SIMULATORS AROUND BASILES

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SUMMARY

BASILES: WHAT IS IT?

BASILES is a simulation infrastructure.

Composed of:

- A simulation runtime environment.
- Toolkit to help in the design, configuration, execution and results analysis of simulators.

It allows representing complex systems within discrete event simulation.

BASILES is also a model library.

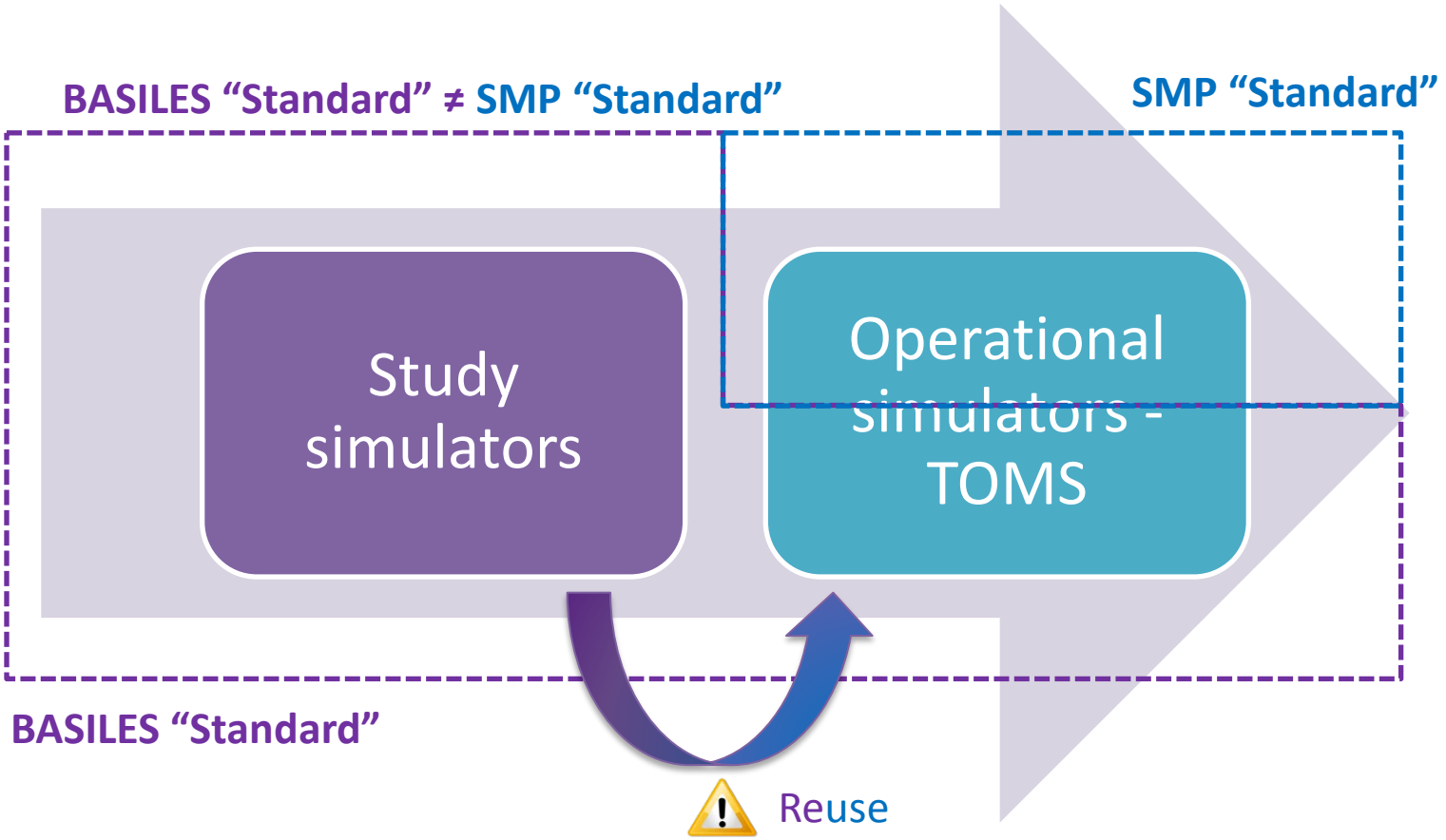
To promote model reuse from one project to another (even inside the same project) and to share and perpetuate CNES expertise.

BASILES provides a methodology and a “standard” for CNES simulation.

More than a simulation platform BASILES gives the approach to develop each new simulator taking advantage of previous developments/feedback.

BASILES: IN WHICH CONTEXT?

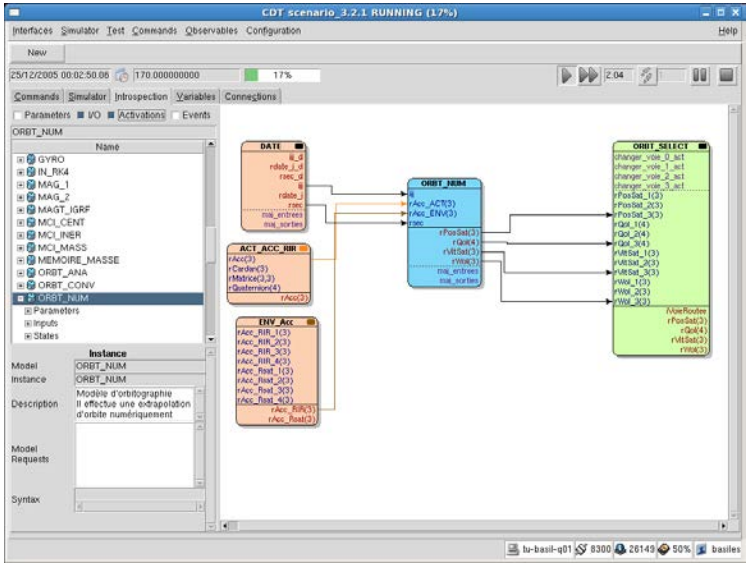
Project Lifecycle



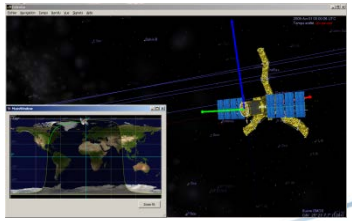
One single platform for all needs : study and operational simulators

BASILES INFRASTRUCTURE

- Based on previous CNES simulation infrastructures (SINUS, MACSIM …).
- 2 approaches:
  - ✦ Novice user: Easy to use
    - » All functionalities are accessible by MMI
    - » Interfaces through formatted ascii files
    - » Code generation facilities ⇨ “Elementary Models”
  - ✦ Advanced user: Multiple functionalities
    - » Access to a lower level in the simulator architecture
    - » Scripting test language (Tcl)
    - » “Specialized Models” (user shall manage all interfaces with BASILES kernel)



- Focus on the core of the simulation activities:
  - ✦ Interface with external tools for plotting (PrestoPlot and VTS)



BASILES & SMP

SMP (Simulation Model Portability):

"Standard" to allow models to be portable among different simulation infrastructures. Interfaces are specified by SMP independently of simulation infrastructures.

- Current version: v1.2, known as SMP2

BASILES SMP adapter:

Software component in C/C++ to provide adaptation of the SMP2 interfaces into the BASILES interfaces. Its role is to hide SMP2 specificities to the BASILES infrastructure.

⚠ SMP Adapter is a run time component.

☹ It does not allow to design SMP2 models nor to generate any of SMP2 artefacts.

- Conformity:
  - ✦ Compliant with SMP2
  - ✦ It also supports two extensions of the protocol:
    - » Automatic data propagation or dataflow enabled field links
    - » Support of the E-40-07 Configuration file

😐 Mixed simulations with SMP2 models and BASILES native models are possible with some limitations.

BASILES & ISIS

ISIS : CNES Initiative for Space Innovative Standards

Define standards, system requirements and generic architectures for system, platform and control ground segment (“generic product lines”).

CNES partnership with TAS and Airbus DS.

ISIS and simulation

Define user requirements for the TOMS:

- In line with SSRA concerning simulator architecture
- In conformance with SMP2 (amended by the automatic dataflow transfer)

Define interfaces:

- ☺ System Interfaces & External Interfaces
- 😐 Physical models interfaces & Central solver interfaces
- ☺ Models and Models Data exchange Interfaces: specification of the exchange of models and associated date (including reference runs)

2 approaches for the System Interfaces:

- Event/field link (TAS) vs interface link (Airbus DS)

ISIS “completes” SMP2.

SUMMARY

- **BASILES**
  - BASILES & SMP
  - BASILES & ISIS
- **BASILES USE CASES**
  - Simulators inside CNES
    - Using BASILES standard
    - Using SMP standard
  - Simulators outside CNES
- **CONCLUSION**

SIMULATORS BASED ON BASILES “STANDARD” INSIDE CNES

From study simulators to system/operational simulators, full numerical or hybrid simulators:

- AOCS simulators: CSO project (observation satellites for image provision and processing)
- In ARGOS simulator (worldwide tracking and environmental monitoring by satellite) a good level of performance has been achieved, around 40000 ARGOS beacons are simulated!
- In the context of NOSYCA (balloon system), a full numerical simulator (SNOB) and a hybrid simulator have been developed (MEDON). It is the first BASILES operational application with hardware in the loop.

Designed for space programs, BASILES is now being used in other application fields. BASILES approach is not specific to aerospace. A prototype of a road network simulator has been developed within BASILES.

SIMULATORS BASED ON BASILES “STANDARD” INSIDE CNES

CSO AOCS simulator:

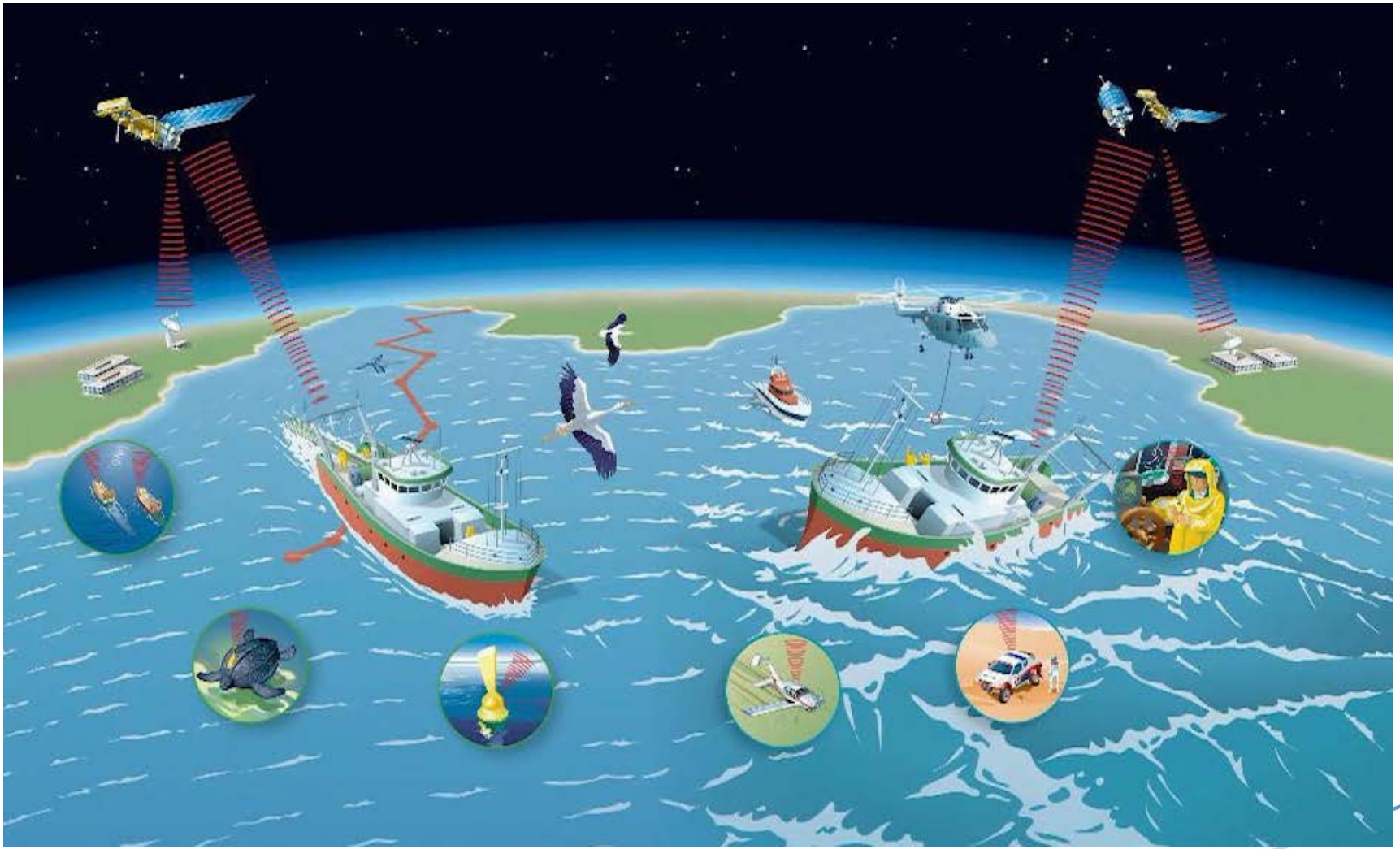
- From the B phase, it is important to have AOCS equipments models as much representative and accurate as possible.
- Requirements:

Study simulator
Model development simple and quick
User-friendly tools
Execution as fast as possible
Hundreds of runs sweeping variables
Results analysis in differed time
Reusable models

- Simulator developed by the AOCS department.
- Solution based on native BASILES with Elementary Models.
- Use of BASILES framework generic MMI.

SIMULATORS BASED ON BASILES “STANDARD” INSIDE CNES

ARGOS system:

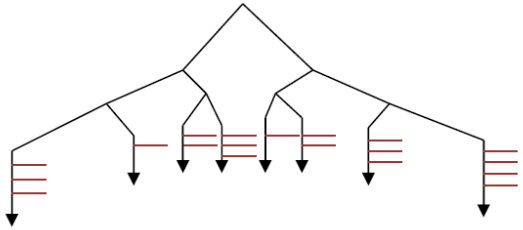


SIMULATORS BASED ON BASILES “STANDARD” INSIDE CNES

ARGOS simulator:

- Main challenge: Simulating up to 40000 objects and 10000 events at any time!
- Modifications at scheduler level ⇨ New “map” scheduler.
- 2 schedulers:
  - “List” scheduler (performant when < 100 events at the same time)

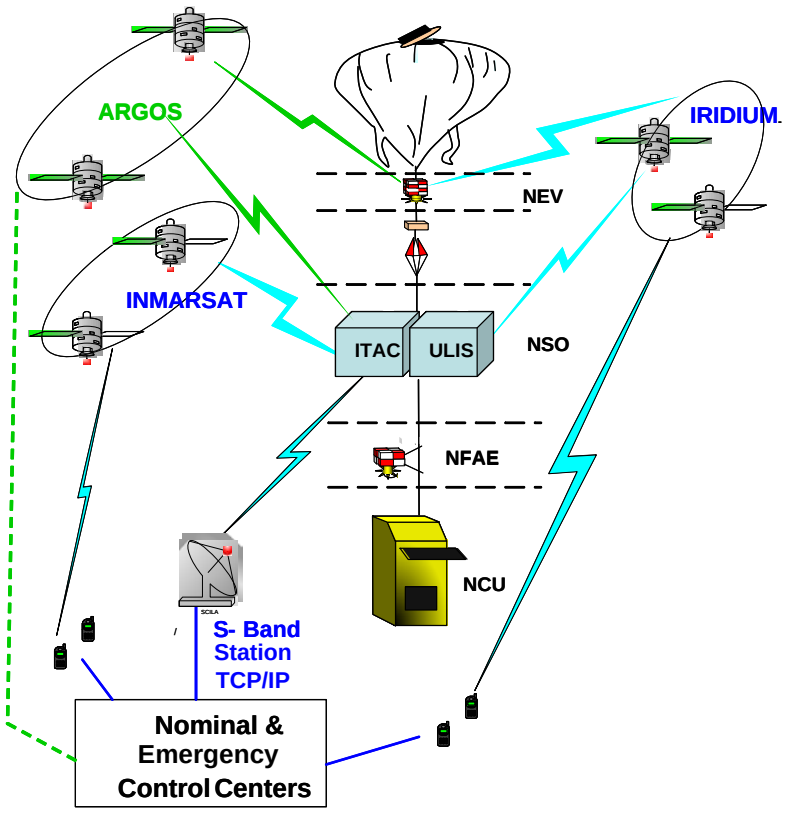
  - “Map” scheduler (performant when > 100 events at the same time)

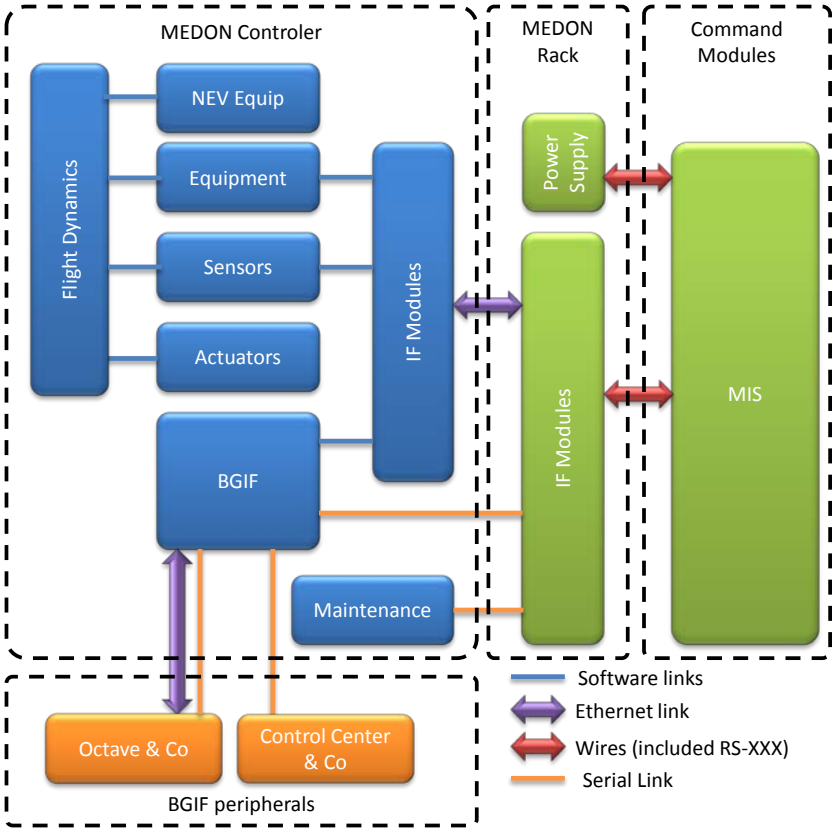


- Solution based on native BASILES with Elementary and Specialized Models.
- Specific tools and GUI to manage thousand of models.

SIMULATORS BASED ON BASILES “STANDARD” INSIDE CNES

NOSYCA system / MEDON simulator:





SIMULATORS BASED ON BASILES “STANDARD” INSIDE CNES

MEDON/SNOB simulator:

- MEDON is the 1st BASILES application with hardware in the loop as well as the 1st TOMS.
- SNOB is the equivalent of MEDON but full numerical.
- Requirements:

Operational simulator - TOMS
Simulator behaviour identical to real spacecraft
Real time execution
Causality and all runs reproducible
Failure and reproducible noise injection
Fine control and inward visibility
Formal and automated procedures for model and simulator validation
Save/restore of context
Perennity guarantees for 15+ year

SIMULATORS BASED ON BASILES “STANDARD” INSIDE CNES

MEDON/SNOB simulator:

- Some models have been developed by CNES and some by SPACEBEL.
- Solution based on native BASILES with Elementary Models.
- Use of BASILES framework generic MMI.
- Operated by NOSYCA project team.
- Strong points raised by users:
  - High level of representativeness (QT, QO)
  - Introspection facilities
  - Simple to understand and to execute
- Areas of improvement:
  - Context management
  - Time management when working with hard real time constraints
- Final users are really  ⇨ New project for another kind of balloon will use the same approach.

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SIMULATORS BASED ON SMP “STANDARD” INSIDE CNES

Used for TOMS when working with external partners:

- Numerical models are developed by the satellite contractor for the SVF and the AIT:
  - Development using their own simulation platform
  - Validation using their own simulation platform as well as BASILES
- TOMS activities (CNES + simulator contractor):
  - Integration of models coming from satellite contractor
  - Development of specific models (e.g. I/F with ground segment)
  - Validation of the whole simulator using BASILES platform
- Different actors ⇨ Different simulation platforms ⇨ SMP2 and ISIS are indispensable!
- Relatively recent, on-going projects:
  - CSO TOMS
  - Myriade Evolutions – MERLIN TOMS
  - …

SIMULATORS BASED ON SMP “STANDARD” INSIDE CNES

CSO TOMS:

- 1st simulator at CNES based on ISIS and SMP2.
- Standalone SMP2 models delivered by Airbus DS :
  - Developed using SimTG
  - Validated in SimTG and also BASILES
  - Only the top level models uses SMP2 mechanisms:
    - ☺ Probably more efficient in terms of initialisation time and runtime performance
    - ☺ Easier at configuration level
    - ☹ Less sub-model visibility/introspection facilities when using other infrastructure than SimTG. To mitigate this limitation:
      - » Complementary SMP2 service to overload variables at sub-model level
      - » Complementary SMP2 service to connect an external model to a port at sub-model level
  - Airbus DS delivers an SMP2 generic failure injection service.
  - Top level models always use the SMP2 software interface when there is an asynchronous behaviour to be simulated

SIMULATORS BASED ON SMP “STANDARD” INSIDE CNES

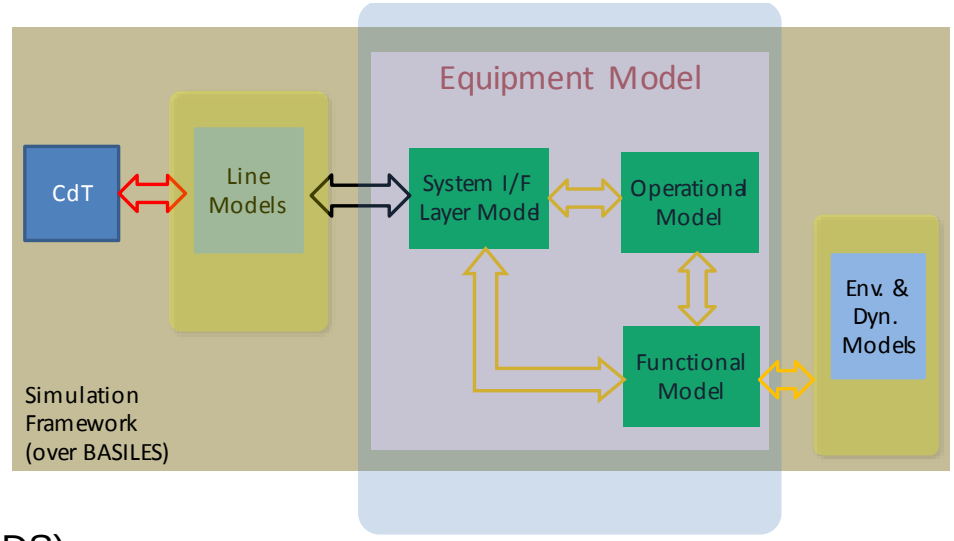
CSO TOMS:

- Model exchange is really efficient thanks to ISIS and SMP2.
- However:
  - Model development/configuration remains very laborious when developing full SMP2 models.
  - Effort at cross-validation level due to the different test languages used.
  - Areas of improvement concerning SMP2:
    - Allowing the use of strings of variable length
    - Support for error injection ⇨ Promote fields with interfaces (e.g. IField setters & getters)
    - Creation and publication of sub-models by the top level SMP model
    - Enable delivering pre-assembled models with corresponding catalogues

SIMULATORS BASED ON SMP "STANDARD" INSIDE CNES

Myriade Evolutions (next generation of the Myriade product line - platform for microsatellites):

- CNES partnership with TAS and Airbus DS.
- 10 new common units + equipments specific to each partner platform.
- 9 new equipment models:
  - Development using ESA tools
  - Validation using BASILES
  - Developed by SPACEBEL/CNES and delivered to TAS and Airbus DS
  - The whole model will be SMP2
  - Based on SSRA approach
  - 2 System I/F models:
    - » With SMP2 software interface (for Airbus DS)
    - » With SMP2 fields and events (for TAS) + automatic data propagation



SIMULATORS BASED ON SMP “STANDARD” INSIDE CNES

MERLIN TOMS (joint French-German cooperation dedicated to the methane monitoring at a global scale):

- 1st Myriade Evolution Application.
- 3 different model suppliers (Airbus DS Fr, Airbus DS Ge, Myriade Evolutions)!

Other TOMS:

- New project where TAS will deliver standalone SMP2 models:
  - ✦ Developed using K2
  - ✦ Validated using K2 and BASILES
  - ⚠ Using automatic data flow propagation
  - ⚠ There will also be models delivered by Airbus DS

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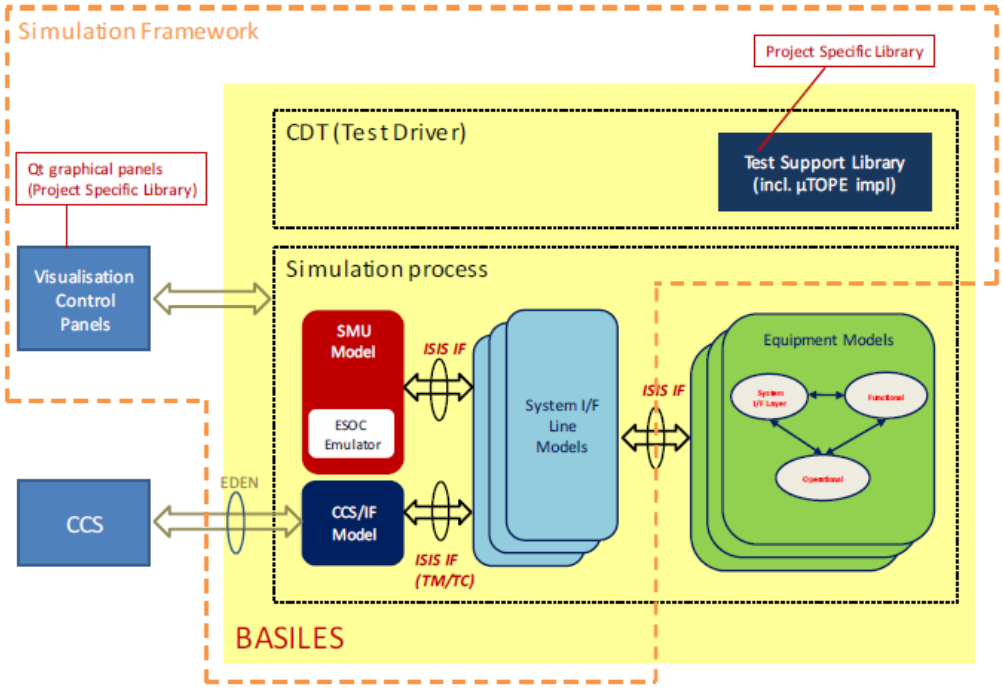
SIMULATORS OUTSIDE CNES

MTG SVF (Meteosat Third Generation):

- New use case: SVF ⇨ New requirements (e.g. multiple OBSW debuggers).
- OHB has chosen to use SMP2 and BASILES.
- SPACEBEL is in charge of this development.



- Strong points of using BASILES:
  - Simple and lightweight simulation kernel.
  - Rich user interface for test driving, management and results exploitation.
  - Fine integration of the emulator and the simulation schedule.
  - BASILES script language is Tcl, same language as in SCOS.
  - Non-intrusive & symbolic debugging with an external tool (e.g. GDB) & map file.

SIMULATORS OUTSIDE CNES

CEAO (prototype to help in the definition and the pre-configuration of the DGA test devices):

- Prototype asked by DGA and developed by SPACEBEL.
- Use case really close to study simulators.
- Based on native BASILES with Elementary Models.
- Specific developments:
  - Interface with World Wind instead of VTS for 3D visualisation
  - Specific GUI
- None major problem to be highlighted.

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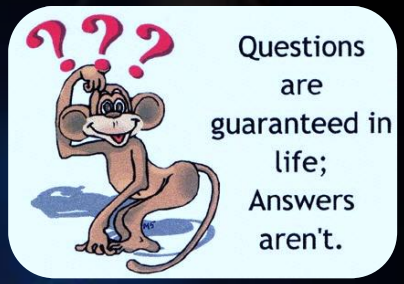
CONCLUSION

BASILES is successfully used in many space programs, inside CNES but also outside:

- SMP2 and ISIS have a main role in our simulation activities.
  - Next working group around SMP2 should deal with the different limitations addressed.
  - ISIS and SSRA are an indispensable complement to SMP2.
- Working group around BASILES to define the next generation of the infrastructure. Scope:
  - Keeping current modularity and multiple functionalities with the good level of performances of the kernel.
  - An upgrade of the technology is imposed.
  - Deeper integration between native BASILES and SMP2.

Thank you!
Questions?
For more information: basiles@cnes.fr



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