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Integrated chemical, technology & equipment process knowledge management system based on risk based process safety

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Abstract. Major accidents in the industry such as fire, gas explosion, and unexpected toxic gas release are continuously reported worldwide. Lacking Process Knowledge Management (PKM) and failure to update and access the information was identified as one of the contributing factors. One of the established elements that intended to minimize this issue is PKM. However, lacking a systematic system to implement the PKM program has hindered the improvement of process safety level at workplace. The study focuses on development of PKMS database based on Risk Based Process Safety (RBPS) guideline. PKMS was developed by using Plan-Do-Check-Act (PDCA) concept. Validation of system was conducted through inserting real plant data from two chemical plants and feedback from process safety expert for further improvement. The developed PKMS allows the end user to store, review, modify and update the data regarding hazardous chemicals, technology and equipment information that involve with the operation. PKMS emphasis hazards related with the process in systematic ways thus minimizing potential incomplete control of hazard. PKMS interfaces allows management to do a self-check audit and helps the management to track the information. As leading indicator, PKMS allows the user to review overall status of the company compliance to the safety standard.

1. Introduction

1.1. Process Safety Incidents in Chemical Plants

Major accidents in the industry such as fire, gas explosion, unexpected toxic gas release continuously occurs due to lack of process knowledge management and failure to properly apply the available process knowledge directly during the event [1]. On October 21, 2016, a chemical release occurred at the MGPI Processing plant in Atchison, Kansas due to the Chemicals, was inadvertently connected to a tank containing incompatible material [8]. Final report investigation found that there are several issues closely related with the lack of chemical hazard information and lack of process equipment information in the organization. In Malaysia, a fire and explosion occurred at an Acetylene Gas Processing Factory on 22 May 2008 causing damages to the factory building structures and more than 360 cylinders have exploded. One of the gas refilling workers suffered burns on 30% of his body [2]. Lack of chemical hazard information is one of underlying factor of this accident. This problem is in need to fix to improve the knowledge management in chemical process plant.

1.2. Process Safety Management (PSM)
From the past major accidents, some new governmental regulations had been developed to manage the root cause of these accidents such as human errors, technical factor and management factor [3]. In 1992, the Occupational Safety and Health Association (OSHA) US had introduced Process Safety Management (PSM) of Highly Hazardous Chemicals standard (29 CFR 1910.119). This regulation aimed to prevent accidental releases of highly hazardous chemicals in the process industry, and to protect employees and the nearby community from exposure to those hazards [4]. The Process Safety Information (PSI) is the first element in the Process Safety Management (PSM). PSI focuses on process chemicals 29 CFR 1910.119(d) (1), technology 29 CFR 1910.119(d)(2) and equipment 29 CFR 1910.119(d)(3) management [5]. Reliable and accurate PSI data provide important resource to the other user that involved in Process Hazard Analysis (PHA) and Operating Procedure (OP) teams. Previous research study already developed PSI4MS that could fulfil all the PSI requirements based on OSHA PSM standard.

1.3. Risk Based Process Safety (RBPS)
RBPS framework is an extension effort for increasing the process safety management performance [7]. Some RBPS elements seem similar with PSM elements [3]. The purpose of RBPS Guideline is to help organizations design and implement more effective PSM systems. It provides methods and ideas on how to design a process safety management to correct deficiency and provide safety management practices. Understand hazards and risk is one from 20 pillars in the RBPS guidelines. There two elements in this pillar which are Process Knowledge Management (PKM) and Hazard Identification and Risk Analysis (HIRARC).

1.4. Process Knowledge Management (PKM)
PKM is an extended version of Process Safety Information (PSI) from PSM regulations. PKM element was introduced to provide details guidelines to comply with PSI standards. Process Knowledge Management (PKM) is one from the two elements in Understanding Hazard and Risk pillar. PKM focuses on information that can easily be recorded in documents and supports any effort to apply the risk-based methods. Prassl, Peden, & Wong in year 2005 reported that the developing of Knowledge Management System (P-KMS) as it permits the combination of engineering simulations with expert knowledge under the inclusion of uncertainty, as well as providing basic knowledge management capabilities [6]. Updating process knowledge in the manufacturing plant is quite common or can be categorized as daily or weekly routine, especially when changes involving chemicals substances, raw materials, facility issues and changing of technology are made. Too often, key data such as design bases, specification, manufacturer’s drawing or data report and other process knowledge are thrown away because the document are not well organized [1]. Therefore, there is a need to develop the Process Knowledge Management System (PKMS) that strives for continuous improvement and prevent safety accidents.

2. Research Methodology

2.1. Research Process Flow
Figure 1 shows the process flow in constructing Process Knowledge Management (PKM) framework and system. First, the elements of PKM need to be analysed. After that, construct the framework for the PKMS by using Microsoft Word application. Next, develop the Process Knowledge Management System (PKMS) by using Microsoft Access and Microsoft Excel. Then, the PKMS should be validated by using data from case studies. Lastly, it is a must to determine whether the developed framework and PKMS have fulfilled with the RBPS guidelines. If it is ‘Yes ‘then the process will end meanwhile if it is ‘No’, then these steps need to be repeated starting from analysing the PKM elements.

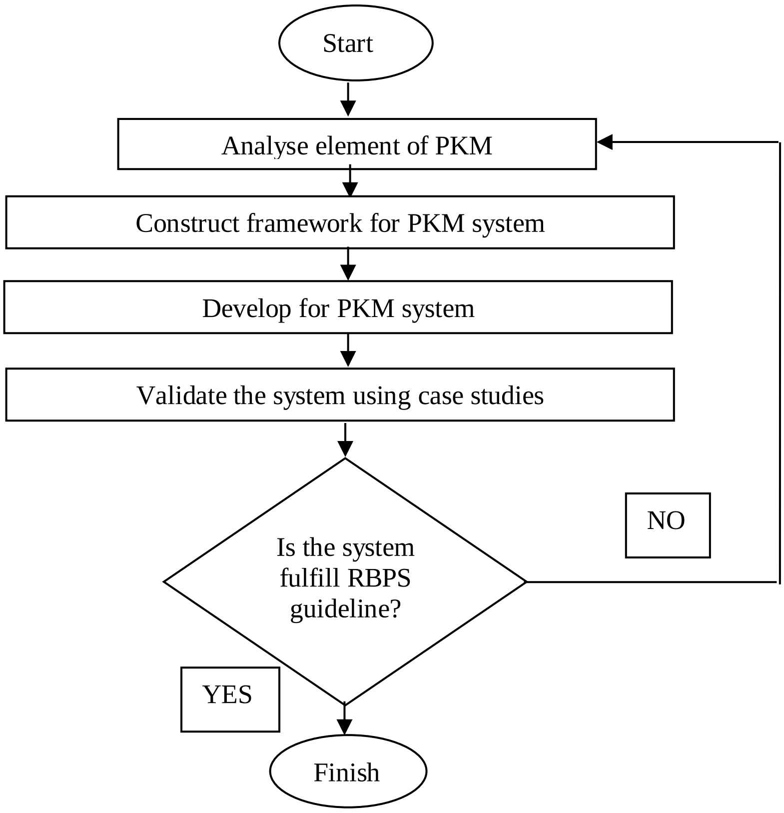

Figure 1. PKMS flowchart

2.2. Plan, Do, Check, Act (PDCA) Cycle Concept

In this study the concept of Plan Do Check Act (PDCA) management system was adopted as shown in figure 2.

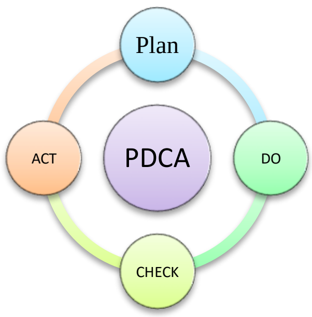

Figure 2. PDCA Cycle

- Plan: Plan for the new Process Knowledge Management System (PKMS) by analysing the requirements of PKM element from the RBPS guidelines.

- Do: Develop PKM Framework and PKMS by using Microsoft Word, Microsoft Access and Microsoft Excel.

- Check: Validate the developed PKM system by inserting raw that obtained from two chemical plants. The raw data including hazardous chemical information, technology information (according to unit or system) and equipment information (according to tagging) into the PKMS using.

- Act: Do improvement to the system based on feedback got from validation process with safety expert.

3. Result and Discussion

3.1. Comparison of Requirement between PSI Element of PSM and PKM Element of RBPS

Both PSI & PKM element was classified under explicit knowledge [3]. Since PKM is an extended version of PSI, so there is must be slightly difference in term of requirements for both elements. Table 1 tabulates the comparison of requirements on information pertaining hazards of highly hazardous chemicals in the process between PSI and PKM. From this table, it can be explained that the extended data requirements of PKM compared to the PSI are thermodynamic data, calorimetric data, shock sensitivity, pyrophoric properties, chemical stabilizer or other chemical species and maximum deflagration/detonation pressure and flame speed.

Next, table 2 tabulates the information pertaining hazards to technology of the process for both PSI and PKM element. From the analysis, there are three requirements of PKM that did not stated in PSI which are adiabatic reaction temperature and the corresponding system pressure, separation equipment design information & design basis and the description of control system logic.

Lastly, table 3 tabulates information pertaining hazards to the equipment in the process plant for both PSI and PKM element. Based on this table, there are several requirements of PKM that PSI did not address which are mechanical data/design basis sheets for process equipment shop, fabrication drawings, piping specifications, isometric drawings, control system logic diagram, loop sheets & interlock tables, instrument data, electrical data, facility data, design basis & analysis for fixed or dedicated hoists, location of safety showers/eye wash station, fire extinguishers and other safety equipment and portable multi-unit equipment information. It can be concluded that, if industries comply with all the PKM requirements, the industry is indirectly complying with the PSI standard. It can be concluded that, PSI4M which was developed by previous researcher only cover PSI of PSM requirements meanwhile PKMS cover both of PSI & PKM requirements.

Table 1. Information pertaining hazards of highly hazardous chemicals in the process

	Requirement	**PSI**	**PKM**
Information pertaining hazards of highly hazardous chemicals in the process	Toxicity information	✓	✓
	Permissible exposure limit	✓	✓
	Reactivity data	✓	✓
	Physical data	✓	✓
	Industrial hygiene data		✓
	Thermal and chemical stability data	✓	✓
	Hazardous effect of inadvertent mixing of typical contaminants with different materials contained in process streams & utility systems.	✓	✓
	Thermodynamic data		✓
	Calorimetric data		✓
	Shock sensitivity		✓
	Pyrophoric properties		✓
	Corrosivity data	✓	✓
	Chemical stabilizer or other chemical species.		✓
	Maximum deflagration/detonation pressure and flame speed		✓

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Table 2. Information pertaining hazards of technology in the process

	Requirement	PSI	PKM
Information pertaining hazards to technology of the process	Simplified process flow diagram or block flow diagram for very simple processes	✓	✓
	Process chemistry	✓	✓
	Hazard related to credible undesired chemical reactions		✓
	Material and energy balances	✓	✓
	Maximum intended inventory		✓
	Safe upper & lower limit for process parameters	✓	✓
	Adiabatic reaction temperature and the corresponding system pressure		✓
	Separation equipment design information & design basis		✓
	Description of control system logic		✓
	Maps/tables showing zone/distance of concern for over-pressurization or toxic exposure hazard based on consequences analysis	✓	✓

Table 3: Information pertaining hazards to the equipment in the process

	Requirement	PSI	PKM
Information pertaining hazards to the equipment in the process	Materials of construction	✓	✓
	Piping & instrumentation diagrams(P&IDs)	✓	✓
	Electrical classification diagrams	✓	✓
	Relief system design basis & calculations	✓	✓
	Ventilation system design basis & calculations	✓	✓
	Listing of design codes & standards applicable to the process	✓	✓
	Safety systems (interlocks, detection or suppression systems)	✓	✓
	Material and energy balances	✓	
	Mechanical data/design basis sheets for process equipment		✓
	Shop fabrication drawings		✓
	Piping specifications		✓
	Isometric drawings		✓
	Control system logic diagram, loop sheets & interlock tables		✓
	Instrument data		✓
	Electrical data		✓
	Facility data		✓
	Design basis & analysis for fixed or dedicated hoists		✓
	Location of safety showers/eye wash station, fire extinguishers and other safety equipment		✓
	Portable multi-unit equipment		✓

3.2. Process Knowledge Management System (PKMS)

PKMS was validated at three chemical plants. PKMS was presented to a group of safety experts from the chemical plants to inform what kind of information that PKMS tend to capture and validate the system.

3.2.1. Login Form and Main Menu Interface.
Figure 3 shows that the login form which will automatically be popping out when user open the PKMS. The function of this interface is to ensure only authorized plant personnel can access the system. When user enter the right username and password, the main menu interface (figure 4) will automatically generate that helps user to navigate which type of process knowledge or information that they want to review.

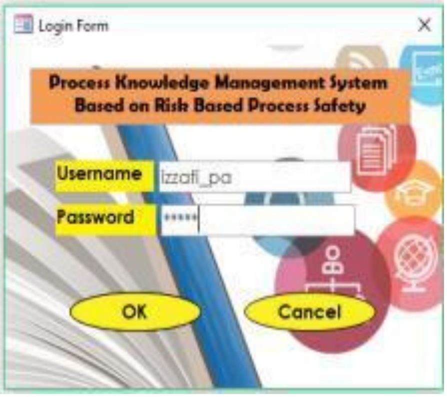

Figure 3. Login Form Interface

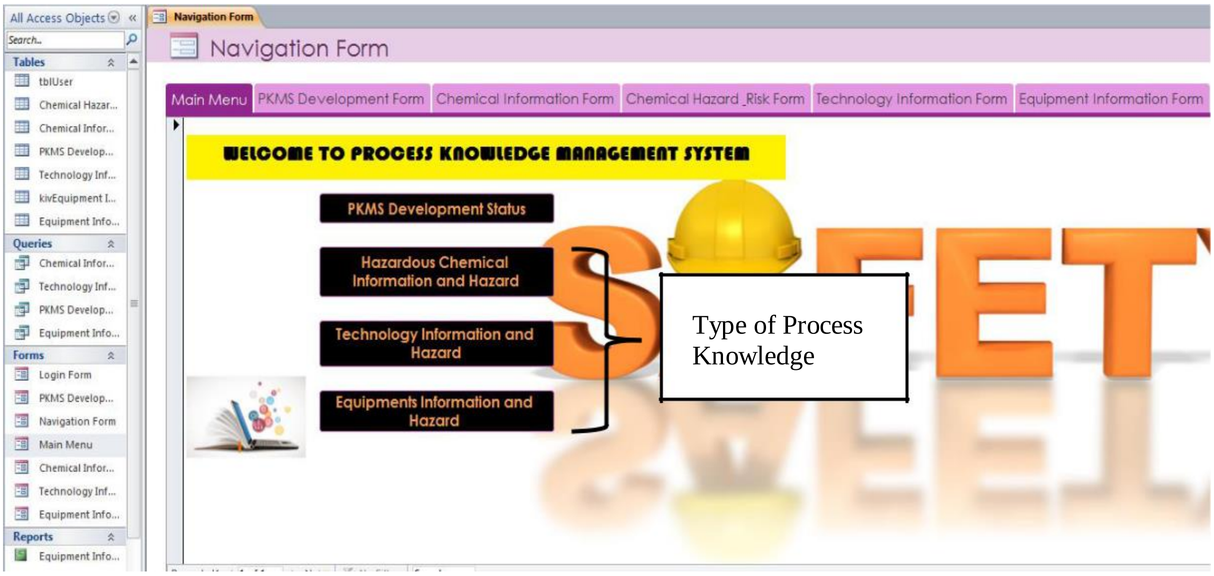

Figure 4. Main Menu Interface

3.2.2. PKMS Development Interface.
Figure 5 shows the main interface in the development of PKMS database. This interface contains 5 columns which are 'Process Knowledge', 'Status', 'Remark', 'Date of Review' and 'PIC'. In summary, this interface gives the user an overview regarding company compliances to the RBPS guidelines and PSM standard. Figure 6 shows the table interface of PKMS development. This interface allows the

management to do a self-check audit and eases the management to track the information regarding to the PKM.

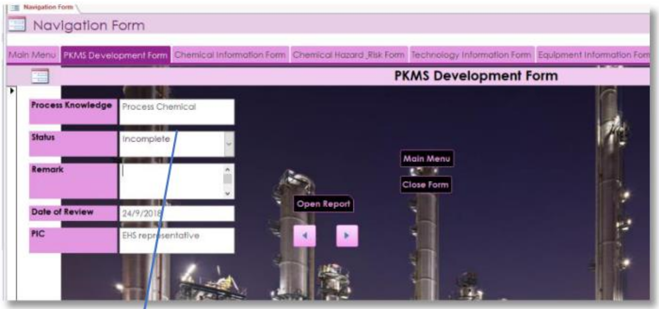

Figure 5. PKMS Development Interface (Form)

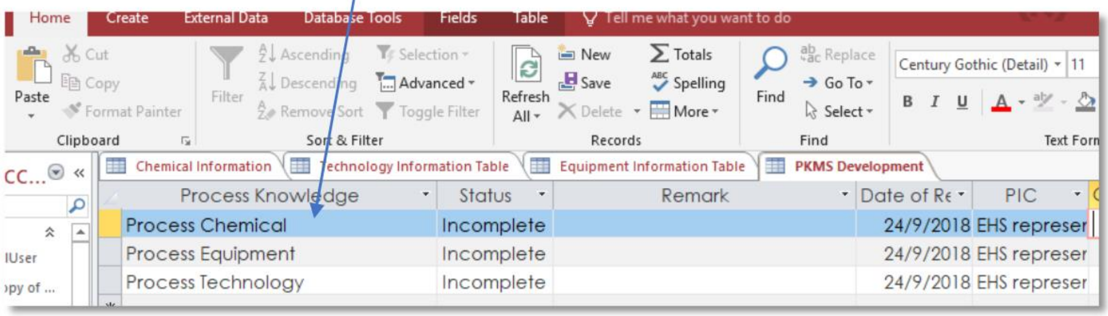

Figure 6. PKMS Development Interface (Table)

3.2.3. Chemical Information Interface.

Figure 7 shows the interface of PKMS for chemical information. This interface contains 136 hazardous chemicals as mentioned in 29 CFR 1910.119(d). The user is guided by a checklist to determine of which process chemical information that needed to be compiled. Evidence which can be store at the 'Document' column such as Safety Data Sheet (SDS). The personnel who familiars with the information involved in the plant can be either a plant coordinator, safety representatives and operation manager acted as the authorized personnel who can modify or update any information related to chemical in this PKMS [7].

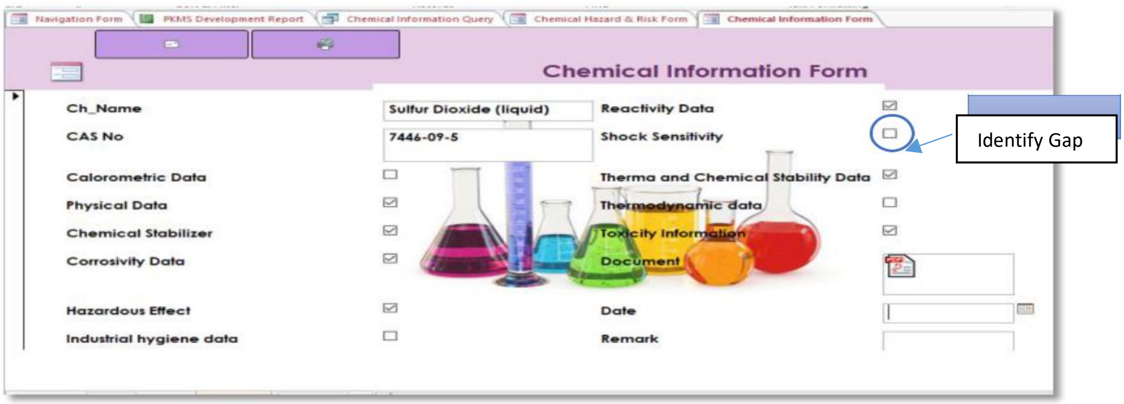

Figure 7. Chemical Information Interface (Form)

3.2.4. Chemical Hazard & Risk Interface.

Figure 8 illustrates the chemical hazard and risk interface. The previous PSI4MS tend to provide complete information concerning management of process chemical in the pilot plant operation meanwhile PKMS tend to cover information concerning the management of process chemical with emphasizing more on the hazard and risk [5]. In addition, the user should key in likelihood and severity of the consequences of the chemical hazard based on the plant standard, reported cases and risk matrix. By doing this, it will increase workers' awareness about the chemical hazard, control measure that need to be followed and who is person in charge in case of accident happen. Some of data from Plant A such as type of control measure, PIC and date of review cannot be share due to confidentiality. PKMS also contains print button which eases the user to print overall report related to chemical hazard and risk for report documentation purposes.

Figure 8. Chemical Hazard and Risk Interface (Form)

3.2.5. Technology Information Interface.

Technology Information was divided into work unit. This interface tends to capture information pertaining to process/ block flow diagram, material and energy balance and process chemistry and others as showing in figure 9. Finally, the 'Hazard Sheet' column was attached with a simple Hazard Identification, Risk Assessment and Risk Control (HIRARC) table also embedded in this system (refer figure 10).

Figure 9. Technology Information Interface (Table)

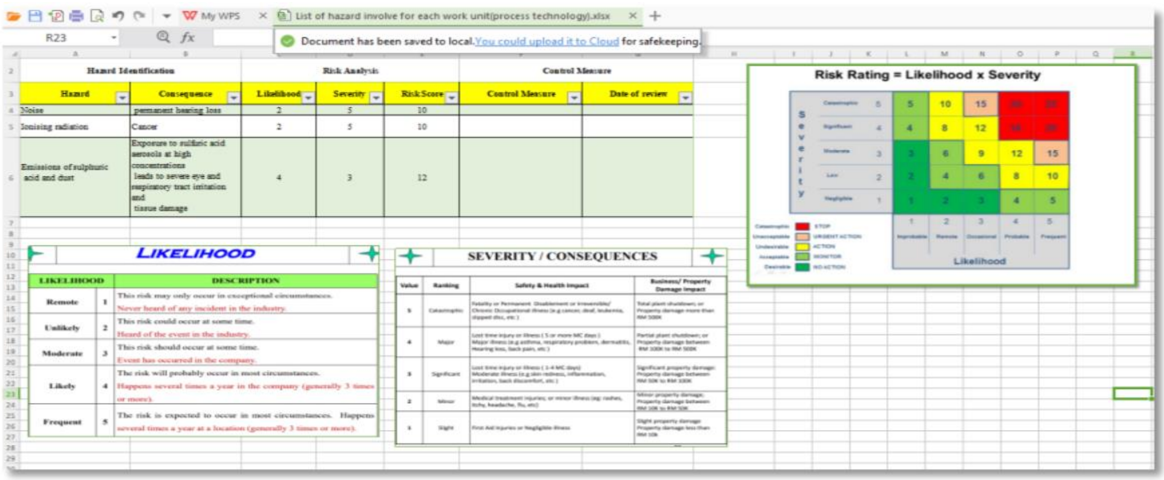

Figure 10. Hazard Identification, Risk Assessment and Risk Control table (attachment)

3.2.6. Process Equipment Interface.

To ensure the worker could operate and maintain the system appropriately, it is important to provide and maintain process equipment information so that worker can get an access to a specific information when needed [5]. Based on Figure 11, the equipment information was captured according to equipment tagging. The user can click ‘Add Record’ button if there is a new equipment purchased by the company with specific record and press ‘Delete Record’ button to delete the record. Besides that, this interface contains print and email button as a well communication medium to ensure the hazard information related to equipment is well communicated within the workplace. This interface captures information about equipment’s’ materials of construction, Piping & instrumentation diagrams (P&IDs, Electrical classification diagram, etc. Next, the user is required to do a process equipment checklist to determine what kind of equipment’s information that contain in the organization. Then all the document of available information should attach at ‘Evidence’ column so the user can review the information easier and effectively. The information obtains from this PKMS also can assist other implementation of PSM elements in Plant such as Management of Change (MOC) and Process Hazard Analysis (PHA) element.

Figure 11. Equipment Information Interface (Form)

4. Conclusion

PKMS allows the end user to store, review, modify and update the data regarding to the PSI and PKM elements. PKMS also can guide the company to comply with the RBPS guideline. Most importantly, PKMS emphasis the hazard related to the process chemical, technology and equipment within company in systematic way and vital to control the process hazard. PKMS implementation helps company to identify the gap in systematic manner. In addition, it provides complete information about PSI that assists other PSM element such as Management of Change (MOC).

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