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Need to integrate the operating phase into the life cycle of a Production Automated Systems (P.A.S)

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Abstract— Flexibility in production leads to more and more automation of production systems. These systems are heterogeneous and increasingly complex to design, implement and operate. Today, highly automated production systems are observed in which various technologies are used. This automation has made production systems quite complex. The constraints linked to the process are becoming increasingly strong. To be profitable, it must be increasingly reliable, easy to use and maintain, and must guarantee the safety of people and the environment. Indeed, experience has shown that during the exploitation phase, the ultimate phase of any industrial project, the operator's limits quickly appear in front of these heterogeneous processes. The problems related to the operating phase of an P.A.S are numerous. The most notable is that linked to incompatible operating modes, in particular for the reconfiguration of automated production systems. In this paper, after having presented the different phases of the life cycle of an S.A.P, we present the operating phase functional analysis of an Automated Production System (P.A.S). The main problems encountered by operators during this phase are raised: In particular the problems related to the system operating mode reconfiguration which are the cause of many operating difficulties.

Index Terms— Production Automated System (P.A.S); Life cycle; Operating phase; Operating mode; Reconfiguration.

1. INTRODUCTION.

Flexibility in production leads to more and more automation of production systems. These systems are heterogeneous and increasingly complex to design, implement and operate.
Today, highly automated production systems are observed in which various technologies are used. This automation has made production systems quite complex. The constraints linked to the process are becoming increasingly strong. To be profitable, it must be increasingly reliable, easy to use and maintain, and must guarantee the safety of people and the environment.
Indeed, experience has shown that during the exploitation phase, the ultimate phase of any industrial project, the operator's limits quickly appear in front of these heterogeneous processes. The problems related to the operating phase of an Production Automated System (P.A.S) are numerous. The most notable is that linked to incompatible operating modes, in particular for the reconfiguration of automated production systems.
In this paper and after having presented the different phases of the life cycle of an SAP, we focus our study on the functional analysis of the operating phase of an P.A.S in order to identify the main problems encountered by operators. In particular the problems related to the reconfiguration of the operating mode of the system which are the cause of many operating difficulties.

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2. LIFE CYCLE OF A P.A.S.

The life cycle of an P.A.S is composed of two macro-phases:

- Its **creation**, including the various operations necessary for the specification, design, implementation, integration and acceptance of the installation.
- Its **use**, taking into account the operation from its launch until its dismantling.

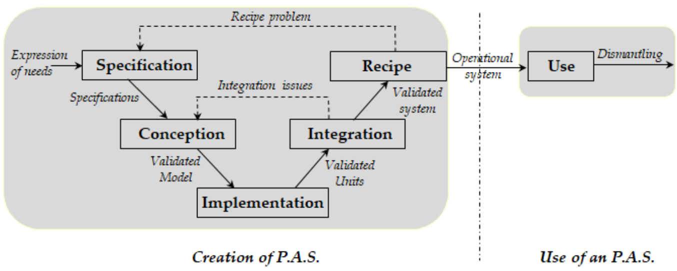

Fig 1: life cycle of an P.A.S.

2.1. Spécification.

the aim of this phase is to draw up the specifications. It intervenes in the context of the need for a new production tool or a modification of the existing tool. It is a specification of the customer's needs specifying the object of the automation, that is to say the description of the products and functions to be performed by the system.
The first step is a detailed description phase. It corresponds to a prior reflection carried out through a designer-client dialogue in order to lead to a definition of the production and automation objectives [1].

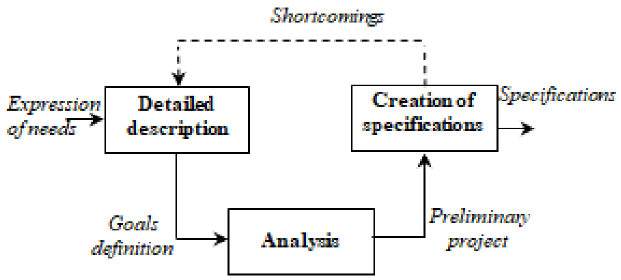

Fig 2: Spécification phase.

The second step, the needs analysis (or pre-study) allows to verify the feasibility of the project. Its result, the preliminary draft, is then submitted to a summary: the specifications.

The last step, the realization of the specifications, defines the project by the expression of:

- Its objectives (new product to be manufactured, automation, new organization, etc.)
- Its technological or operational constraints which relate to the manufacturing process, already existing elements, the environment, etc.
- Its study and implementation constraints indicating the technological limitations of the system, the budgetary, temporal, human aspects ...
- Its performance evaluation scenarios for debugging, integration, and finally acceptance tests.

2.2. Conception.

The conception allows to analyze, model and validate the production system described in the specifications.

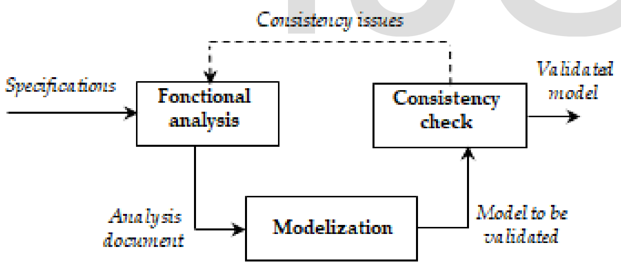

Fig 3: conception phase.

2.2.1. ***Functional analysis:*** constitutes a guide for the designer to better understand the system under study, to communicate with other project stakeholders, diagnose critical points, manage the teamwork of design and implementation, and finally document [2]. Methods such as SADT [3] [4], IDEF0 [5] [6], AXIAL [7], Petri nets [8], Uniform Modeling Language (UML) [9]…

2.2.2. ***Modelization:*** formalizes the description made during the previous phase. It must meet several criteria:

- It must describe the system in a coherent manner so as to provide both a global and detailed view of the entire project, hence the need for a hierarchical model.
- It must faithfully represent the physical system. The consistency of the model is thus more easily obtained.
- It must be particularly modular. Modifying entities should not force the designer to completely overhaul the model.
- Finally, the use of the conceptual model must use suitable graphics for better communication to the different bodies of trades concerned.

Here the design methods and tools (Petri nets, GEMMA [10], GRAFCET [11], Logigrams, Technoguides, UML…) can be used.

2.2.3. **The validation**: of the model goes through a simulation which allows the study of its behavior and its evolution. It updates the good integration of the different modules and their consistency with regard to the objective to be achieved. The simulation results provide information on:

- The study of the influence of technological choices,
- The evaluation of the different operating rules,
- Determining the influence of certain disturbances ...

2.3. Implementation.

The on-site implementation is based on the model validated by simulation. This activity consists in carrying out:

- A detailed organic analysis which provides the breakdown of functional instructions into Processing Units (U.T.), and a programming folder for each U.T., intended for coding teams,
- A manual or automatic code generation, then on-site implementation,
- Unit tests to allow the recipe element by element.

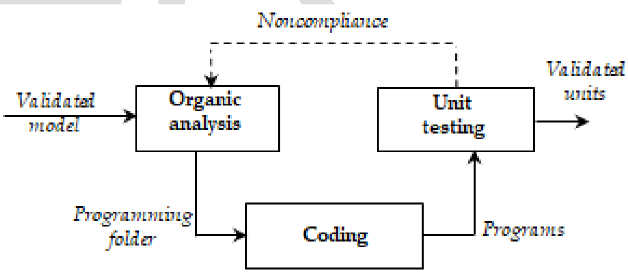

Fig 4: Implementation phase

2.4. Integration.

The integration must assist by progressive validation the different components of the system. This phase is important, especially in the context of large projects which call for subcontracting.

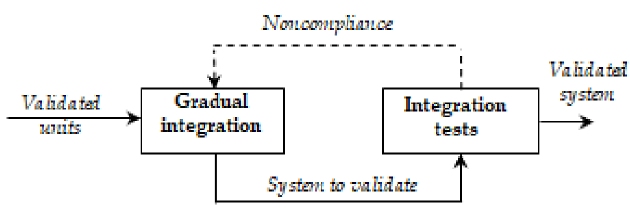

Fig 5: Integration phase

2.5. Recipte.

The installation recipe allows the user to see that the realized system meets his expectations. It is based on scenarios defined in the specifications. It relates to tests of equipment operation, functional conformity, performance, safety, availability and operation at the limits. It authorizes the delivery of the operational system and its documentation.

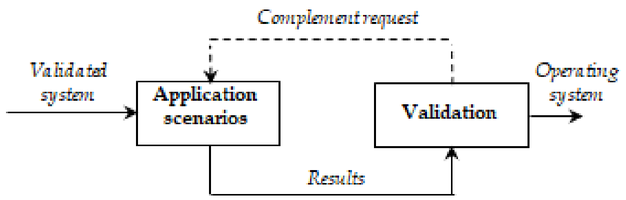

Fig 6: Recipte phase

3. USE: OPERATING A PRODUCTION AUTOMATED SYSTEM (P.A.S.).

The life of a system does not end at the end of its development and its recipe. The operation, the phase which interests us more particularly corresponds to the final goal of any design. Its role is to bring the automated system to life. Its objectives are to manufacture in quantity, quality and on time. Its main activities are presented below. The IDEF0 tool is used to develop this analysis.
The diagram in fig7 represents the initial activity and the context against which our analysis was conducted. This first activity "***Operating a Production Automated System (P.A.S.)***" uses the existing system. These initial data are defined by:

- ***P.A.S. state*** : characterized by the state of resources (machines), the state of tools, the state of raw materials and semi-finished products and control software.
- **Expected objectives**: can be expressed in terms of respect for deadlines, quality and quantity of product to be produced on the one hand and the choice of a particular order structure (hierarchical, distributed) on the other hand,
- ***Tasks to perform***: correspond for example to process monitoring, operations on the product (production program) ...

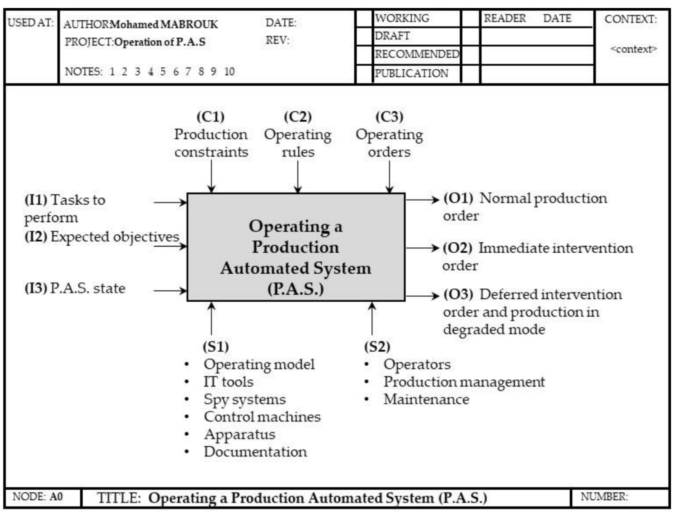

Fig 7: Operating a P.A.S.

The results provided by this activity are presented according to three categories:

- the first result, expressed by "***Nominal production order***" is the most obvious. It expresses the fact that all the planned objectives have been achieved.
- the second result, defined by "***Deferred intervention order and production in degraded mode***", expresses the fact that a malfunction exists within the P.A.S but its consequences on the expected objectives are minimal and acceptable for a period limited to during which it is not necessary to modify the behavior of the system.
- the last reported result is: "***Immediate intervention order***". This result implies that an intolerable malfunction (attack on the safety of people for example) is detected in the P.A.S. This malfunction absolutely requires immediate intervention on the P.A.S in order to change its behavior (emergency stop for example). This intervention can also induce a change in production (new product).

The supports for this activity are:

- An behavioral, structural and functional models of SAP (MESAP for example),
- Programs and softwares for control,
- Tools for functional monitoring,
- Operating documents, important supports for knowledge of the equipment (design, conditions of use, operating conditions),
- System operators (maintenance personnel, operating personnel, etc.),
- Machines, devices and IT tools facilitating the use of P.A.S.

The constraints to which this activity is subject are:

- production constraints; expressing the needs of production in terms of product quality, quantity demanded and production lead time.
- Workshop constraints; expressing the limits of the system. These limits can be located both at the production level (case where certain tasks cannot be performed by the P.A.S), or at the operational level (this is the case where the intervention on the system calls upon specialists from outside the site).
- operating rules; expressing the methods and rules to be followed to modify the behavior of the production system. These rules must respect certain functional constraints such as the synchronization between the operating modes of the system components.

The first level of activity decomposition " ***Operating a Production Automated System***" is given by figure 8.

Three activities are identified in this breakdown:

- ***Supervise the state of the P.A.S***: this activity is both complex and essential for the PAS exploitation. Its objective is to maintain the system in its production context mentioned above. It encompasses the three activities described in Fig 10. three activities are distinguished:

– *"Acquire the state of P.A.S":* this activity has the role of acquiring data concerning the system state (states of the products circulating in the system, tools states (geometric, technological and functional characteristics) used for production , machine operating mode states). This activity is supported by the operator and/or dedicated sensors.

– "*Compare and deduce the system deviation*": comes downstream of the acquisition activity mentioned above. It consists in comparing the acquired state of the system with the expected state which is considered as a reference. The expected result of this activity is the existence or not of a deviation in the behavior of the system. This activity can be carried out visually (by the operator) and / or automatically by using spy sensors.

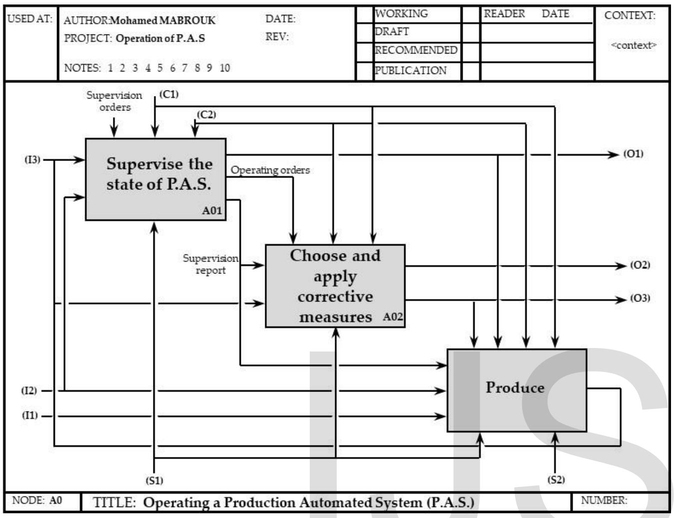

Fig 8: Decomposition of "operating a P.A.S" activity.

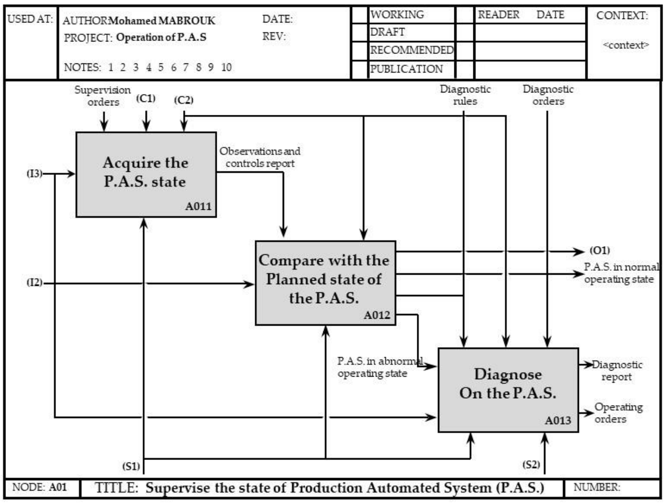

Fig 9: Supervise the state of P.A.S

– "*Diagnose on P.A.S*": is a very complex activity. Its objective is to find the system elements that are really faulty. As shown in Fig 10, this activity includes the activity "*identify failure*" which consists of finding the failure nature, the activity "*search the causes*" which consists of listing the different possible causes causing the observed deviation, and finally the activity "*locate faulty element*" which allows the knowledge of the failing elements. The difficulties encountered by the operator in ensuring this diagnostic activity and the importance of the dependability that automated production systems must take, led to several research works [12] [13]. These led to the implementation of fault diagnosis assistance systems based on several techniques such as data analysis methods [14], signature analysis [15], filter methods [16], knowledge-based systems [13], AMDEC [17] techniques and fault trees, installation of self-diagnostic systems [18], artificiel intelligence [19]...

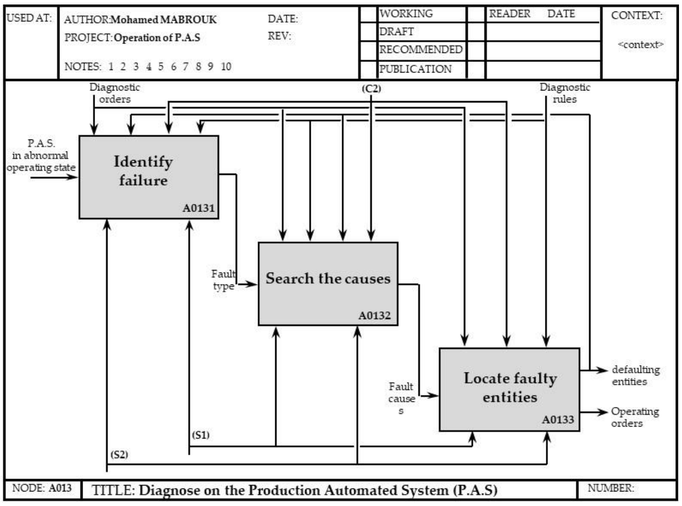

Fig 10: Diagnose on the P.A.S

• "*Choose and applying corrective measures*": this activity includes a decision-making aspect and an intervention aspect. The objective of the decision-making aspect is to choose (according to criteria) a solution to deal with the anomaly. As for the intervention aspect, it consists in the application (on the production system) of the chosen solution. This activity is decomposed into three sub-activities as shown in Figure 11.

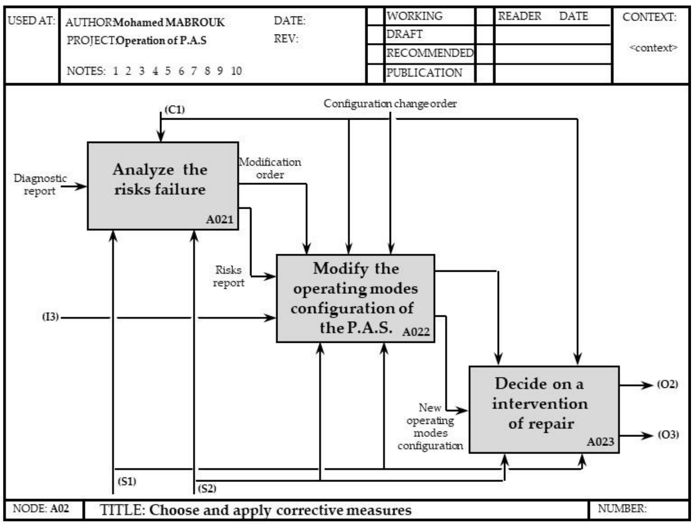

Fig 11: Choose and apply corrective measures

– "*Evaluate the severity of the failure on the P.A.S*": this activity consists of an assessment of the malfunction consequences on the objectives (safety, product quality, deadline ...) planned from the start. Simulation tools can be used to assist in the assessment. The result of this activity is a report detailing the consequences and the decision made to deal with the problem. In the majority of cases, this decision consists of a modification in the production program. This modification is established by the driving function (suspension of range operations for example). Consequently, a modification of the operating modes configuration of P.A.S. is necessary.

– "*Modify the configuration of the P.A.S. operating modes*": It is an intervention activity which consists of putting the production automated system in a very precise operating mode state, according to well-defined protocols under security conditions. This activity is decomposed into three sub-activities as shown in fig 12.

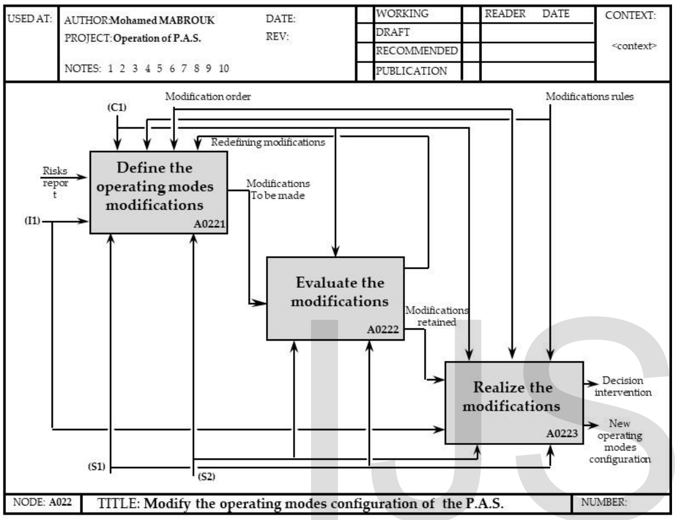

Fig 12: Modify the operating modes configuration of P.A.S.

- The first sub-activitie is "*define the operating modes modifications*": its objective is to list all the possible solutions allowing the modification of the material operating modes, the modification of the control software as well as the protocols (or actions) to follow up for the implementation (by the operator and/or by the control /command system) of the modifications to be carried out.

- The second sub-activitie is "*evaluate the modifications*" should allow the choice of a solution among those defined by the first sub-activity. This choice is obtained according to criteria (completion time, security, etc.). This evaluation can be established by a simulation of the possible solutions.

- The third sub-activitie is "*realize the modifications*" (shown in fig 13) consists in applying, according to well defined protocols, the retained modifications.

4. Problèms related to P.A.S oprating.

Problems related to the operational phase are found during the use and maintenance phases of the system and require the development of aiding tools. To mention only the largest categories, we can consider:

- **Diagnostic problems:** which were the subject of several research studies [1][2][3]. These led to the implementation of the troubleshooting support systems. They are generally designed independently of the control system. Therefore, they are still inadequate. An integrated monitoring control is necessary.
- **Problems with incompatible operating modes:** these are crucial problems, including the reconfiguration [20] that can intervene if:
  - passage in degraded mode after fault,
  - recovery and reintegration; it is essentially to reinstate a machine after repair, requiring a specific state of control-command system and the operative part of the P.A.S.

These problems are the result of several factors, the most important are:

- The non integration of the operating needs in the life cycle of the system,
- The diversity of particiants in the development of automated production systems. In fact, each participant is expressed in language appropriate to its specialty. This absence of a common language between the various project participants can only cause problems at several levels (relations between the subsystems, relations between the user and the system ...),
- Lack of training of operators that are generally low skilled,
- The poor definition of system specifications (the client is not always the future operator of the system),
- Lack of operating documentation.

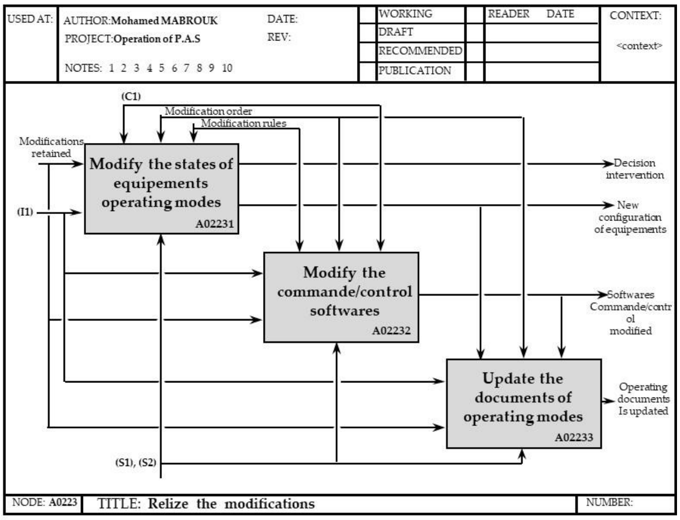

Fig 13: Relize the modifications.

5. Conclusion.

In this paper we have presented the main characteristics of an production automated system as well as the life cycle of these complex systems. Through this cycle we have presented a detailed analysis of the function "*Operating a Production Automated System (P.A.S.)*". This analysis is supported by the IDEF0 formalism. It enabled us to identify the main activities characterizing the operating phase of an P.A.S. and consequently the problems linked to this phase. Problems related to diagnosis have led to several works in the field of research. These led to the implementation of fault diagnosis assistance systems based on several techniques. As for the problems linked to non-compatible operating modes, notably for the reconfiguration [20] of automated production systems, few researchs has been carried out. Our future research reflection is part of the resolution of these problems and with the objective of contributing to the design and implementation of P.A.S. operating model taking into account the reconfiguration of these systems (self-configuring system).

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