance E3 used for work	-	[W/m2/µm/sr]		Det_Ls_E3_band
Source radiance E4 used for work	-	[W/m2/µm/sr]		Det_Ls_E4_band
Central wavelength	-	[µm]		Det_Lambda_band
Bandwidth	-	[µm]		Det_DeltaLambda_band
Number of pixels across track (ACT) (specification)	-	[N.A]		Det_pixel_number_ACT_Spec_band
Number of pixels along track (ALT) (specification)	-	[N.A]		Det_pixel_number_ALT_Spec_band
ACT Pixel size	-	[µm]		Det_pixel_size_ACT_band_user_for_SNR
ALT Pixel size	-	[µm]		Det_pixel_size_ALT_band_user_for_SNR
GSD at Nadir	-	[m]		Det_GSD_Nadir_band
Mean Altitude	-	[km]		Det_Altitude
Geometrical Etendue	#VALEUR!	$[m^2.sr]$		Det_S_omega_band
Sampling time	-	[s]		Det_SamplingTime_band
Oversampling coefficient	-	[N.A]		Det_OverSamplingCoefficient_band
Number of TDI lines	-	[N.A]		Det_NbTDI_band
Integration Time	#VALEUR!	[s]		Det_Ti_band
Global transmission of the optics	-	[N.A]		Det_Trans_Opt
Optimised central obturation diameter	-	[mm]		Det_OptimObtDiam
Quantum Detector				
Microbolometer detector				
INSERT ROWS ABOVE THIS ROW IF YOU NEED TO ADD PARAMETERS				

Figure 4-12 Snapshot view of the SNR estimation sheet

To complete the tools accessible to the detection chain expert, a link to a detector database has been implemented in the Focal plane sizing sheet, which gives access to a set of detectors characteristics:

in red: parameters to be used in the radiometric performance model.

Company	Technology
KODAK	CMOS
CYPRESS	CMOS

Process	XFAB 0,35µm	TSL 0,18µm
Minimum feature size	7µm	
Nominal voltage supply	3V	3,3V-1.8V

	KAC-9628
Pixel Structure	
Resolution	664 x 504 Total / 648 x 488 Active
Pixel pitch (µm)	7.5
QExFF typical over [470-830] (%)	27%
Fill Factor	47%
Sensitivity (V/lux.s)	2.7
Output Dynamic Range (dB) in linear mode	62
Operating T° (°C)	-40 - 85
Tintegration Time Range (ms)	33
Output data rate (Hz)	30
Number of video outputs	2
Read Noise (LSB/s)	4
Dark Signal (LSB/s)	130
FPN (%)	0.1
DSNU (V/s)	
PRNU (%)	1.5
Power Consumption (mW)	168
Color Mosaic	Bayer
Package (mm²)	
Doc. Reference	KODAC KAC-9628 CMOS IMAGE SENSOR

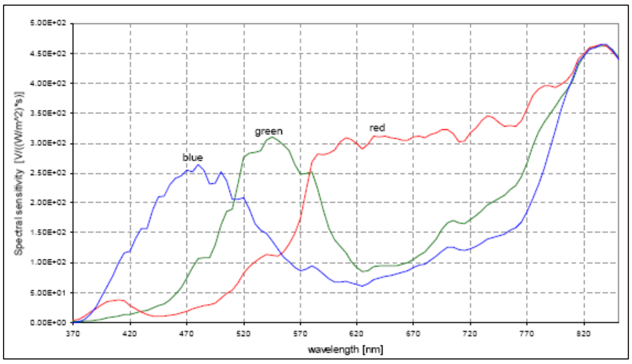

Figure 4-13 Snapshot view of the detectors database

4.3.3 Focus on Fourier Transform spectrometers:

4.3.3.1 Instrument system workbook

In a Fourier Transform Spectrometer design activity, the instrument system expert is in charge of several activities:

- determination of the dwell time (either for Leo or Geo type orbits),
- selection of the metrology laser and calibration concept,
- determination of the required OPD, interferogram sampling requirements (sampling time, frequency, number of samples),
- determination of he maximum achievable GSD considering the FOV impact on fringe contrast,
- establishment of contrast loss contributors allocations .

In the instrument system workbook, these activities are addressed through the use of dedicated sheets each of them including specific tools.

The Figure 4-14 view illustrates the FTS OPD/IFOV sizing sheet. Other specific FTS sheets included in the instrument_system workbook are:

- FTS acquisition,
- FTS contrast budget.

Parameter	Value	Units	CellName
	Spectral band number 1		
INPUT PARAMETERS	-		
Optics pre-sizing LIP			
Estimated Afocal magnification factor	-	[N.A.]	
Metrology laser wavelength	-	[µm]	
Single or double sided interferogram	-	[N.A.]	
OPD margin	-	[%]	
Nyquist oversampling coefficient	-	[N.A.]	
Interferometer type	Michelson	[N.A.]	
Imager or sounder	Sounder	[N.A.]	
Estimated FTS Input pupil diameter	-	[mm]	
Required FTS input pupil diamter	-	[mm]	
sizing FTS pupil - selection	Estimated FTS		
sizing FTS	-	[mm]	
Mission Parameters			
Orbit type	LEO	[N.A.]	
Mean Altitude	-	[km]	
Stare size	-	[m]	
Instrument Requirements			
Min wave number	-	[cm-1]	
Max wave number	-	[cm-1]	
Spectral Sampling Distance	-	[cm-1]	
GSD at Nadir	-	[m]	
FTS Acquisition			
Dwell Time	#VALEUR!	[s]	
CALCULATED PARAMETERS			
Wave Data			
Mean wave number	#VALEUR!	[cm-1]	mean_wave_band
bandwith	#VALEUR!	[cm-1]	bandwith_band
Min wavelength	#VALEUR!	[µm]	min_lambda_band
Max wavelength	#VALEUR!	[µm]	max_lambda_band
Mean wavelength	#VALEUR!	[µm]	mean_lambda_band
OPD Sizing			
Max OPD	#VALEUR!	[cm]	Max_OPD_band
Corner cube stroke	#VALEUR!	[cm]	Cc_stroke_band
Spectral resolution	#VALEUR!	[cm-1]	Spectral_res_band
Resolving power	#VALEUR!	[N.A.]	Resolving_power_band
Sampling frequency sizing			
Sizing wavelength	laser wavelength		
Sizing wavelength (min or laser)	-		sizing_lambda_band
Nyquist sampling frequency	#VALEUR!	[Hz]	Nyquist_freq_band
Sampling frequency	#VALEUR!	[Hz]	Sampling_frequency_band
Sampling time	#VALEUR!	[s]	Ts_band
Number of samples	#VALEUR!	[N.A.]	samples_number_band
OPD sampling	#VALEUR!	[µm]	OPD_sample_band
IFOV sizing			
Max GSD in stare corner	#VALEUR!	[m]	Max_corner_GSD_band
Effective GSD	#VALEUR!	[m]	Effective_GSD_band
Number of super pixels per matrix side	#VALEUR!	[N.A.]	Sup_pixels_stare_side_band
Total number of super pixels	#VALEUR!	[N.A.]	Sup_pixel_number_band
INSERT ROWS ABOVE THIS ROW IF YOU NEED TO ADD PARAMETERS			

Figure 4-14 Snapshot view of the FTS OPD/IFOV sizing sheet

4.3.3.2 Detection chain workbook

With respect to imagers and imaging spectrometers, the FTS radiometric performance estimation shows some specificities:

- spectral band specified in terms of wavenumbers [cm-1],

- bandwidth large with respect to the central wavenumber which imposes the use of numerical integration methods to calculate sources flux,
- the radiometric performance can be expressed as a function of the wavenumber and not of the spectral band,
- Noises are expressed through spectral densities to take into account non white noise (1/f) and wavenumber dependency.

These specificities have imposed the implementation of a sheet dedicated to the FTS radiometric performance estimation. Illustrations of the tool are given in the following figures:

Parameter	Value	Units	CellName
	Spectral band number 1		
INPUT PARAMETERS			
selected model	Photonic Noise	[N.A.]	
spectral band name	-	[N.A.]	
Mission			
Mean Altitude	-	[km]	
Instruments system			
Estimated pupil diameter	-	[mm]	
required pupil diameter	-	[mm]	
choose estimated-required pupil diameter	Required Pupil Diameter	[-]	
sizing pupil diameter	-		FTS_SNR_pup
Dwell time	-	[s]	FTS_SNR_Dwell_time
Single or double sided interferogram	-	[N.A.]	FTS_SNR_SingleDoubleSided
Stare size	-	[m]	FTS_SNR_stare
Allocated Instrument temperature	-	[K]	FTS_SNR_I_temp
Interferometer contrast	-	[N.A.]	FTS_SNR_C_int_band
Interferogram sampling time	-	[s]	FTS_SNR_Ts
Max OPD	-	[cm]	FTS_SNR_Max_OPD
ACT super pixel size on ground (GSD)	-	[m]	FTS_SNR_ACT_sp_band
ALT super pixel size on ground (GSD)	-	[m]	FTS_SNR_ALT_sp_band
Min-wave number	-	[cm-1]	FTS_SNR_Min_wave_band
Max-wave number	-	[cm-1]	FTS_SNR_Max_wave_band
Spectral sampling Distance	-	[cm-1]	FTS_SNR_Spectral_sampling_band
Scene min temperature	-	[K]	FTS_SNR_Scene_min_temp_band
Scene typical temperature	-	[K]	FTS_SNR_Scene_typical_temp_band
Scene max temperature	-	[K]	FTS_SNR_Scene_max_temp_band
Scene saturation temperature	-	[K]	FTS_SNR_Scene_satur_temp_band
FTS type	-	[N.A.]	FTS_SNR_FTS_type
Optics			
Radiometric transmission	-	[N.A.]	FTS_SNR_T_rad_band
Useful transmission	-	[N.A.]	FTS_SNR_T_use_band
Optical transmission (except interferometer)	-	[N.A.]	FTS_SNR_T_Opt_band
FP sizing & detector selection			
Oversampling coefficient (from max pixel charge handling or max video frequency)	-	[N.A.]	FTS_SNR_OversamplingCoeff_band
Quantum efficiency	-	[%]	FTS_SNR_QE_band
Number of video outputs	-	[N.A.]	FTS_SNR_VIDEO_NbOutputs_band
ACT pixel size in FPA	-	[µm]	FTS_SNR_pixel_size_ACT_band
ALT pixel size in FPA	-	[µm]	FTS_SNR_pixel_size_ALT_band
Conversion factor	0	[µV/e-]	FTS_SNR_FC_band
fill factor	-	[%]	FTS_SNR_Ff_band
Detection chain FTS SNR LIP			
Number of calculation points for black body integration	10	[N.A.]	
Selected calculation wave number	1050	[cm-1]	LIP_Calc_wave_band
Constants			
Electron_charge (constant)	1.60E-19	[C]	

Figure 4-15 FTS radiometric performance input parameters

Atmospheric Transmission parameters			
Wavenumbers range name	u_sp1		WaveRange_band
Transmission range name	a_sp1		AtmosphericTrans_band
Atmospheric transmission for the selected WaveNumber	0.75		InterAtTrans_band
CALCULATED PARAMETERS			
Intermediate Calculations			
Mean wave number	#VALEUR!	[cm-1]	
Mean wavelength	#VALEUR!	[µm]	
Spectral band limitation due to time analysis	#VALEUR!	[Hz]	
Fringes speed	#VALEUR!	[cm/s]	
Number of super pixels per stare	#VALEUR!	[N.A.]	
Total number of super pixels	#VALEUR!	[N.A.]	
Geometrical etendue of super pixels	#VALEUR!	[m².sr]	
Integration time	#VALEUR!	[s]	
Integration frequency	#VALEUR!	[Hz]	
Number of effective samples	#VALEUR!	[N.A.]	
Datarate before decimation	#VALEUR!	[Mb/s]	FTS_raw_datarate_band
Decimation factor	#VALEUR!	[N.A.]	
Datarate after decimation	#VALEUR!	[Mb/s]	FTS_datarate_after_decimation_band
Instrument emissivity	#VALEUR!	[N.A.]	
Required focal length	#VALEUR!	[mm]	
Required F-number	#VALEUR!	[N.A.]	
Photonic signals Calculations			
Contrast due to integration time (fringe smearing) at mean wave number	#VALEUR!	[N.A.]	
Modulated instrument background of the interferometer baseline	#VALEUR!	[e-]	
Modulated intrument background at ZPD	#VALEUR!	[e-]	
Scene signal level of the interferometer baseline @ Ttyp	#VALEUR!	[e-]	
Scene signal at ZPD @ Ttyp	#VALEUR!	[e-]	
Scene signal level of the interferometer baseline @Tmin	#VALEUR!	[e-]	
Scene signal at ZPD @Tmin	#VALEUR!	[e-]	
Scene signal level of the interferometer baseline @Tmax	#VALEUR!	[e-]	
Scene signal at ZPD @Tmax	#VALEUR!	[e-]	
Scene signal level of the interferometer baseline @Tsat	#VALEUR!	[e-]	
Scene signal at ZPD @Tsat	#VALEUR!	[e-]	
Total signal (Smax) @ Ttyp	#VALEUR!	[e-]	
Max output voltage @ Ttyp	#VALEUR!	[V]	
Total signal (Smax) @Tmin	#VALEUR!	[e-]	
Max output voltage @ Tmin	#VALEUR!	[V]	
Total signal (Smax) @Ttmax	#VALEUR!	[e-]	
Max output voltage @ Tmax	#VALEUR!	[V]	
Total signal (Smax) @Tsat	#VALEUR!	[e-]	
Max output voltage @ Tsat	#VALEUR!	[V]	
Noise Calculations			
Instrument response	#VALEUR!	[e-.m².sr/W]	
Dark current noise	0.00	[e-/Hz^1/2]	dark_current_band
1/f noise (at mean wave number)	0.00	[e-/Hz^1/2]	one_over_f_noise_band
Video chain noise	0.00	[e-/Hz^1/2]	video_chain_noise_band
Quantization noise	0.00	[e-/Hz^1/2]	quantization_noise_band
Read out noise	0.00	[e-/Hz^1/2]	read_out_noise_band
E1			
Photonic @ E1	#VALEUR!	[e-/Hz^1/2]	photonic_noise_E1_band
Total noise @ E1	#VALEUR!	[e-/Hz^1/2]	
NeDL @ E1 Specification	-	[W/m²/cm-1/sr]	Det_FTS_NeDL_Spec_E1_band
NeDT @ E1 Specification	-	[K]	Det_FTS_NeDT_Spec_E1_band

Figure 4-16 FTS radiometric performance calculations

At the opposite, the Focal Plane sizing sheet is common to all the passive optical instruments

5. CONCLUSION

During this study Thales Alenia Space has proposed an IDA Model dedicated to the pre-design of passive optical instruments derived from its current instrument design methodology. The proposed developed model is generic and flexible enough to be adapted to specific Earth observation or exploration missions.

The developed model has been validated at Thales Alenia Space premises. It has then be tested by ESA in the frame of a test case dedicated to the study of a dynamic FTS instrument in ESA CDF premises. These tests have confirmed the flexibility of the model either to modify the integrated tools or to integrate new ones covering other instrument categories.

END OF DOCUMENT