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Summary

In large (space) programmes the road from feasibility study to operations and/or training may be long and demanding. During a typical programme many application models will be developed and usually different development environments are used during different phases of a programme.

The Model-Oriented Software Automatic Interface Converter (MOSAIC) automates transfer of simulation models from MATLAB®/Simulink®/Stateflow® to both EuroSim and to ESA's Simulation Model Portability (SMP) standard. Updates of Commercial Off-The-Shelf (COTS) tools and model standard definitions result in an upgrade of MOSAIC.

Developments of MOSAIC are driven by customer requests. The MOSAIC product is developed and maintained by the National Aerospace Laboratory NLR. MOSAIC already is an important ingredient of various space development projects like ATV, SMART-I and GSSF. It has been experienced that the use of MOSAIC reduces costs, time, and effort in simulator development. In this paper the wide applicability and the use of MOSAIC is discussed.

Contents

(12 pages in total)

1 Introduction

Within the aerospace industry, simulation models are often developed using Commercial Off-The-Shelf (COTS) tools like MATLAB®/Simulink®/Stateflow®, or, for short, the MATLAB Toolbox [1]. Without tooling, transfer to another simulation environment may require time-consuming adjustment of the simulation model by the model developer. On the other hand, a typical requirement for simulation models is compliance with interface standards because they are software application components that interact with other simulation components.

The National Aerospace Laboratory NLR develops and maintains the Model-Oriented Software Automatic Interface Converter (MOSAIC) tool [2]. MOSAIC automatically transfers simulation models from the MATLAB Toolbox to the real-time simulation tool EuroSim [3] and ESA's Simulation Model Portability (SMP) standard [4]. It has been experienced that automatic model transfer with MOSAIC significantly reduces time and cost.

The remainder of this paper is as follows. First the MOSAIC philosophy is presented. Second, focus is on automated model transfer to the (hard) real-time EuroSim environment. Third, the generation of models that are compliant to ESA's SMP Standard are detailed. Some applications, the raison d'être of MOSAIC, are listed. Finally, the MOSAIC test bed and future plans are given.

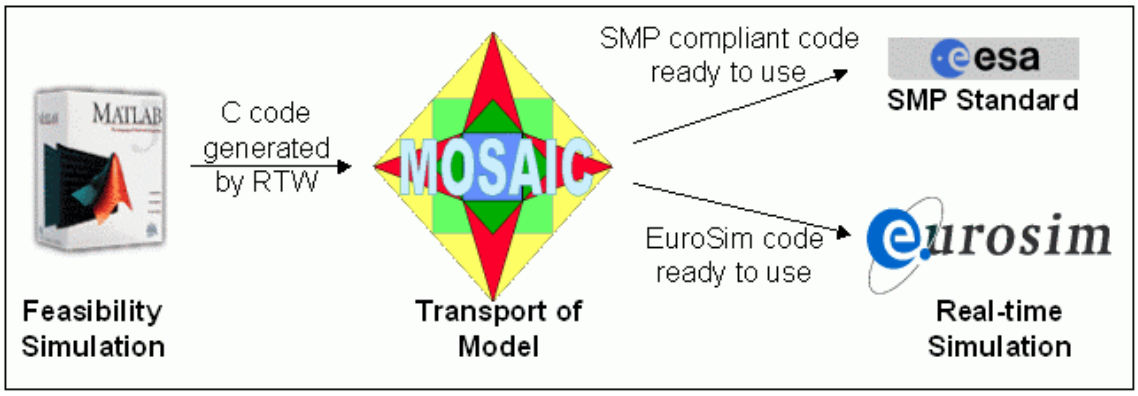

Fig. 1. MOSAIC place in the simulation model development process.

2 MOSAIC philosophy

MOSAIC fits within the simulator development life cycle. The purpose of MOSAIC is to let the model developer take advantage of dedicated model and simulation tools whenever possible. This requires an automatic model transfer tool between simulation environments that avoids the need to change low-level model source code. MOSAIC is such a tool.

The design of MOSAIC is based on the philosophy that models are the products of complex design cycles and have been verified and validated with system requirements in mind. Therefore, MOSAIC does not in any way affect the mathematical logic of a model. MOSAIC adds the required interface code to a model, while leaving the internal model logic as a black box. Simulation results before and after a transfer using MOSAIC are identical up to machine level.

When applying MOSAIC the powerful MATLAB Toolbox can be used for feasibility studies, model decomposition and verification of model interactions. Subsequently, application model parameter tuning in the target environment, e.g. for optimisation purposes, can be carried out in the real-time simulation environment using e.g. EuroSim or other SMP compliant environments. Changes in model design by the developer should take place in the originating environment, e.g. the MATLAB Toolbox.

3 MOSAIC and EuroSim

Since the first official release of MOSAIC in 1999 it is possible to transfer MATLAB/Simulink models to EuroSim. MOSAIC automatically converts model source code that has been generated with the Real Time Workshop (RTW) of MATLAB into model source that can be incorporated in EuroSim (see Fig. 2). Additional EuroSim specific files are also created. Within EuroSim extra steps can be performed to further customise the model and the simulation specific information such as schedules to the user's needs. For example, one can add additional API information, change the simulation frequency, or change tuneable model parameters during simulation.

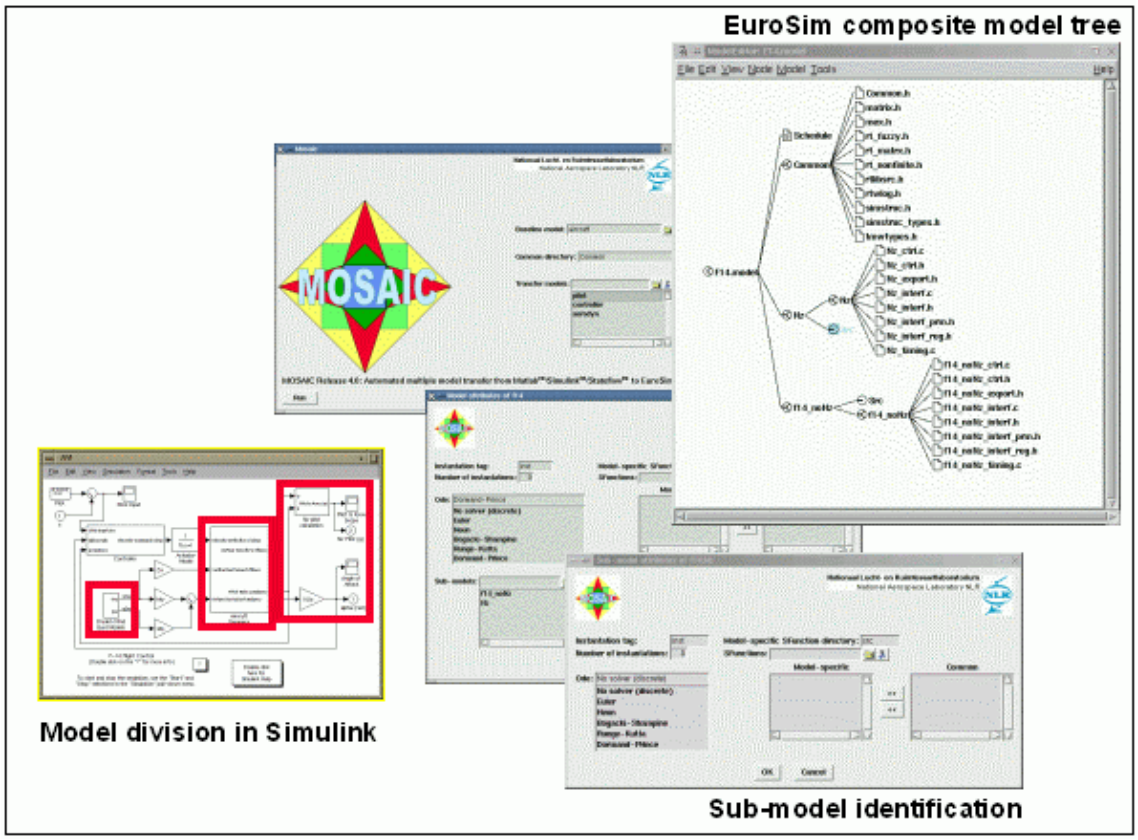

Fig. 2. MOSAIC multiple model transfer process

On special request of the Automated Transfer Vehicle (ATV) project [5] new features have been added to the MOSAIC product. Since MOSAIC Release 4.0 [6] in 2001 it is possible to choose between two ways of model transfer using MOSAIC from the MATLAB Toolbox to EuroSim:

- Atomic transfer, in this case a Simulink model is transferred as one entity.
- Multiple transfer, in this case a Simulink model can be divided into subsystems that will appear as submodels within the complete EuroSim model. MOSAIC Release 4.0 can transfer multiple model sources in one step, see Fig. 2. In EuroSim these models can be integrated with each other and with models originating from other sources, e.g. hand-written code.

Using multiple model transfer allows models to be instantiated automatically by MOSAIC. Release 4.0 also allows user defined functions, e.g. S-functions, to be either shared by all transferred models or to adhere to a specific model.

4 MOSAIC and ESA's Simulation Model Portability (SMP) Standard

The international simulation community is in the process of defining standards with respect to model portability. One of the main objectives is to enable simulation models (source code) to run in any simulation tool, independent of which tool was used for model creation. As a rationalisation of simulation developments ESA has defined the SMP Standard [4]. The main purpose of the SMP standard is to promote portability and re-use of simulation models in different simulations with different simulation environments. NLR has developed MOSAIC Release 5.0 [7] to facilitate atomic model transfer from the MATLAB Toolbox to the SMP standard.

Models that have been transferred by MOSAIC Release 5.0 can run in any SMP compliant simulation environment. It features the generation of SMP compliant model source code, including SMP specific files such as a Model Manager, and automatically generated model documentation. The Model Manager initiates publication of the models to the environment and scheduling of the model services within the simulation. As a special feature MOSAIC generates Model Manager routines that perform the SMP compliance test [4] of all transferred models, see Fig. 3.

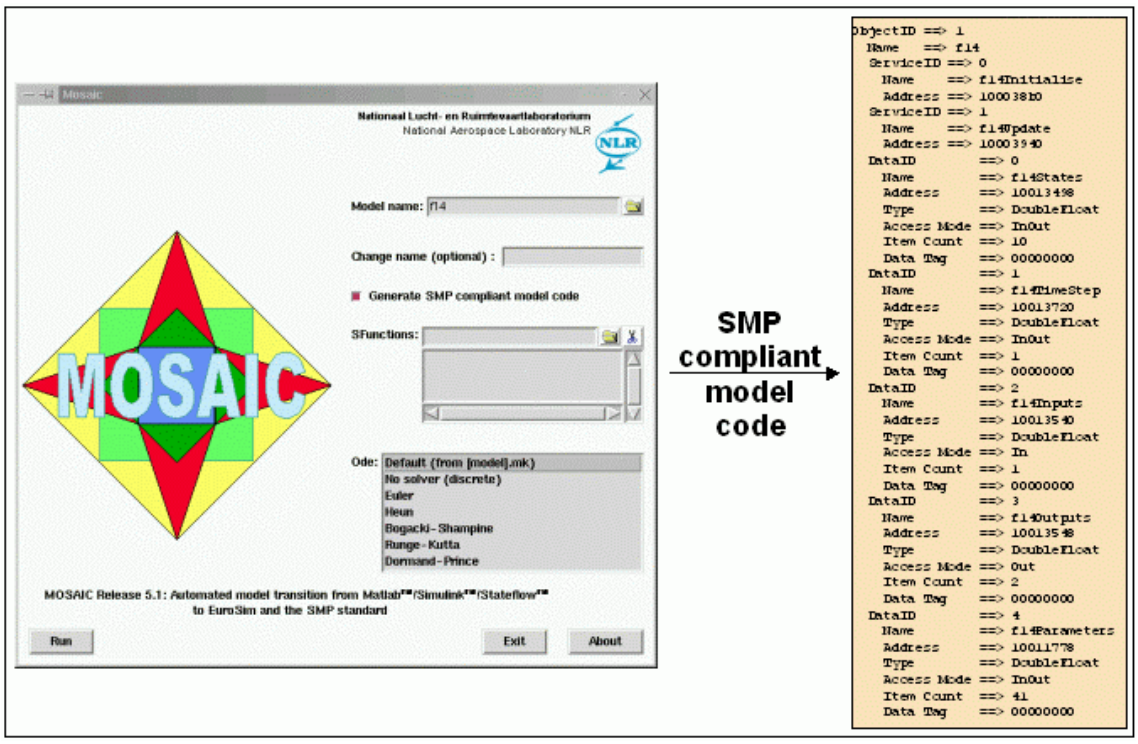

Fig. 3. MOSAIC to SMP transfer

There exists a trend that simulation environments adhere to the SMP standard. For example, EuroSim is capable of running models that are SMP compliant. In this way full advantage can be taken of both the SMP standard and the (real-time) capabilities of EuroSim.

5 MOSAIC in Applications

In the last two years the MOSAIC user community has increased significantly both inside and outside the space community. One can conclude that MOSAIC has become an important ingredient of various space development projects. Some examples of its use are:

- For the Small Missions for Advanced Research in Technology (SMART) I [8] development project ESTEC used MOSAIC to transfer MATLAB Toolbox models to EuroSim.
- For the Automated Transfer Vehicle (ATV) project EADS-LV [5] uses MOSAIC for multiple model transfer from the MATLAB Toolbox to EuroSim, see Fig.4.
- VEGA has successfully evaluated MOSAIC for use in the Galileo System Simulation Facility (GSSF) project [9], because it facilitates the generation of SMP compliant models.

Evidently, there are more (proprietary) applications.

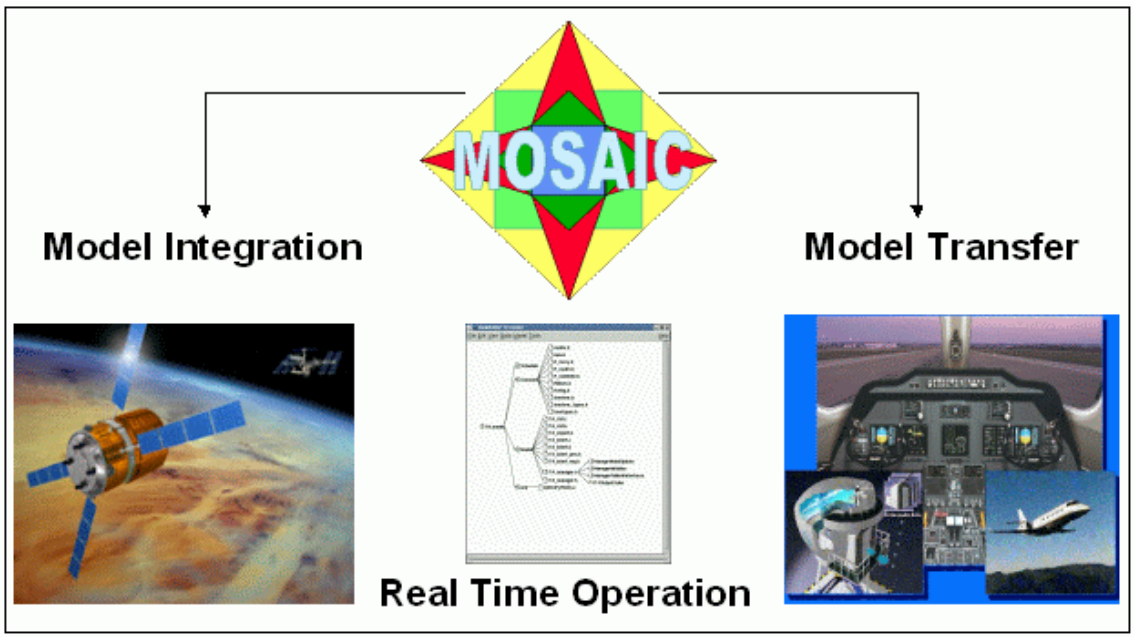

Fig. 4. MOSAIC application in simulator development

NLR itself also uses MOSAIC in a wide variety of projects. A typical example is model development in the Affordable Digital fly-by-wire Flight Control System (ADFCS) project [10], executed in NLR's Flight Simulators. The goal of this project is to develop an architecture for affordable fly-by-wire digital flight control systems for small commercial aircraft. ADFCS

partners have created models of flight control systems all over Europe using the MATLAB Toolbox. NLR transfers the MATLAB Toolbox models with MOSAIC for use in the real-time simulation environment ProSim. (ProSim is an instantiation of EuroSim that has been adapted to the NLR flight simulator.) Other MOSAIC applications with the NLR flight simulator are the development of Joint Strike Fighter Simulation Architecture (JSA) project and the GARTEUR-AG 12 project for aerospace vehicle dynamics. Another challenging and rewarding application of MOSAIC is its usage in the development of on-board software for NLR's research aircraft.

The wide use of MOSAIC shows it reduces time, effort, and error-prone source code editing. Therefore it is a crucial step within the simulator development process, see Fig. 4.

6 MOSAIC Test Bed

Maintaining the quality of the MOSAIC product is one of our goals. This holds for the product itself, as well as all the user documentation, software quality and configuration management. Extensive use of MOSAIC within NLR ensures ongoing extensive testing of MOSAIC capabilities with ever more complex models in an increasing number of applications.
At NLR, MOSAIC is also part of a larger model development and test environment for Computer Aided Control Engineering (CACE). Besides the actual simulation software, the CACE environment also facilitates documentation and tools for management and education. Development processes are structured by means of tool chaining in so-called workflows (see Fig. 5), allowing easy re-use of knowledge. The construction of the CACE environment is based on the SPINEware product [11]. SPINEware, developed by NLR, facilitates multiple and remote access to applications over a network through a single graphical user interface.

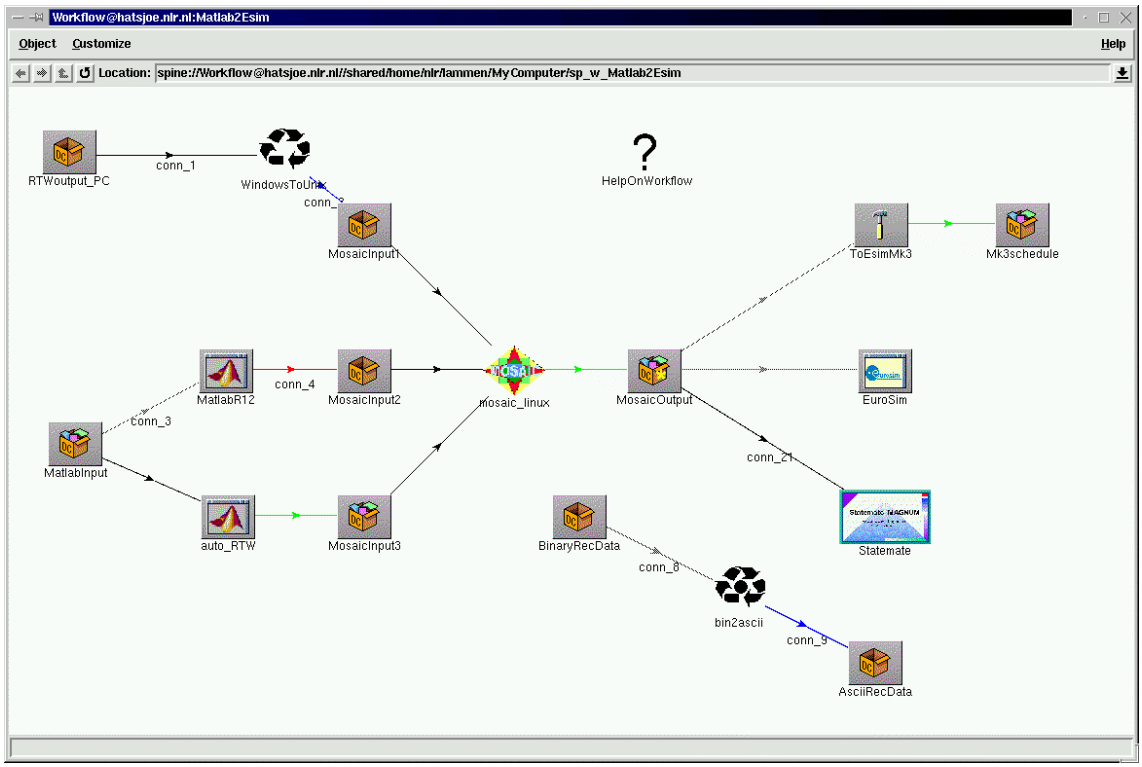

Fig. 5. MOSAIC embedded in an automated CACE workflow

7 MOSAIC Future Plans & Policy

Developments of MOSAIC are driven by customer requests. Updates of COTS tools and model standard definitions usually result in an upgrade of the MOSAIC capabilities. NLR already upgraded MOSAIC twice to new versions of the MATLAB Toolbox. In the near future it will be upgraded to EuroSim Mk3.

MOSAIC only requires the user manuals of the COTS tools or standards between which it facilitates model transfer. In 2003 MOSAIC will be enhanced to support a new version of the SMP standard on hierarchical model structures as expected to be released by ESA by the end of 2002. This includes

- automatic creation of a generic model manager for multiple models;
- integration of model-specific files into a hierarchical model-tree;
- optional re-use of an existing Model Manager during each transfer.

MOSAIC is available on Linux and SGI. Current work is directed to the release of a Windows version of MOSAIC.

MOSAIC is available as a licensed NLR product [12]. More information can be obtained from mosaic@nlr.nl.

8 References

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Appendix A List of Abbreviations

ADFCS	Affordable fly-by-wire Digital Flight Control Systems
ATV	Automated Transfer Vehicle
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
CACE	Computer Aided Control Engineering
COTS	Commercial Off-The-Shelf
EuroSim	European Real-Time Operations Simulator
GSSF	Galileo System Simulation Facility
JSA	Joint Strike Fighter Simulation Architecture
MOSAIC	Model-Oriented Software Automatic Interface Converter
NLR	National Aerospace Laboratory NLR
RTW	Real Time Workshop
SMART	Small Missions for Advanced Research in Technology
SMP	Simulation Model Portability