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### ► To cite this version:

Jeremy Bourdon, Pierre Couturier, Vincent Chapurlat, Robert Plana, Victor Richet, et al.. Document to model transition for architecture evaluation approach: Application to a nuclear infrastructure project. 10th IFAC Conference on Manufacturing Modelling, Management and Control (MIM) 2022, IMT Atlantique, Nantes, Jun 2022, Nantes, France. pp.3250-3255, 10.1016/j.ifacol.2022.10.137 . hal-03834881

**HAL Id: hal-03834881**

**<https://hal.science/hal-03834881>**

Submitted on 31 Oct 2022

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# Document to model transition for architecture evaluation approach: Application to a nuclear infrastructure project.

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**Abstract:** In large engineering projects, multiplicity and heterogeneity of business actors, domain and business constraints, and stakeholders' needs become more and more difficult to manage and are even moving. To allow projects members to converge in confidence, reducing time, costs and avoiding risky situations due to errors, misinterpretations, or omission, Model Based System Engineering (MBSE) replaces today the classical documents centric engineering approach. It promotes modeling, models and data management principles that are largely used in several domains with success. This article focuses on Nuclear Infrastructure engineering projects. It intends to demonstrate the interest of deploying MBSE approach in this field, particularly concerning architectural solutions evaluation. Main principles and application results of an MBSE driven method called EVA-CIME are proposed, presenting some gains and perspectives.

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**Keywords:** System Engineering, Model Based System Engineering, Architectural Definition, Deployment.

## 1. INTRODUCTION

In the context of nuclear industry as in other domains (transportation, defense...), engineering projects remain difficult to master and drive from end to end. These projects are technically and organizationally more and more complex for various reasons e.g. large number of roles of business actors, vocabulary not shared, appearance of ambiguities, omissions, and contradiction in objectives to reach, diversity in used tools, various life cycle duration, resources reconfigurations, actors' reorganizations, evolution of stakeholders' expectations... That's why various principles and processes (ISO, IEC and IEEE, 2011, 2015, 2019; ISO and IEC, 2016) have been published to help deploy System Engineering (SE) approach (Rechtin, Maier and Maier, 2000; BKCASE Editorial Board INCOSE, 2016). We focus here on the period when engineers and architects must, iteratively and in confidence, study, tests, make emerge, check, enhance maturity level and improve the relevance of various architectural solutions. This has to be done considering all stakeholder's viewpoints, values, requirements and constraints. To move towards an ideal situation this requires to work, at both enterprise level and project level, on among other particular points:

- Describing these solutions, justifying and qualifying them limiting ambiguities or misinterpretation, and providing various proofs of qualification then to become able to compare them;
- Tracing all representation propositions, proof, decisions and choices;
- Developing, connecting, sharing and maintaining a large amount of data, representations, models and knowledge.
- Handling methods, tools, principles specific to a business field or engineering domain cannot be understood by others.

For this, Model-Based Systems Engineering (MBSE) is a way to follow Systems Engineering (SE) principles and aims, focusing and insisting on the relevance and importance of modelling and models of the so-called "System of Interest" (SoI) instead of documents. The systematic use of a modeling, verification and validation methodology limit the risks of rework and improves efficiency (Sillitto, 2010). In addition, models facilitate the creation, manipulation, consistency check and traceability management of engineering data. A data-centric approach facilitates the development of automation mechanisms, which further increases the overall benefits. However, this ideal situation is still far from being achieved in the nuclear field. It remains common to share a large number of textual documents of various kinds. For example, numbers provided by ASSYSTEM resulting from the first use-case presented are more than 200 documents produced for a total of about 16000 pages in one year. In addition, very few models are available to define architectures, to carry out the various evaluations, making evaluation activities tedious, costly and time consuming. In practice, one type of model, the breakdown structure diagrams, is mainly used for communication and organization purposes, neglecting other possible models. This practice leads to difficulties in:

- Managing traceability between requirements and architecture;
- Identifying the impact of a change in waste characteristics on the architecture;
- Identifying the impact of a change in the architecture on the management of the flows of waste;
- Identifying the points of attention of the architecture (e.g. room in which a large number of different flows pass);
- Elaborating intelligible descriptions that are always coherent with the current development of the architecture;

- Managing the large quantity and multiplicity of data concerning the waste to be treated;
- Ensuring that the architecture is properly dimensioned to handle all the types of flows it will have to process.

These elements show that the interests of moving from documents to models, through MBSE, need to be clearly identified to support the actors in charge of these essential activities. This article aims to show the difficulties encountered and solutions brought to take advantage of these interests, particularly in the case of architectural solutions evaluation that remain a crucial activity for these actors. For this demonstration purpose, a use case is presented on which an MBSE driven method called EVA-CIME for conducting architectures evaluation is applied, presenting some gains and perspectives.

## 2. STATE OF THE ART AND EXPECTED CONTRIBUTIONS

MBSE is: *"A System Engineering methodology that focuses on creating and exploiting domain models as the primary means of information exchange between engineers, rather than on document-based information exchange"* (Gianni, D'Ambrogio and Tolk, 2018). All SE are then concerned e.g. mission and business studies, requirements engineering, architectural design, architecture evaluation and system verification and validation (V&V).

A model is a representation of reality that allows us to abstract certain details and reduce in appearance the complexity. It can be a mean of communication and exchange between several actors (explanatory), and a support for the reasoning and analysis that are necessary to judge the opinions and choices of these actors (prescriptive, normative). Thus, the MBSE puts forward and relies on different methods of modeling, analysis, evaluation, ... which are deployed in SE as well as, more upstream, in the architecting phase. Finally, the MBSE uses multi-paradigm and multi-user modeling tools sharing common repositories. This allows to have a coherent working environment, as much as possible interoperable.

In fact, the MBSE can be implemented to support the whole life cycle of the system of interest, but also to focus on the integration and implementation of the different disciplines involved during a project. MBSE is an asset for data manipulation for system engineering processes as architecture evaluation. Nevertheless, there are gaps in the consideration of the evaluation activity in model development that prevent this activity from taking advantage of the benefits of MBSE. This is why we proposed the EVA-CIME method allowing to pass from a document centric approach to a data centric one guided by models considering architecture evaluation needs as presented in (Bourdon et al., 2021).

This method is then largely inspired from MBSE principles and by ISO 42030. Last, it is equipped, being then a response to some MBSE practitioners' but also managers' expectations when facing system analysis problematic at both projects and enterprise levels. Thus, EVA-CIME contributes to a repository of knowledge and expertise supporting the deployment of MBSE for architecture evaluation within a company.

## 3. EVA-CIME METHOD DEPLOYMENT

### 3.1 Use-case context presentation

The application case focuses on the preliminary design stage of a Nuclear Infrastructure (NI) devoted to nuclear waste management. This NI must meet various requirements concerning storage forms, types, and locations where wasted elements may be stored permanently or temporarily. Different scenarios for the recovery and treatment of waste from dismantling were studied. The retained principle is to ensure the treatment and reconditioning of irradiating waste in a single facility. This one must be able to receive, sort, size, condition, characterize, and block certain wastes, and to send the waste packages produced to the outlets. These functions define the scope of our experiment.

### 3.2 Objectives/Motivation of this deployment as a demonstration

The EVA-CIME deployment on projects is part of a global deployment strategy of MBSE principles and practices within ASSYSTEM company. It supports the development of methods adapted to the company's organization, aims and objectives thanks to various application domains and among other, Nuclear Infrastructures engineering projects. These objectives regarding this experimentation are to:

- Ensure the feasibility and benefits of a model-based approach on this type of project;
- Promote a model-based approach as close as possible to the operations;
- Appropriate existing MBSE tools and approaches and develop methodologies tailored to project needs;
- Initiate the development of an architecture description framework for nuclear waste treatment systems.

The project described below presented a relevant initial situation, being really document-centric. The corpus used was composed of 5 hundreds of pages distributed in about ten textual documents, in addition to which spreadsheets for a total of 600 lines. Engineers had to produce and update a representation of the waste movements within the facility to communicate with the client. These representations, although relevant as a support, had to be however reworked at each modification.

EVA-CIME is then here applied considering the use case proper objectives which were:

- To have a clear, coherent and evolving communication support with the customer about the distribution of functions within the installation;
- To dispose and promote a way to prepare, organize, perform and check architectures evaluation by using and privileging existing data and models.

### 3.3 Stakeholders involved in EVA-CIME deployment

This experimentation involved first a dedicated MBSE deployment team operating in parallel and in interaction with the project team. The goal was to reduce the experimentation impact on the project schedule while being as close as possible to the expectations of the project team. Various roles and responsibilities have been requested and then allocated to teams' members:

- Project team

- Project Leader
- SE Methods and Tools Manager
- MBSE deployment team
  - SE & MBSE Technical Manager
  - SE & MBSE Technical Coordinator
  - Modeler

The responsibilities of the SE & MBSE technical manager and the project leader are to ensure that the experimentation remains consistent with the objectives of the company and the project respectively. Last, all the teams' members have been involved in each of the exchanges, restitutions and reviews.

### 3.4 Use case needs for guiding EVA-CIME deployment

The evaluation process supported by EVA-CIME allows, among other things, to establish the judgments to be made about the architectures by determining the use of indicators. These ways of being applied could be:

- To identify points of complexity to implement more detailed specification actions;
- To trigger specific workarounds (additional deliverables, riders, etc.);
- To support design reviews: choose a different architecture if the load of a room is too high; guide design choices (choice of remote operation elements, package tracking system, etc.).

Considering judgements to be made and teams' members exchanges, a set of modeling expectations are to:

- Clarify the scope of the System of Interest (SoI, so hereafter an NI) as well as the interfaces with external systems;
- Define and maintain an up-to-date representation of the functional tree structure;
- Define and maintain an up-to-date representation of the rooms hierarchy;
- Identify and represent all the incoming and outgoing flows of the NI;
- Define a data model for characterizing without ambiguities the waste in order to define the items exchanged between the functions, to group waste flows by category and to follow the transformations that the flows undergo;
- Define a functional architecture based on the functional tree, *i.e.* define the input and output flows of each function in the tree and structuring adequately these functions and flows;
- Project then contextualize (as much as possible from automated or assisted manner) the functional architecture on a map of the NI in order to define the storages locations and movements (flows between storages locations) of waste packages.

With regard to these expectations, MBSE deployment team is in charge of establishing the main steps to follow in order to reach the expected objectives.

### 3.5 Steps/What to do?

The deployment approach is divided into 4 main steps summarized in **Erreur ! Source du renvoi introuvable.** and detailed in the next.

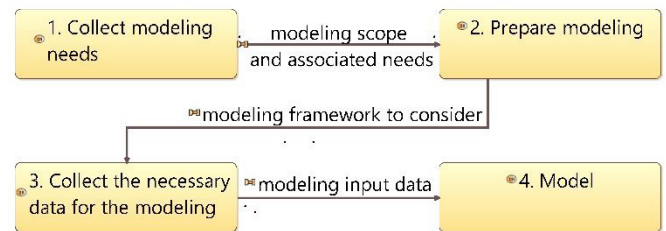


Figure 1. Main activities performed during the experimentation

**1. Modelling needs collection activity:** A first collection of needs with regard to modeling are identified as those described above for our application case. From this list of needs, which should be as exhaustive as possible, the stakeholders of the deployment agree on the needs that will be addressed for the first iteration.

The scope of the studied system is defined in accordance with this reduced list of needs. It is necessary to consider the availability of resources when defining the scope. These resources are the associated engineering data, the technical actors aware of the elements of the perimeter as well as one or several modelers. Finally, the operating principle is fixed, who interacts with whom, at what time and in what way.

**2. Modelling preparation activity:** With the deployment activity framed, the MBSE deployment team establishes a first draft of a modeling framework to be respected. A generic version of this framework is furnished by the EVA-CIME method as a guide. It gathers the requested concepts and their associated definitions that will be used, the model kinds that could be built, the representation of the different concepts as well as the objectives covered by each model kind. The development of a modeling framework is important so that all parties share the same vocabulary, so that the project actors can appropriate the models produced and finally trace the modeling choices providing a common core of rules for model verification. The various alternative model kinds are then presented, discussed and arbitrated with the project stakeholders to establish the final set to instantiate on the scope. Particularly, various criterion must be considered and cannot be neglected when choosing model kinds. Hereafter, one of these criteria is the availability of an interoperable modelling environment able to give access to the set all the chosen model kinds, even based on several tools.

**3. Data collection activity:** Based on the model kind set, the MBSE deployment team defines the data deemed necessary to develop the different models. EVA-CIME framework proposes classical list of data as a basis for discussion to determine specific data and how they will be obtained: available as is in a document, available in a document after interpretation or available from a project actor. This requests setting up one or more interviews with some project actors, access to the directory containing the documents, etc.

**4. Modeling activity:** It begins as soon as enough data have been specified to start and build expected models. It is necessary to plan regular feedback and models reviews points involving then both MBSE and practitioner actors. These exchanges ensure that the modeling is carried out in the direction of the project's needs while making the project's actors aware of the modeling process. Indeed, allowing the project actors to follow and participate in the evolution of the

model and to see it grow facilitates their involvement. This way of proceeding is in line with the enterprise's objectives of promoting the model-based approach as close as possible to the projects. Moreover, as the modelers, within the framework of an experimentation, do not necessarily have the technical knowledge which is essential to have the models validated by a third party. The modeling activity proceeds until the parties are confident that the objectives defined during the kick-off have been met.

### 3.6 Results and benefits

From different documents such as a technical specification of the preliminary needs, a note of hypotheses on the incoming flows, a functional analysis, a list of premises and a synthesis of the dimensional data and hypotheses taken we were able to converge with the project on a set of models. In this deployment work, we faced some difficulties for which we had to find solutions.

**1. Results of modelling needs collection activity:** It is common that the project actors do not have a clear idea of what modeling allows. This is why it is up to the team in charge of the deployment to present the capabilities enabled by the modeling. It is possible to elaborate this presentation according to two approaches. The first one, adapted in the case where the practices of MBSE within the company is quite rare, consists in a high-level presentation based on different white papers of methods or tools, or results of explorations realized internally. The second one, allowed when a certain number of experiments has already been conducted, consists in presenting the models and the associated uses on different projects. These experiments can be grouped and categorized in order to present relevant usages as soon as possible. Since the project team has a range of possibilities at disposal, the needs are easiest to define.

Concerning the organization to be set up for the initiation of the modeling, three modes of operation can be distinguished and are grouped in Table 1.

The first one consists in entrusting the modeling activities to a modeler with technical support. This has the advantage of reducing the investment to begin modeling activities. On the other hand, it requires the continuous availability of people with technical skills and knowledge of the system in support, which represents an additional cost for the project and which may not be logistically possible. This mode of operation is particularly suitable if the model is to be made on an already completed system.

The second, on the contrary, consists in entrusting the modeling activities to a project actor by providing him with modeling support. This has the advantage of strongly involving the project actors in the modeling in exchange for a greater investment by the project, which must dedicate the time of a resource to its modeling training before starting modeling. This mode is particularly suitable if the modeling activities have been identified before the official start of the project.

The last one consists in setting up a binomial consisting of one person with modeling skills and the second with technical skills. This has the advantage of encouraging the transmission of modeling skills to the technical actor without freezing the modeling activities at the beginning. It has the disadvantage of

having to dedicate at least two resources to it until the modeling autonomy on the project side is reached. This mode is particularly suitable if the modeling activities are deployed during the project or if the timing before the start of the project does not allow the use of the previous operating mode.

Table 1. Three organizations to initiate modeling activities

<i>Organization principle</i>	<i>A</i>	<i>B</i>	<i>C</i>
Modeling performer	Modeler	Project actor	Binomial technical actor and modeler
Enabler	Technical support from project	Modeling support from MBSE team	Synergy between the two people involved
Advantage	Low modeling pre-launch investment	Strong involvement of project actors	Quick launch of modeling activities
Drawback	High availability of technical parts required	Large investment in training required	Two dedicated resources required
Adapted for	Retro-modeling	Modeling identified before the start of the project	Modeling identified during the project and strong schedule constraints

In the case of our experiment, the perimeter chosen concerned elements that had already been completed. We therefore preferred organization A to the other two. We have made the drawback noted in the table. Indeed, our interlocutor had very little availability making the modeling activity cadenced by it. The modeler had to face periods of inactivity on this project followed by periods of intense activity. This is why it is necessary to agree on the availability of each person at the beginning of the project in order to smooth out the activities as much as possible over time.

**2. Results of modelling preparation activity:** One of the questions during preparation, especially about the functional view, was whether it was more relevant to go into detail quickly on a very limited perimeter or to have a very large perimeter with a fairly low level of detail. This question must be confronted with the needs identified for the experimentation. We were particularly interested in the movements of waste within the installation. Consequently, the functions which decompose it are the only ones to be considered in our perimeter reducing the number of functions to be included in the modeling to 245.

In addition to the choice of the perimeter we determined which model kinds, and so which tool, would be the most relevant for our experiment. Capella (Roques, 2018) was chosen in particular for its free availability, the implementation of a documented and proven method Arcadia (Voirin, 2017) and its portability. So, we use the model kinds provided by Capella, avoiding questions of connection between models already solved by the tool provider. Nevertheless, this solution limits the types of models to those provided. It could then be interesting to develop a pool of interchangeable tools according to the identified needs.



We distinguish three views with regard to the identified needs. The informational view gathers the characteristics of the waste and the data model associated with the items exchanged and the premises. The functional view describes the functional architecture, i.e. the different functions of the system of interest, the functional exchanges, the waste carried by these exchanges as well as the functional chains representing the functional path followed by a specific waste category. The structural view presents the infrastructural elements which are the premises, the associated properties and their layout in space. The type of model that we considered the most relevant to group these different views is the Logical Architecture Blank diagram (Voirin, 2017). We have adapted the layout of this one to our needs. The combination of the elements and the relationships between them enable the elaboration of models, compliant with the model kind chosen (Figure 2).

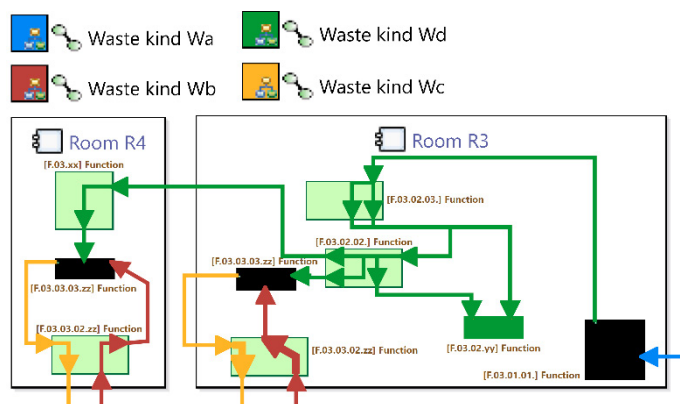


Figure 2. Model example to project function on ground plan

**3. Results of data collection activity:** We did not encounter any notable difficulties in obtaining the raw data, i.e. the documents containing the data. Nevertheless, some difficulties are to be noted for their extraction. The analysis and extraction of the corpus data was done manually by the modeler. The understanding of the different information in the documents was done through numerous exchanges with the project contact. This analysis brought up a certain number of inconsistencies and contradictions within the different documents. This could be a difference in the naming as a different allocation of the function to a room. These elements had to be discussed with the project contact in order to decide on the data to be considered for the modeling. This activity was the most time consuming in the realization of the experiment. It represented 70% of the time spent in total. The time allocated is not negligible, so it is important when migrating a project from a document centric to a data centric approach to think about the extraction of old data. This can be done by setting up a task force to handle the migration or by using a natural language processing mechanism. In view of the scope of our experiment, we were able to assign this task to the modeler. The biggest obstacle for the extraction of these data was the availability of the technical contact person. There was no time constraint regarding the results of this experiment, so we were able to take the time we needed to access the data. Nevertheless, this difficulty highlights the need to clearly define access to information and resources when framing the deployment.

**4. Results of modelling activity:** The elaboration of the global model and the representations that compose it led us to alter the functional analysis previously performed. We can distinguish the following categories of rework:

- [SAME]: Function kept as is;
- [NEW]: A new function has been created;
- [RENAMED]: Function renamed;
- [MOVED]: Function changed (i.e. upper-function);
- [DEPRECATED]: Function that no longer exists.

■ [MOVED] ■ [SAME] ■ [NEW] ■ [DEPRECATED] ■ [RENAMED] ■ [REUSED]

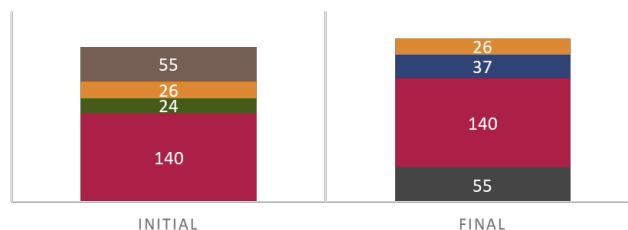


Figure 3. Functional analysis reworks

In addition, the development of these models allows for the automatic extraction of a certain amount of information. The information and associated formats considered relevant for our case are:

- number of functions carried by a room;
- number of functional exchanges between two functions carried by two rooms;
- number of interfaces between rooms;
- number of functional chains involving a particular room or a particular function;
- number of in/out exchanges from a given room;
- tables of all functions and exchanges;
- tables of all rooms and interfaces;
- tables of exchanges with specified exchanged items (quantity of waste, flow, format of exchanged data).

In addition to this information, a booklet of 30 diagrams is generated containing each of the associated diagrams for each of the waste types in the same format as described in Figure 2. This booklet is used for communication purposes with the client.

From this information made available by the development of models, a set of indicators is defined. These indicators are identified through an architecture assessment preparation activity that allows us to establish the information needed to assess the response to the architecture's concerns based on the stakeholders' concerns. These set of indicators include:

- architectural indicators (based on the number of functions, functional exchanges, interfaces, density of exchanges, etc.) at the level of a room or a function/system;
- load indicators (by aggregating the inputs and outputs of a room or a function);
- domain-oriented indicators (change of color according to the type of interface, i.e. color x for a civil engineering/electricity interface, color y for a ventilation/electricity interface);
- non-functional oriented indicators on different properties (availability, robustness, safety, accessibility, performance, security, maintainability, ...);
- indicators of utility consumption (ventilation, fluids, electricity, ...).

After discussions with the parties, several benefits are highlighted in implementing even a partial model-based approach:

- The realization of a data model allowed the stakeholders of the project to agree with a common vocabulary and thus to remove any ambiguity on the elements exchanged within the installation;
- The modelling allowed to highlight gaps in the functional analysis which have been corrected;
- The model was used to generate a booklet of diagrams to represent all the flows according to the types of waste in the facility;
- The definition of properties for a room led to the development of new viewpoints for the study of waste treatment systems that will contribute to develop an architecture description framework;
- The implementation of models has greatly facilitated the realization of these evaluation activities;
- Modeling allows us to identify the impact on the architecture of changes in incoming flows, as well as the domains mainly involved;
- The documents have not disappeared from the project, but they have become model kind integrated at the architecture description and no longer the container;
- The models produced in this experimentation are easily reusable in projects with similarities.

#### 4. CONCLUSION AND PERSPECTIVES

The implementation of modeling on a part of this project facilitated the identification of points of vigilance and lack of details in the definition of the architectures of the expected solution. The implementation of modeling is a fundamental element to develop methods that rely on models as it is the case for EVA-CIME. The course of this experimentation has highlighted the need and the interest to develop a framework of description of architecture adapted to the waste treatment facilities. The key success factors for this type of implementation are to plan model-based systems engineering activities as early as possible when setting up the project and to involve the parties concerned as much as possible.

Concurrently, it will be interesting to develop an architecture evaluation framework so that the needs coming from the architecture evaluation activities are considered in the description framework. The lessons learned from this experiment will participate in the next ones. In order to take full advantage of this learning, it is necessary to set up a system for capitalizing on and disseminating this knowledge at the company level. In order to allow the global implementation, it will be necessary to formalize an approach that can be taken in hand by the operational staff and to provide them with a network of experts so that no point of misunderstanding is left. This is why the architecture description framework must necessarily be accompanied by an operational approach, a tool environment and a repertoire of knowledge and expertise (past experience, network of experts, patterns, guidelines, ...).

Define the architecture description framework through an instantiable model on a project would allow the generation of certain documents requested by the client, such as an MBSE management plan and a methodological guide to be set up. Thus, the model-based approach would in no way make

documents disappear, but instead they would become a means of representing data rather than a simple container.

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