

# Real time simulation tools in the CHORALE workshop

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## ABSTRACT

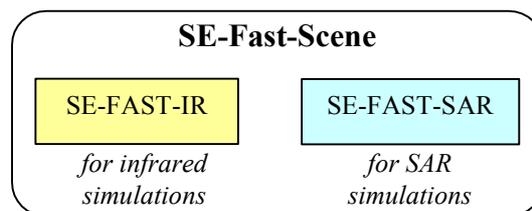
CHORALE (simulated Optronic Acoustic Radar battlefield) is used by the French DGA/DET (Directorate for Evaluation of the French Ministry of Defense) to perform multi-sensors simulations. CHORALE enables the user to create virtual and realistic multi spectral 3D scenes, and generate the physical signal received by a sensor, typically an IR sensor. To evaluate their efficiency in visible and infrared wavelength, simulation tools, that give a good representation of physical phenomena, are used. This article describes the elements used to prepare data (3D database, materials, scenario, ...) for the simulation, and the set of tools (SE-FAST-IR), used in CHORALE for the Real Time simulation in the infrared spectrum. SE-FAST-IR package allows the compilation and visualization of 3D databases for infrared simulations. It enables one to visualize complex and large databases for a wide set of real and pseudo-real time applications. SE-FAST-IR is based on the physical model of the Non Real Time tool of CHORALE workshop. It automatically computes radiance textures, Open GL light source and fog-law parameters for predefined thermal and atmospheric conditions, specified by the user.

**Keywords:** Real Time simulation, sensor effect, infrared, API, low light level, Open GL, shaders

## 1. INTRODUCTION

CHORALE is a software workshop that enables to create Synthetic Environments and to simulate any sensor associated perception both for research simulation including hardware in the loop, and training simulation with man in the loop. CHORALE is a winning initiative of the French DGA MoD, for sharing R&D efforts and federating a user group community that intends to exchange experience and knowledge. CHORALE is entirely based on the SE-Workbench from OKTAL-SE and realize the multi-spectral unification of optronic, electromagnetic and acoustics, using a common kernel & physical extensions affectation both aimed at a unique 3D scene and a common technology.

The purpose of this paper is to describe the tools used in the CHORALE workshop for real time infrared simulations. This package, called SE-FAST-IR, is a part of the SE-Fast-Scene package:



## 2. THE CHORALE WORKSHOP

CHORALE aims at mastering all the aspects of the multisensor synthetic environment creation and exploitation. For this purpose, very close connections have been made with state-of-the-art data representation models. For exploitation in distributed simulation networks, close connections to modern distribution and interoperability technology have been implemented at the end of the chain.

With the help of CHORALE, it is possible to produce multispectral scenes from visible 3D synthetic environments. The aim of this suite of tools is to calculate the physical transmission of the synthetic environment, as precisely and accurately as possible, to the entry of any sensor. For special application in order to ease the data analysis, sensor models are provided and libraries for user-model integration are available.

One of the aims of CHORALE is to provide the end user with an easy to use, integrated and efficient simulation workshop of the synthetic environment creation and analysis. Thus it provides a coherent and accurate way of simulating the sensor perception of Synthetic Environments in visible, infrared, intensification of light and acoustic spectrum, and more recently, in the high frequency electromagnetic domain. Over the production process of equipment, CHORALE can be positioned at the three major steps: Specification, Development and Qualification. In that frame, CHORALE offers a coherent and continuous chain, all over the production process.

The CHORALE workshop is made of a suite of individual tools organized in a logical and functional way.

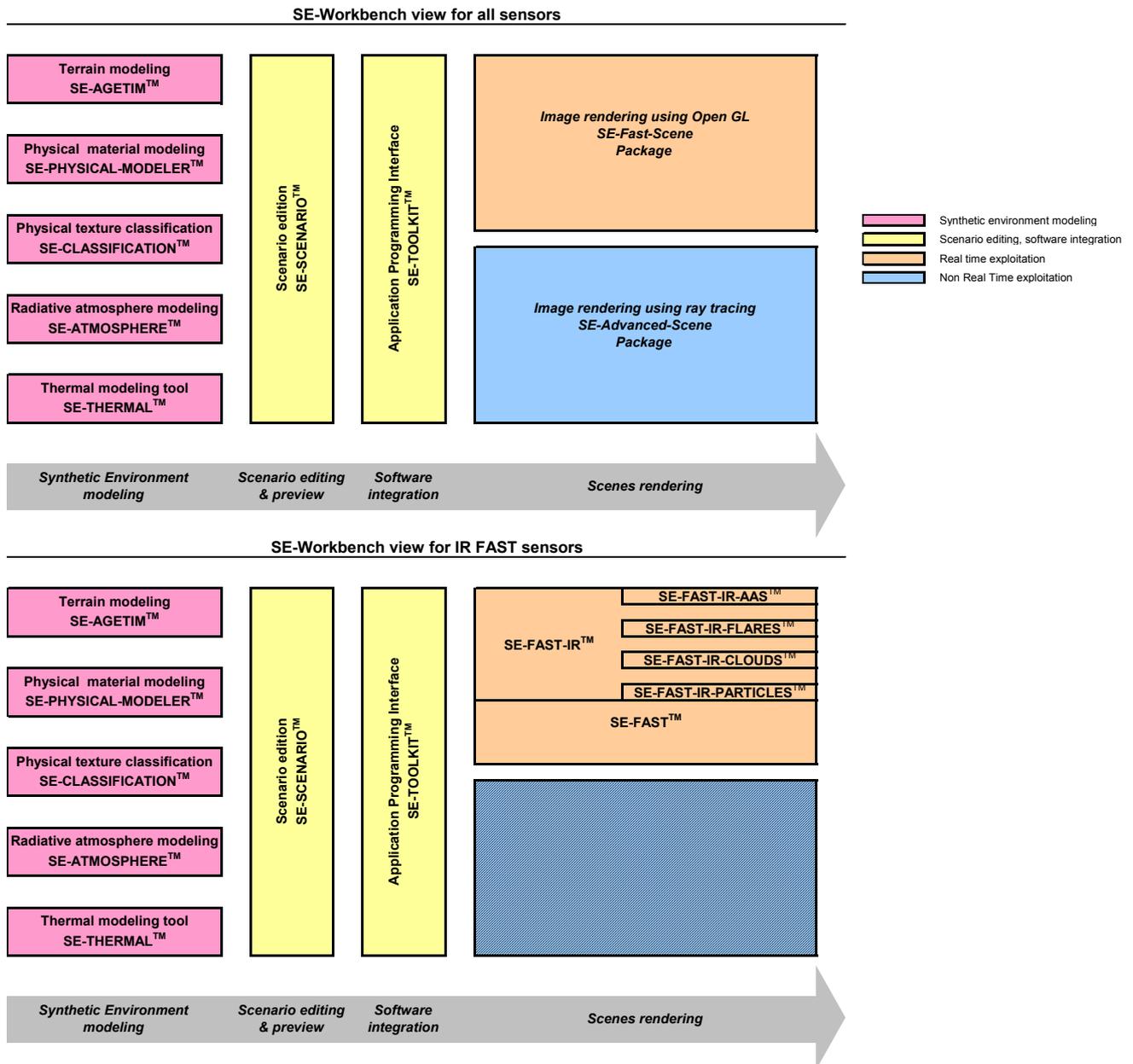


Fig 1: CHORALE architecture

The architecture of CHORALE presented above can be detailed following a logical chart from the data production to the final result exploitation and analysis.

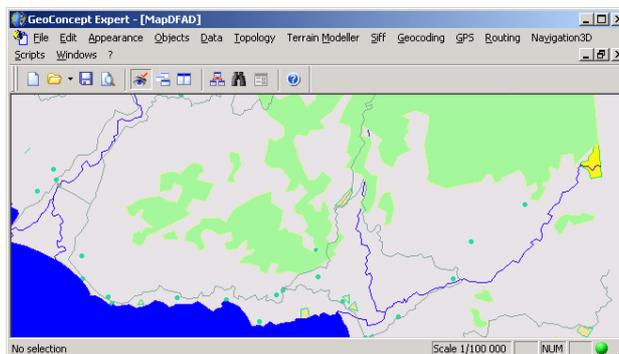
- ❑ The synthetic environment modeling part consists of the different steps that are needed in order to produce a physical multispectral synthetic environment. Five functions can be identified:
  - Geometrical databases need to be generated from heterogeneous geographical information data (SE-AGETIM).
  - The physical data needs to be set and associated to the 3D scene (SE-PHYSICAL-MODELER).
  - Each element of the 3D scene needs to be characterized in terms of its physical material content (SE-CLASSIFICATION)
  - The atmospheric conditions play a very important role in the quality of the generated scene (SE-ATMOSPHERE).
  - Finally, the temperature computation of the scene is relevant for most of the analyzed spectrums (SE-THERMAL).
  
- ❑ The scenario construction & preview stands between the modeling phase and the scene generation process, the user can build scenarios that will be helpful for the scene specification. Static scene generation can be expensive in terms of calculation time. The advantage of the scenario is the ability for the user to place the sensors, to fine-tune their positions and the overall control (SE-SCENARIO). Trajectories can be assigned to sensors through the same user interface.  
Furthermore, the user can do software integration in order to control the generated scenario execution from a remote or custom application. This can be achieved with the help of the SE-TOOLKIT consisting of a set of libraries and high-level integration functions.
  
- ❑ Two types of scene generation processes are available. High precision and multispectral static scenes can be generated using a very efficient industrial packaging of the ray tracing technology (SE-Advanced-Scene). With the help of some pre-calculation steps, real time sequences are computed with the SE-Fast-Scene solution.

### 3. SYNTHETIC ENVIRONMENT MODELING

The Synthetic Environment modeling step is described by 5 tools described here after:

#### 3.1. SE-AGETIM

The SE-AGETIM (*Synthetic Environment Multisensor Terrain Generation Tool*) product is an integrated software that enables the generation of 3D synthetic environment with a user specified resolution and realism. It provides the user with a unique way of integrating heterogeneous geographical data to produce a coherent 3D database. Corrections and enhancements can be applied on source data. The SE-AGETIM product is based on a reference of the market Geographical Information System (GIS) for its user interface.



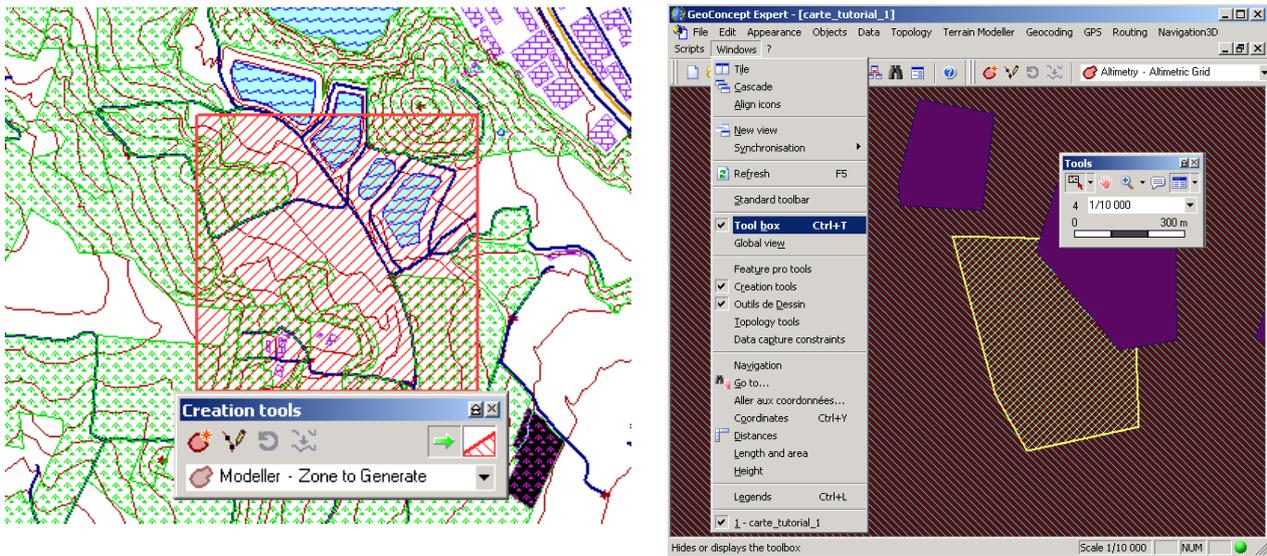


Fig 2: Map data edition with the help of the GIS functions of the SE-AGETIM product

### 3.2. SE-PHYSICAL-MODELER

The product SE-PHYSICAL-MODELER (*Synthetic Environment Physical Modeler*) enables the 3D synthetic environment developer to easily characterize the elements of the scene in terms of their physical properties. It gets state-of-the-art display capabilities, including interactive 3D visualization window based on Open-Inventor. The visualization windows are updated when modifying mapping or material. All the material used can be shown with a palette editing, with spectral and thermal characteristics graphic display.

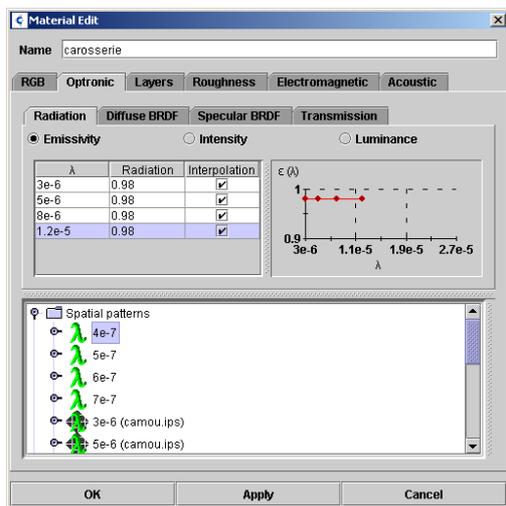


Fig 3: Infrared material physical properties edition

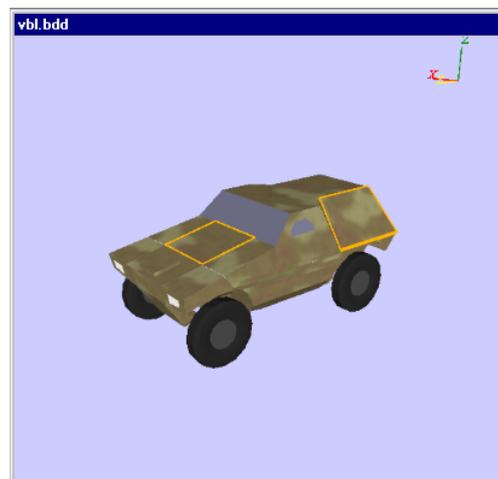


Fig 4: Polygon edition for structure modification, material association, texture assignment

### 3.3. SE-CLASSIFICATION

The SE-CLASSIFICATION (*Synthetic Environment Classification*) product is used to classify texture of physical materials. The picture to be classified is decomposed in layers. For example, one “roughcast” layer, one “window” layer and one “shutter” layer are created for a wall picture. For each layer, a material modulation is computed. For the “window” layer, brown pixels are associated with the “wood” material, and the others ones with the “glass” material.

The classification panel enables the selection of a color by picking on the picture; the association of a physical material is based on photo-interpretation. To check the spectral behavior of materials in use, and the result of the classification, a visualization panel enables the pre-view of the resulting multi-spectral image.

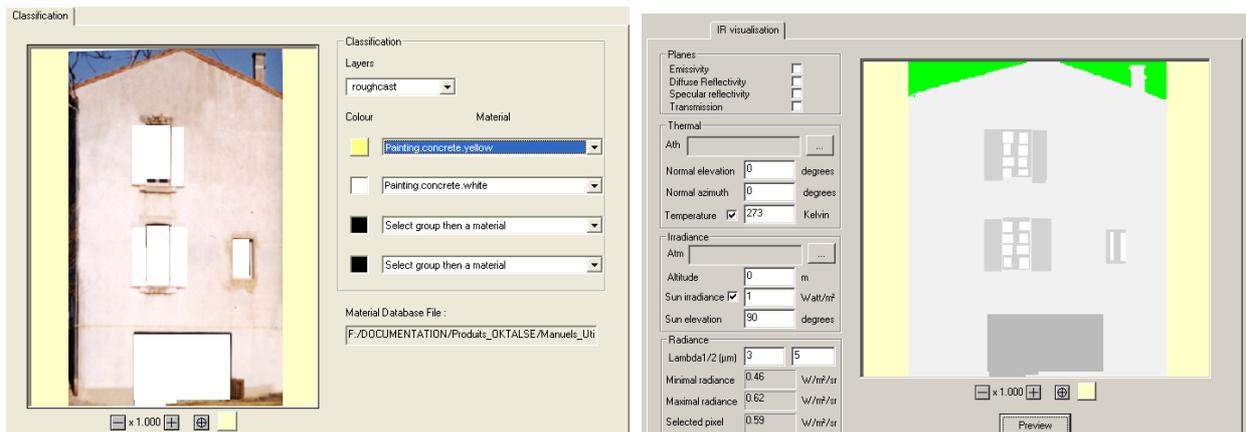


Fig 5: Textures classification panel as function of a material library and pre visualization window

### 3.4. SE-ATMOSPHERE

The SE-ATMOSPHERE software allows the user to characterize the atmosphere. It can be used to parameterize the LowTRAN and ModTRAN kernels as well as a generic atmospheric model whose physical model has been developed by Oktal-SE in cooperation with CELAR. It can ease the edition of the configuration files with the help of a JAVA based user interface that avoids parameterization errors.

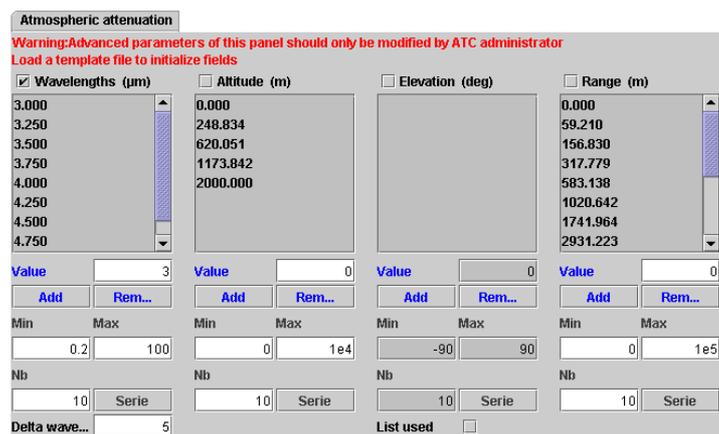


Fig 6: Atmospheric model parameterization window and atmospheric effect visualization

The SE-ATMOSPHERE software computes:

- ❑ a table of spectral data of sun/moon irradiance for a list of altitude  $h_j$  and a list of wavelength  $\lambda_i$ ,
- ❑ a table of atmospheric transmission for a list of wavelength, altitudes, and Lines of Sight (LOS),
- ❑ a table of sky radiance for a list of wavelength, altitudes, and Lines of Sight (LOS),

These data are stored in a file and used by:

- the scene generation software (SE-RAY-IR and SE-FAST-IR) for the computation of atmospheric transmission, sun/moon irradiance and sky radiance,
- the thermal software (SE-THERMAL) for the computation of incident fluxes.

### 3.5. SE-THERMAL

The thermal software (SE-THERMAL) enables the pre-calculation of all the possible temperature states of a scene at a given time of the day for a given atmosphere (SE-ATMOSPHERE). It also contains a module that enables the thermal shadow calculation (SE-THERMAL-TSC).

The thermal software takes into account:

- ❑ the history of atmospheric conditions,
- ❑ a decomposition in layers of the polygons and, for each layer, the thermal attributes (conductivity, specific heat, thickness, convection coefficients, ...),
- ❑ two kinds of polygons: “terrain polygons” and “wall polygons” (for which an inner temperature or an inner heat flux can be defined by the user),
- ❑ the wind and its direction,

## 4. SCENARIO EDITION AND PREVIEW

The scenario construction & preview stands between the modeling phase and the scene generation process, the user can build scenarios that will be helpful for the scene specification. Static scene generation can be expensive in terms of calculation time. The advantage of the scenario is the ability for the user to place the sensors, to fine-tune their positions and the overall control (SE-SCENARIO). Trajectories can be assigned to sensors through the same user interface. The SE-SCENARIO tool is an interactive 3D database analysis and scenario preparation tool. It also contains preparation, logger and playback functions. It can be used to edit SE-Advanced-Scene and SE-Fast-Scene scenarios for visible, infrared, electromagnetic and acoustic simulations. It offers the possibility to control position, orientation and behavior of sensors and moving objects.

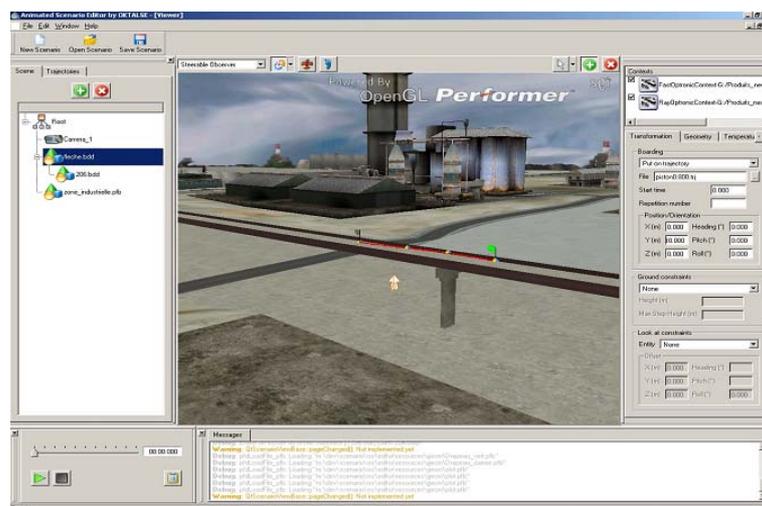


Fig 7: Example of trajectory edition with SE-SCENARIO

## 5. SE-TOOLKIT

Furthermore, the user can do software integration in order to control the generated scenario execution from a remote or custom application. This can be achieved with the help of the SE-TOOLKIT consisting of a set of libraries and application programming interfaces (API) to help the complex application design and integration. The main objective of SE-TOOLKIT is to provide the user with the maximum of assistance while integrating hardware and software in the loop simulations. In that frame, SE-TOOLKIT programming library has been developed in order to be able to answer two important customer requests:

- Take control of the SE-Fast-Scene products and SE-Advanced-Scene products from an external application without having to recompile or change/adapt the application code.
- Perform the SE-Fast-Scene and SE-Advanced-Scene calculations on different computers with distribution capabilities.

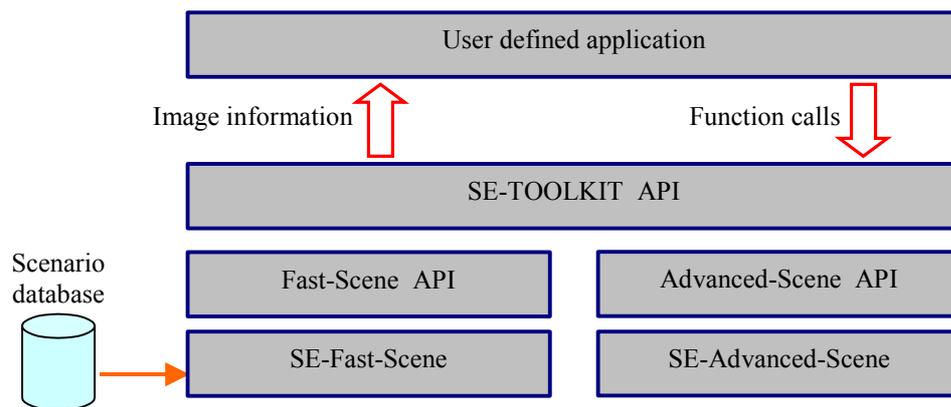


Fig 8: General application of the SE-TOOLKIT programming interface

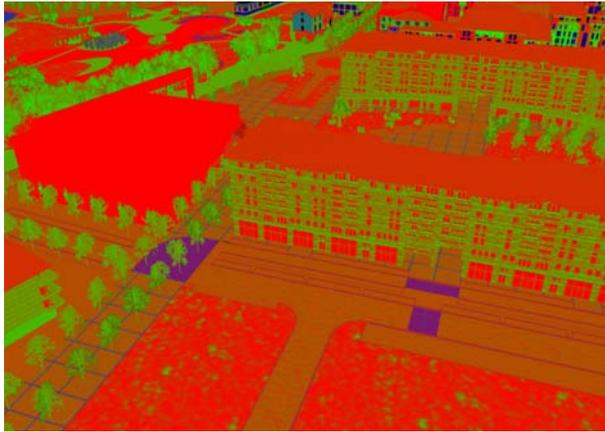
## 6. SE-FAST-IR PACKAGE

The SE-FAST-IR package is made of a major product (SE-FAST-IR) and additional modules depending on the considered application.

With the help of some pre-calculation steps, real time images are computed with the SE-FAST-IR solution. It is dedicated to low light level and near to far infrared sequences of image calculation. The products make use of the results of the SE-CLASSIFICATION tool, the SE-PHYSICAL-MODELER modeler and the SE-ATMOSPHERE atmospheric files computation product. The thermal pre-calculations are based on SE-THERMAL code.

The previous version of SE-FAST-IR was based on a pre computation of the whole 3D scene with specific radiance texture adapted to a given waveband for a given spectral response. The real time process only consisted in using OpenGL laws basically for non-static parts of the scene (for instance the specular parts, or the moving objects) and for the atmosphere propagation modeling depending on site, azimuth and range.

The new release of SE-FAST-IR brings a technological rupture by using OpenGL pixel shaders enabling direct calculation on 3D graphic cards. A shader is a procedure written in a special purpose high-level language that replaces a part of the graphic pipeline of a 3D graphic board.



*Fig 9: Image in false colors of the material classification*



*Fig 10: Band I – Fine weather – Daylight – Noise*



*Fig 11: Band II – Fine weather – Daylight*

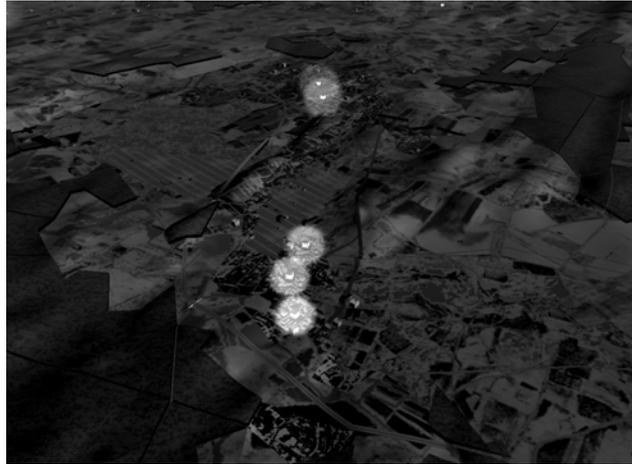


*Fig 12: Band III – Fine weather – Daylight*

The main advantages are:

- the ability to dynamically change the sensor band and spectral response (very convenient for training simulation application), without reloading any geometry nor texture, which was not possible in the previous release,
- the ability to compute a multi wavelength image (limited by the graphic board memory of texture), which was not possible in the previous release, and which is very convenient to stimulate a spectral model of the technological sensor,
- a better dynamic due to HDR (floating point radiance computation, no more limited to 8 bits),
- an implicit dynamic gain control,
- a better management of dynamic parts of the 3D scene (targets, specular parts, ...),
- the management of emissive textures and light points,
- the computation of temperature, emitted radiance and reflected radiance at pixel level due to classification process.

All the computations for the illumination are done in real time (the Black Body law, the specular and diffuse reflections). For each pixel, a radiance value is calculated. It takes into account the atmospheric conditions (atmospheric transmission and irradiance of the sky). Basic sensor effects can be applied on the resulting radiance image (non stationary noise and contrast inversion). A complementary OKTAL-SE product, SE-FAST-IR-SENSOR enables to create more sophisticated sensor effects. As these computations are performed using 16, 24 or 32 bits floating values, the final color of the pixel is computed according to the pixel radiance and Automatic Gain Control (AGC) capabilities.



*Fig 13: Low light level image with halos*

The SE-FAST-IR process is made of two steps:

- first step: the 3D database compilation (physical materials and textures are turned into Open GL materials and textures)
- second step: the infrared visualization. Given the compiled 3D database, the table of temperatures defining the material behavior with regard to heating sources, the infrared features of the materials (spectral emissivity, spectral BRDF, spectral transparency), the real time software computes real time black body law, specular and diffuse reflections, the effects of the atmosphere.



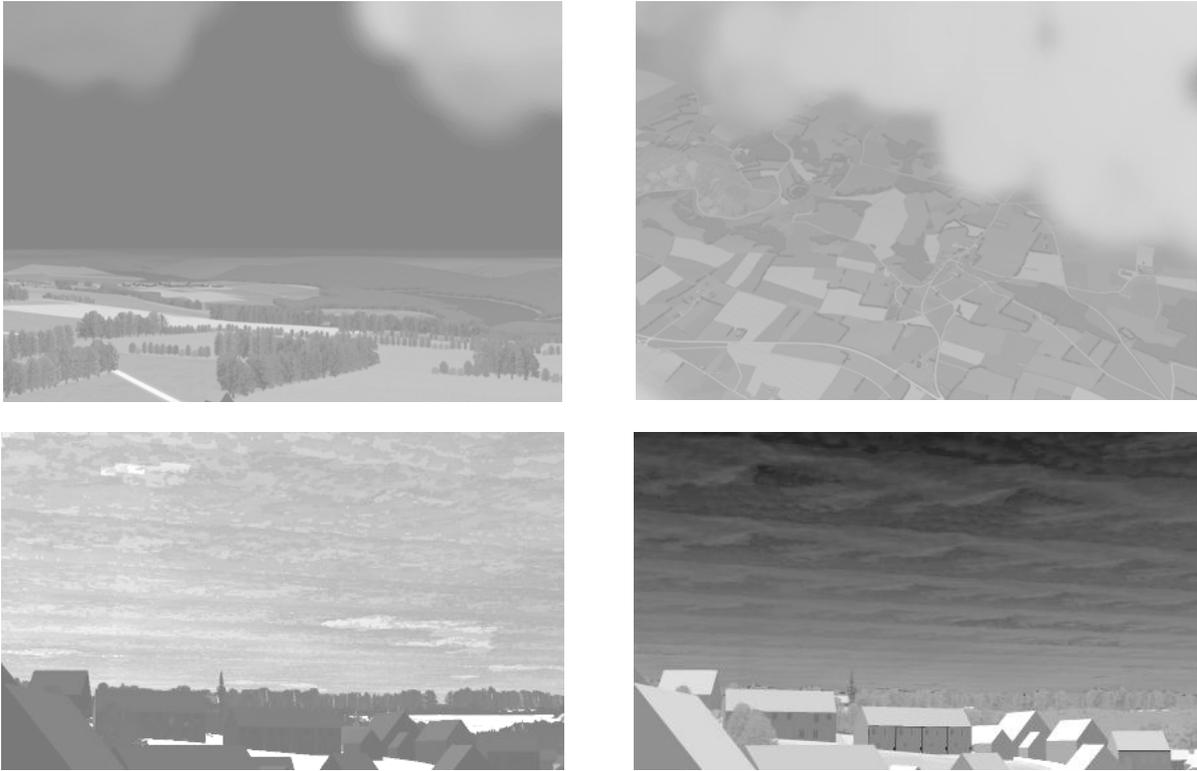
*Fig 14: Examples of objects in band III*

The SE-FAST-IR software inherits the SE-RAY-IR validated physical models, which allows a maximum level of accuracy and realism. They also use a unified scenario (created by the SE-SCENARIO tool).

Additional modules can be used to add more realism or extend the physical accuracy of the generated scenes.

- ❑ SE-FAST-AAS: advanced atmospheric transfer function calculation. This module enables to access to atmospheric tables, pre-computed using SE-AMOSPHERE tool, pixel by pixel, in real time, in order to take into account very accurately the atmosphere spectral attenuation and self emission as a function of site, azimuth and range
- ❑ SE- FAST-FLARES: optimized flare countermeasure generation tool. This module enables to create special laws of radiance and irradiance of high-level light sources.

- ❑ SE- FAST-CLOUDS: optimized cloud generation and calculation tool. This module enables on one hand to create physical cloud layers consistent with SE-AMOSPHERE tool, and on the other hand to create isolated clouds, made of transparent billboards with levels of detail.



*Fig 15: Examples of infrared images with clouds*

- ❑ SE-COMP-PARTICLES: particle generation tool for special effects. The particles system can be applied to very complex dynamic effects just like fireworks or exhaust plumes. The SE-SCENARIO tool enables to assess the parameterization of the associated dynamic laws in order to achieve the desired effect.

## 7. VALIDATION PROCESS

For the validation process, in the frame of the SE-Workbench, a documented comparison between simulated images and measurements is provided. Input data for the validation are made of pictures in the visible domain, infrared images from calibrated cameras and associated atmospheric measurements, a database of physical materials, temperature measurements, a precise physical model of the camera and its sensors.

According to these data, we create a 3D scene as close as possible to the ground truth, we associate materials to the polygons and textures of this 3D scene, we create a simulation scenario and compute infrared simulated images using:

- ❑ the non real time ray tracing tool SE-RAY-IR
- ❑ the real time simulation tools SE-FAST-IR V2 and SE-FAST-IR V3
- ❑ the sensor models SE-RAY-IR-SENSOR and SE-FAST-IR-SENSOR software.

At each step, we compare the simulated infrared images and the reference infrared images.

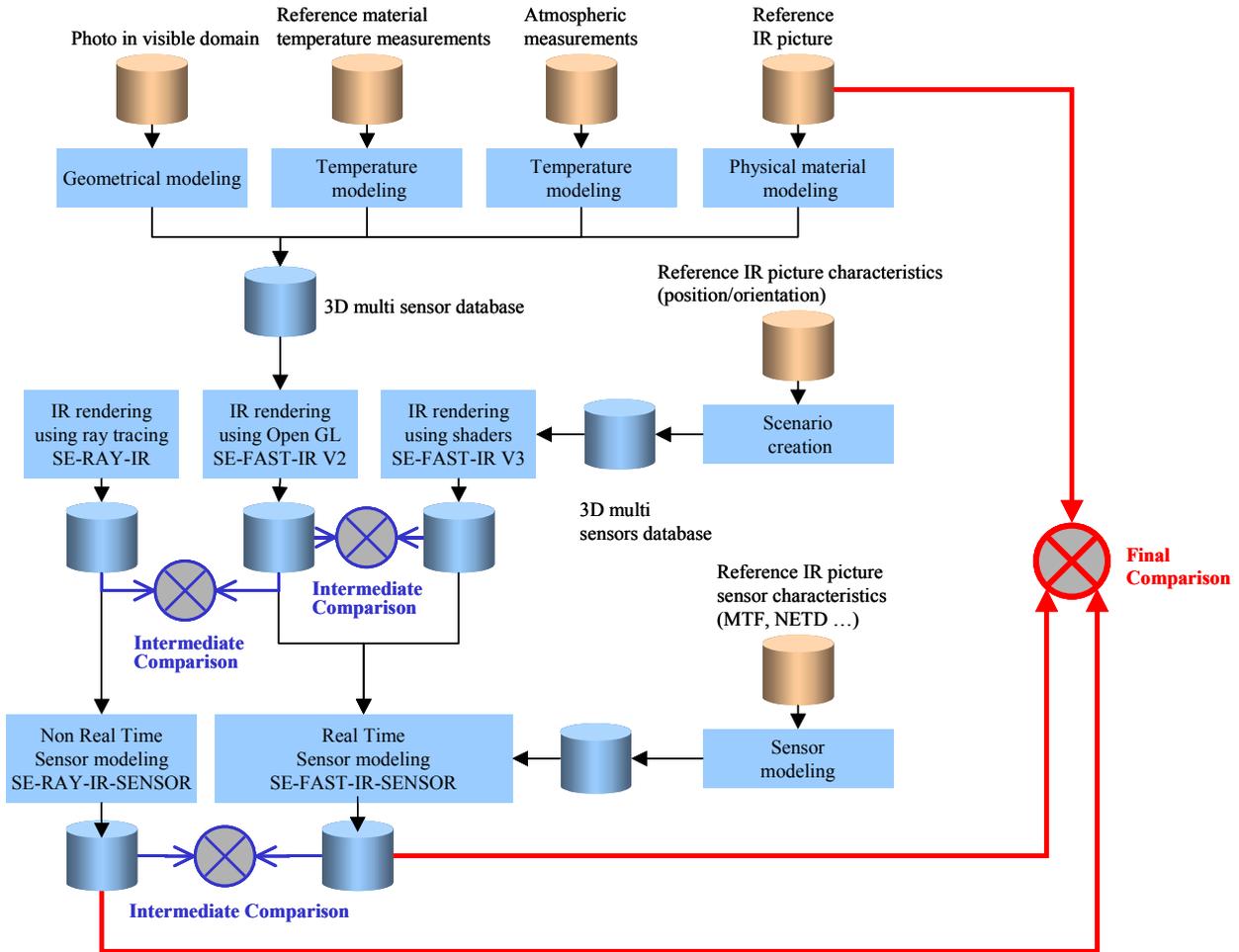


Fig 16: Methodology of validation

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