

SIMAGE: From rapid prototyping to end to end performance simulation for imaging payloads

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1. INTRODUCTION

Image processing is a key contributor in overall space imaging systems performance and design. The trade-off between payload specifications, platform requirements and ground processing capabilities has to be addressed since the early design phases. The associated radiometric and geometric performance budgets have to be evaluated and validated through the whole development life cycle. To support this engineering activity and capitalize knowledge EADS-ASTRIUM has developed since the early 90's the SIMAGE image processing and simulation toolbox. This toolbox is used on many projects from fast early prototyping to end to end performance simulation and validation. A major version 6 release is delivered in 2008. It takes benefit of our experience in French, ESA and export projects to provide a strong modularity with reusable and validated component for the different products levels and processing steps. It provides an integrated Matlab SIMAGE Toolbox with an Object Oriented Architecture, supporting geomatic industry standard, providing bridges to IDL or C libraries within a robust framework and can be used as a base to create deliverable application for dedicated projects. The present paper describes the SIMAGE V6 objectives and features and shows how it is integrated in the development process to support specification, design and validation phases.



Fig. 1. Example of image enhancement through restoration processing

2. IMAGE QUALITY, PROCESSING AND SIMULATION DURING SPACE SYSTEM DEVELOPMENT

EADS-ASTRIUM was the first company involved in Earth Observation space systems in Europe, being the prime contractor for SPOT (and follow on Pleiades), HELIOS (military), METOP satellites and the principal contractor for ERS and ENVISAT programmes. Recent activities with ESA or Eumetsat involve in particular Sentinel2 or MTG. EADS-ASTRIUM experience developed through institutional programs is now applied on export satellite programs such as FORMOSAT, THEOS or ALSAT, involving a few meters resolutions systems, or such as COMS, a geostationary meteorological satellite for Korea. This evolution conveyed EADS-ASTRIUM to develop a strong expertise in Image Quality, Image Processing and Simulation. The missions of this group are:

- To provide EADS-ASTRIUM with a high level of expertise for better understanding of the final user's need
- To come to new design options since processing techniques allow for a huge improvement of the image products while relaxing the instrument/satellite definition.
- To master the E2E (end-to-end) performances budgets (mainly radiometry and geometry) through image quality, a core aspect of the system architecture.
- To support the in-orbit testing, including development of processes and tools for calibration
- To develop and maintain image simulation tools in order: 1-to show to the customer a final image product at the very beginning of the system definition and to reach more adequate system/satellite requirements specifications, 2- to prove image algorithms concepts.
- To design and specify image processing algorithms for: 1- embedded systems with high autonomy capabilities, 2- for the image production of earth observation systems.
- To specify, develop and validate operational ground processing chains
- To lead the space image processing R&D through: 1- the development, evaluation and implementation of "state of the art" image processing solutions, 2- the analysis of new observation concepts performances and 3- the proposition of innovative solutions to future systems.

If we map these activities on the different development phases we get the following figure.

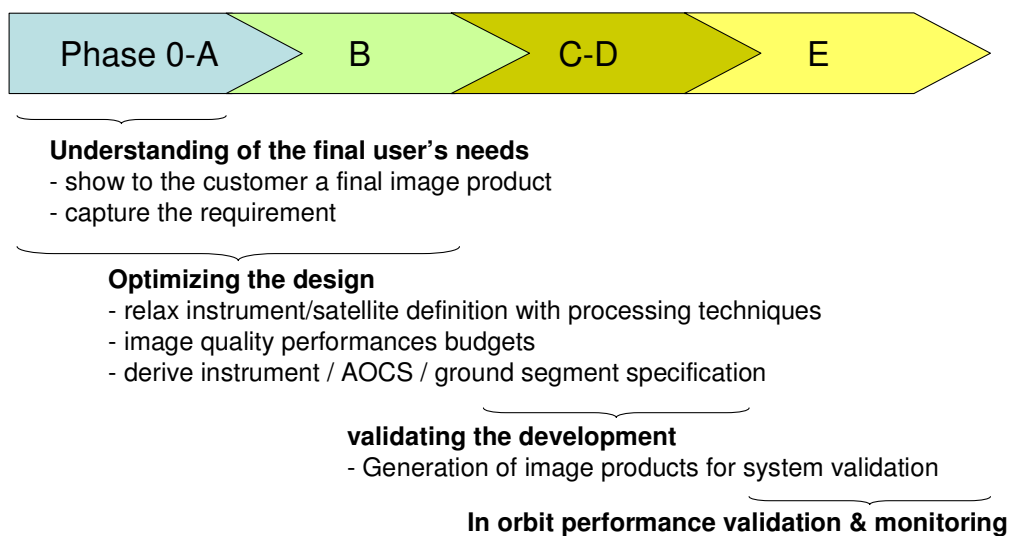


Fig. 2. Image E2E performance, from early design to in-orbit validation

3. THE SIMAGE TOOLBOX

Since the early 90's, EADS-ASTRIUM has developed SIMAGE, an image processing toolbox including a complete image simulator. SIMAGE is used internally and adapted for any spacecraft and instrument simulations. Based on this toolbox, EADS-ASTRIUM has already delivered to external customers dedicated image simulation chains for systems studies, covering a large range of mission and producing images representative of various resolutions, radiometric and geometric performances.

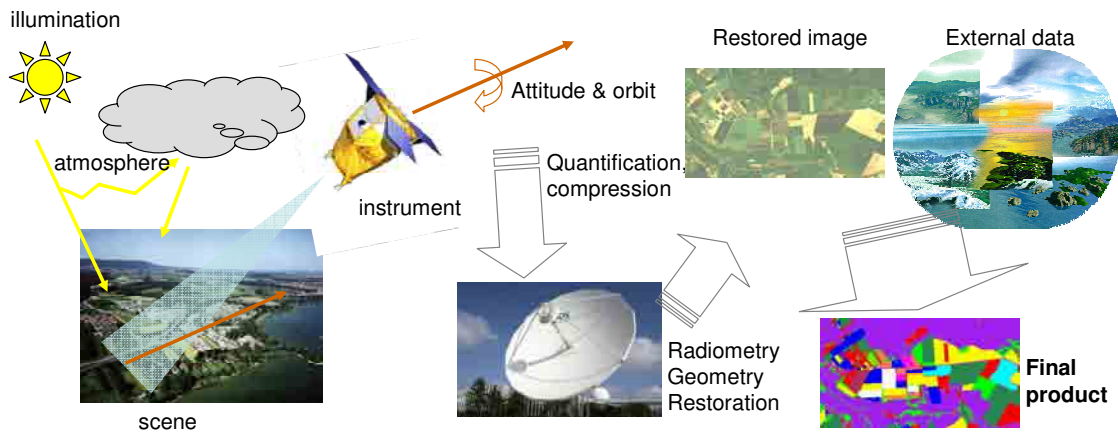


Fig. 3. SIMAGE simulation: from the scene acquisition conditions to the final products

The core of the tool covers the simulation of multi-channel CCD push-broom imagery for low earth orbit. Additional modules provide processing representative of first levels of ground processing (equivalent to Spot level 2 products) or handle instruments imagery with TDI detectors, scanners, matrixes and from geo-stationary orbits. The tool also offers facilities for absolute radiometry and atmosphere contribution and correction through Lowtran, Modtran or 6S.

SIMAGE also integrates a complete image processing library including: restoration solutions to denoising and deconvolution, image data fusion and super-resolution, image registration, geometric compensation, DEM stereo generation, calibration tools, compression and decompression algorithms, detection/recognition/identification processing chains, feature extraction and tracking, ...

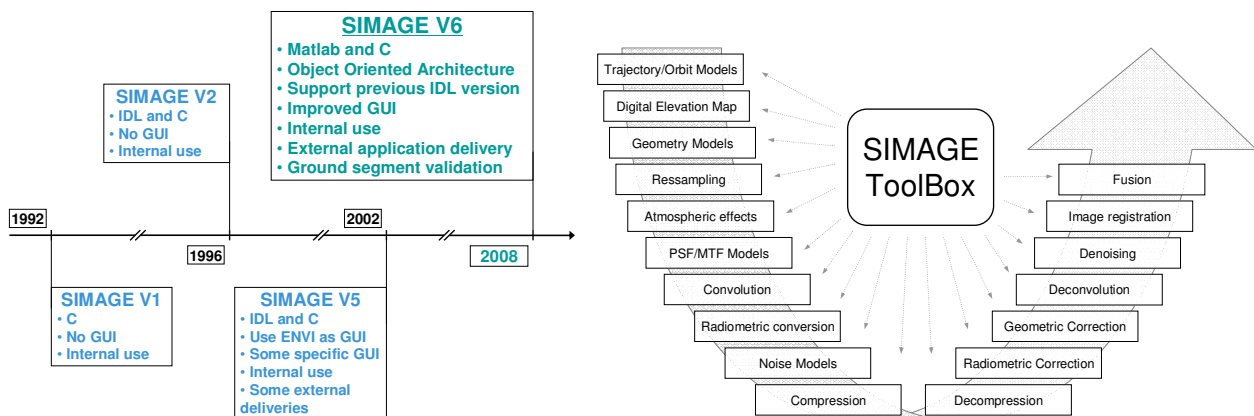


Fig. 4. SIMAGE V6 gathers all EADS-ASTRIUM experience accumulated in image simulation and processing

3.1. SIMAGE V6

SIMAGE V6 is a major upgrade of the toolbox started in 2007 and delivered in 2008. The ambition of this release is to maintain a high degree of flexibility and adaptability in the tool while reinforcing the validation and operability of the software. To answer to these competing objectives, a new design, taking into account a capitalization process, is implemented. This development takes advantage of the experience gathered by EADS ASTRIUM in image simulation and processing for activities ranging from R&D prototyping to operational ground segment validation.

The new design relies on Matlab and on an Object Oriented Architecture. Matlab gives access to a large collection of functions, coming from Matlab toolboxes or through a large set of open source libraries. Most of common processing is then available into Matlab. Combined with the dedicated framework and a validation environment this allows R&D and image processing developers to focus “only” on few state-of-the-art or space-specific algorithms.

3.2. Framework:

The software infrastructure developed provides a framework to support and control the simulation definition and execution. It includes a GUI and database capabilities that enable to perform all the functionality of the simulator. The main functionalities available are summarized in Fig. 5.

SIMAGE V6	
Log and trace activity	Log display and save
Load and save parameter files	XML
Load and save configuration files	XML
Load and save data files	XML
Data definition	Each data is described with its control and its dependency
Data storage management	Planned for future upgrade
Data history management	Planned for future upgrade
Data display or plot tool	All Matlab display and plot + a dedicated image viewer
Data comparison tool	Matlab
GUI definition	Modular and generic GUI
Models definition	Object oriented models
Simulation definition	Any algorithm can be used with any previously defined simulation
Simulation execution	Execution is monitored (progress status)
Multi-parameter run and analysis	Generic GUI with advanced Monte Carlo execution.
Allow batch processing	Multi computer batch execution support
Standard	File formats are based on industry standards: XML, Tiff, ENVI, Shape file

Fig. 5. SIMAGE V6 framework support a large set of advanced features

3.3. Object Oriented Architecture:

SIMAGE allows constructing a system based on objects interacting with each others. At the highest level we have SIMAGE “modules”. They provide the way to instantiate the SIMAGE “algorithms” and “objects”, with associated input data and parameters. This will define the sequence of all the SIMAGE “processing” to achieve a more complex task. An “object” hides all variant of a “processing”. For instance “add noise” can use many variant of noise at “processing” level, such as “white noise”, “offset”, “sinus”, “photonic”. The “algorithm” gives the sequence skeleton of “objects”. It is an abstract view of a sequence of “processing”. For instance an “algorithm” (A) can “add noise”, “quantify” and then “compress”, where “add noise”, “quantify” and “compress” are objects hiding all the alternate “processing” possibilities. The use of an abstract representation through “algorithms” and “objects” allows to ease the extension of the functionalities: if we implement a new “add noise” model such as “1/f noise”, “algorithm” (A) and any “module” using it can activate “1/f noise” through adequate input parameters, with no other code modification.

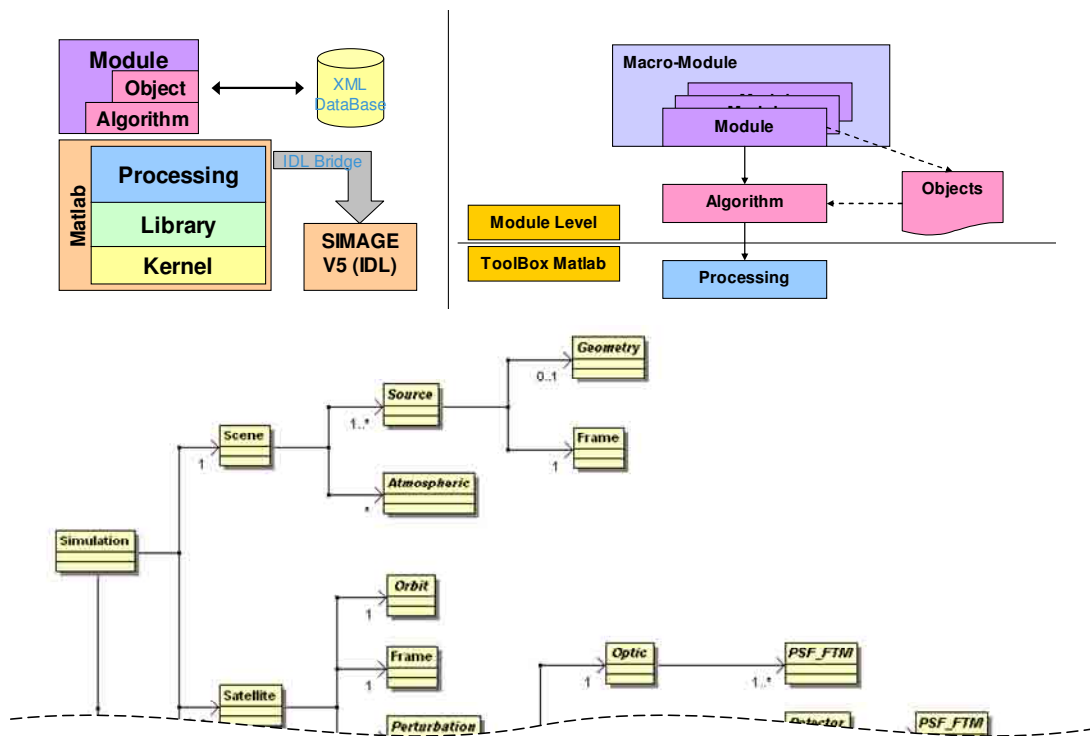


Fig. 6. SIMAGE V6 object architecture

3.4. Validation environment:

To ensure a high level of validation our development process involves systematic and automated unitary tests and a test coverage analysis.

The unitary test is done through MUnit, the Matlab unitary test environment (see <http://xtargets.com/cms/index.php>). This allows an automated non regression analysis and is used for each module/algorithm/processing.

The coverage analysis is built on Matlab ‘profile’ tool that is integrated into our validation framework. We have thus access to branch coverage, with automatic report of non-covered line of code.

These systematic analyses are done for each new intermediate release version V6.x.y delivery (y changes for patch and bug corrections without impact on I/F, x changes for new functionalities or I/F modification).

3.5. A continuous capitalization process including collaborative communication tools

The framework functionalities, the Object Oriented Architecture and the validation environment give the foundations for a whole capitalization process, supporting the R&D prototype to operational software transition. These foundations are completed by a formalization of the level of validation of a new SIMAGE development and by a way to support communication among developers or users through both an interactive help system and a WIKI based documentation.

Three level of validation are identified for new development. At level 1, when working on rapid prototyping and experiments, the engineers need to have a large freedom. The software is “as is” with just a technical note description to inform others that the software exists. At level 2: the code can be shared with other R&D developers. This involves that the level 1 code has been cleaned and better documented, with some robustness and error handling effort, with I/F controls. At level 3: the code is integrated in SIMAGE, validated and operational. This means a full implementation of SIMAGE standard: rules for comments, coding, large image/tiling implementation, automated testing, coverage analysis and documentation. This integration step is supported or done by SIMAGE a dedicated maintenance team.

Within a continuous capitalization process the way to access and share information is critical. The size of both the SIMAGE libraries and of the user community is such that a simple “static” documentation scheme is not sufficient. Two interactive communications channels are proposed. The first one uses the Matlab interactive help system to provide an on-line help to any SIMAGE functionality. This is a powerful mean to support developers manipulating large libraries with precise and updated information. A WIKI documentation repository provides a second channel for sharing information. It allows providing tutorial, technical notes, and updated information in a collaborative mode.



Fig. 6. The SIMAGE WIKI support information sharing

4. WAY FORWARD

A SIMAGE V6 beta version is being used since mid 2008 to support R&D activities. First feedbacks are confirming that the objective of having a toolbox supporting both fast prototyping and whole end to end performance simulation is within reach. The SIMAGE V6 operational version, delivered by end of 2008, is a powerful image processing toolbox dedicated to space imaging applications. The coming space imaging projects involving EADS ASTRIUM will take advantage of it. The first satellite project opportunity for a complete application through the development life cycle is Astoterra. This high resolution imaging satellite is planned to be SPOT5 follow-on and shall be funded largely by EADS.