SPIGA, Integrated Digital System for Process Safety and Asset Management in Ecopetrol S.A.

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Abstract— Asset Management (AM) and Process Safety Management (PS) are two of the main processes in the Oil & Gas –Energy- industry, ECOPETROL S.A. within its policy of integral responsibility has been managing them in a sustained manner for several years. The experience and maturity of these processes, together with the Information Technology (IT) development and the advances of the 4th industrial revolution, is allowing ECOPETROL S.A. to take a quantum leap towards a new management level today.

Keywords—Process Safety, Asset Management, Management of Change (MOC), Process Safety Information (PSI), Turn Around (TA), Risk Management (RM), Digital Transformation, 4th Industrial Revolution, Engineering, Virtual Reality (VR), Augmented Reality (AR), Digital Twin

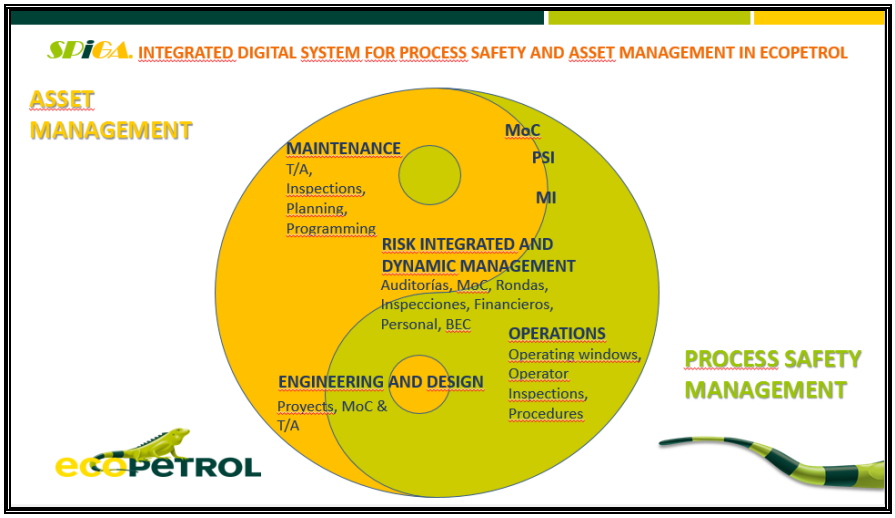
Background

Historically, AM and PS processes were originated from different sources, in one case of Maintenance and in another case of HSE. ECOPETROL managed these two processes in a parallel but not in a fully integrated way -in terms of the information they require or generate-, using multiple tools and in different scenarios, causing several difficulties, mainly those described in the following section.

Main challenges in a separate Asset Management and Process Safety approach

- *Difficulty to perform operational analyses*. The analysis of the performance of the productive processes, focused to the diagnosis, prediction and recommendation of actions for its optimization, is based mainly on the technical information of the design of the process -and assets- and the historical and real time information of its behaviour. This information is searched and extracted from different sources that are not integrated, some managed by AM sub-processes and others by PS sub-processes.
- *Difficulties in making decisions due to not having an integrated, updated or real-time information*. Related to Operational Analysis, one step further, is decision making, generally made based upon risk. The absence, outdated, lack of completion or lack of integration of the information make decisions difficult or can lead to erroneous decisions, generally causing cost overruns or incidents.
- *Duplication in the management causes cost overruns*. Redundant indicators (KPIs), which require more manpower for consolidation, increase in the number of meetings required, to manage two processes and then integrate them; redundant plans to manage the same risk found; duplication of or inadequate purchases; are some of the examples of cost overruns.
- *Ununified risk assessment and consequently, of the actions to control it*. Although ECOPETROL has a RAM (Risk Assessment Matrix) for risk assessment in its operations, the perceptions and risk assessment differ when the views are different. The risk perception for the same scenario may vary, for example, a risk study executed in the Maintenance process may differ from one executed as part of a project, another executed in a MoC process, or one executed in Operations.
- *Potential incidents due to outdated information*. The use of outdated information within a project or MoC increases the likelihood of causing an unwanted event. Specific cases of this are: incidents due to the use of inappropriate materials or spare parts (the installed equipment is different from the one presented by the diagram or schematic), excavations on sites that have buried assets -generally pipes-.
- *Cost overruns due to the need to consolidate / integrate information from both processes –PS and GA-*. Given that the processes are independent, the information is contained, in the best of cases, in different repositories; the case that is isolated in personal computers is also presented; therefore, when consolidated information is required, a large number of man-hours are invested in its consolidation.
- *Isolated information, inaccessible by inter-related processes, which is required for their operation*. Figure 1 presents several subprocesses of AM and PS that require sharing information for their proper operation. For example: MoC requires information from engineering, PSI or maintenance; Engineering requires and generates risk information related with PHAs; "As-Built" information is necessary for TA, MoC or for the elaboration of operational procedures; Dynamic Risk Management is based on the findings of the operation (rounds) or maintenance (inspections); inspections and improved maintenance can be derived in MoC or a new project; Risk analysis (HAZOP, HAZID, LOPA, etc.) can be derived in a MoC and at the same time require "As-Built" information for their proper development, etc..

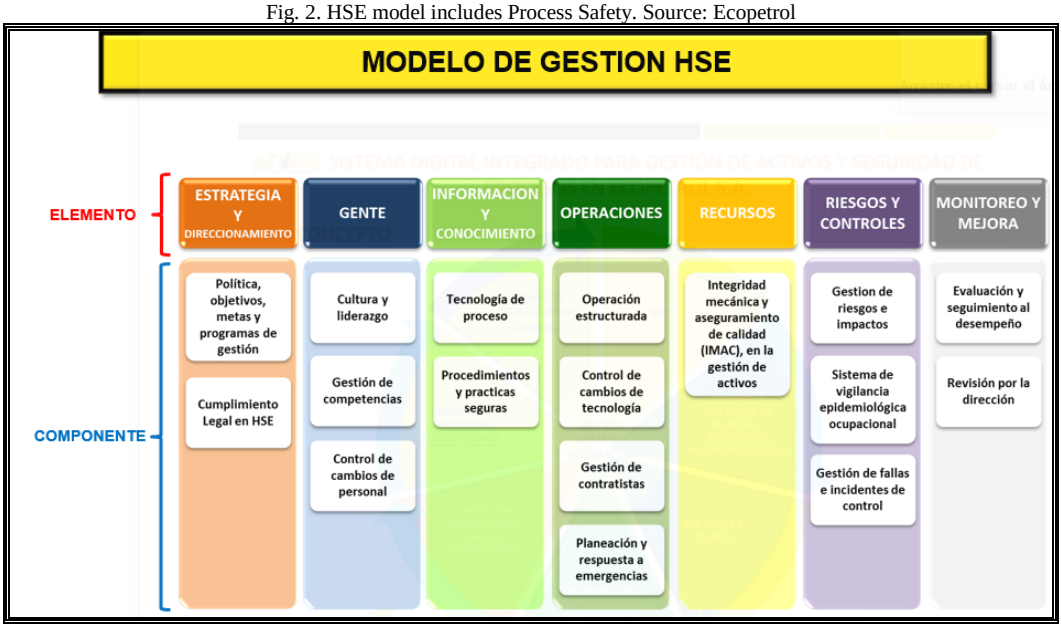
Fig. 1. Symbiosis between AM and SP. Source: ECOPETROL S.A.



Ecopetrol's initial efforts for digital integration of PS and AM, beginning of the SPIGA project

Figure 2 shows the constituent elements of PS in Ecopetrol, one of them is MOC, a process initially installed in the Barrancabermeja Refinery, which was later extended to the entire organization. To implement MoC, Ecopetrol formed a Corporate Committee, whose members came from each company area: Upstream, Midstream, Downstream and the Research Centre.

Fig. 2. HSE model includes Process Safety. Source: Ecopetrol



From a digital point of view, MOC is a workflow, it was implemented in a digital application that shortly, after installed and tested, exhibited a low standard of performance and was obsolete. This 'fortunate' situation motivated the Committee to look for alternatives for its implementation. The following is the chronology of attempts to search for a suitable solution for MOC:

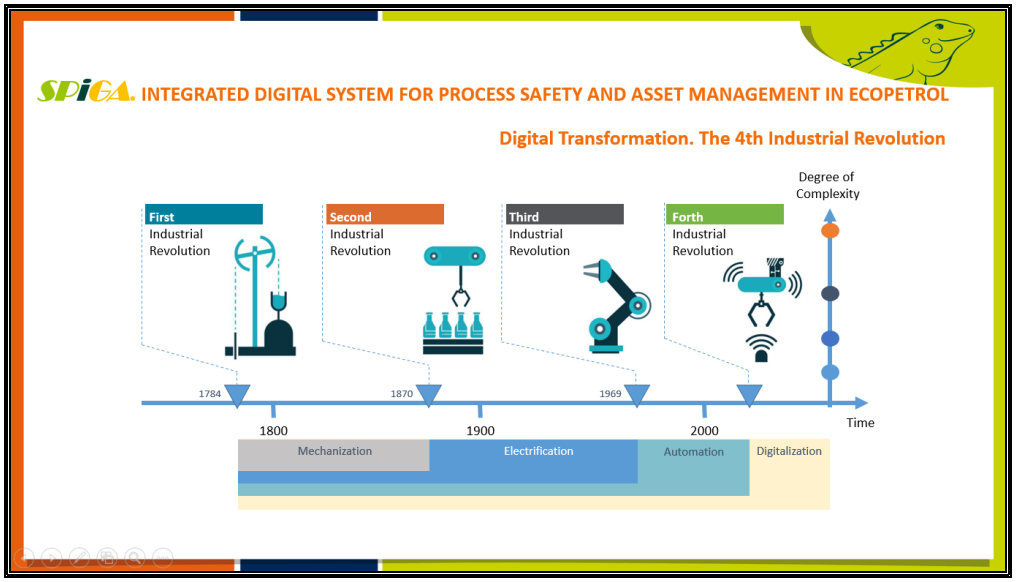
- 2013. Diagnosis of the initial digital implementation of MOC

- 2014. The SITREC project (Technical Information Service for the Cartagena Refinery) was born at the Cartagena Refinery, focused on technical documentary management for the expansion and modernization project of that refinery. SMARTPLANT is selected as technological platform, its initial scope covered only the Cartagena Refinery.
- 2015. Attempt to implement MOC process in SAP PM
- 2016. Business case to implement MOC in the specialized SAP application for MOC
- 2017. The concept of Integral Management for Process Safety and Industrial Assets (SPiGA) arises.
- 2017. The MOC-PSI Corporate Committee formalizes to TI the recommendation about the platform to fully manage Process Safety and Asset Management.
- 2017. The SITREC process is selected within the "Best of the Best" program in the Ecopetrol Refining Vice Presidency
- 2018. SPiGA is registered as a Project at Barrancabermeja Refinery and its execution is approved
- 2018. The SPiGA project emerged as a corporate initiative within the Digital Transformation initiatives of the Vice Presidency for Development and Production.
- 2019. The implementation of SPiGA starts in the Barrancabermeja Refinery and in the Production Vice Presidency (around 60 plants).

The Fourth Industrial Revolution

ECOPETROL is executing a big effort in its Digital Transformation, SP and AM processes take advantage of its technologies, especially those related with the fourth industrial revolution (see figure 3 below). In first place, to solve the concerns described in (1.1) and additionally to optimize its processes through Data integration, 3D models, virtual reality, augmented reality, Mobility, predictive analysis, as will be mentioned later.

Fig. 3. The 4th Industrial Revolution. Source: https://marcellusdrilling.com/?s=industrial+revolution



Main identified needs

Ecopetrol identified the following main needs:

- Potentiate Operational Analysis as a tool to improve decision making and the Refining Margin
- Support decision-making based on risk, using mainly: real-time indicators and 'digital twins' (3D models, integration with CMMS, 'Data Historian', Virtual Reality and Augmented Reality)
- Establish or Improve - when it exists - the exchange of information between the processes and sub processes of AM and SP, initially: MOC, PSI, TA, Engineering for Projects and MOC, Reverse Engineering, Dynamic Risk Management, Training (Operational Excellence).

- Strengthen the interactions and synergies between the different corporate areas and their stakeholders: Management, Engineering, Maintenance and Reliability, Operations, Projects, HSE, Risk Management, IT. Also, strengthen the interactions and exchange of information inside the same areas.
- Eliminate cost overruns, related to manpower, caused by duplication in process management and consolidation of information for the AM and the SP
- Unify the risk assessment between processes and different corporate areas, which results in the definition of better action plans for risk reduction
- Eliminate incidents caused by the use of outdated information in the maintenance, operation, projects and MOC processes.
- Provide a digital solution for AM and PS processes, also for their sub processes, initially MOC, PSI, TA, Risk Management, and Engineering.
- Contribute to the consolidation of the fourth industrial revolution and the Digital Transformation in ECOPETROL, with the objective of making the most of its advantages and managing risk - in all its perspectives: people, economic, image, reputation, environmental - in an appropriate manner.

Implemented solution in Ecopetrol S.A.

Stage 1. Document Management and Early Design Management

As mentioned in section (1.2), in 2014 an important milestone took place in the history of SPiGA, SITREC was born in the Cartagena Refinery in response to the need to ensure the technical information of the Cartagena's expansion project would generate; thousands of documents related to the process information required a complete management system to guarantee its storage, consultation, modification and custody, that is, its complete life cycle. The evaluation of alternatives contemplated several 'state of the art' platforms. Some of main objectives to evaluate the alternatives are shown below

- Ensure sufficient storage capacity for all information, corresponding to around 60 new plants, that would be received: drawings of all disciplines, P&IDs, PFDs, loop diagrams, wiring diagrams, cause effect matrixes, line listings, tests evaluations, 3D models, plot plans, data sheets, equipment manuals, calculation memories, area classification, single line diagrams, process risk analysis studies, etc. Additionally, the capacity should be dimensioned in such a way that it foresees the growth of the information once the refinery comes into operation.
- Guarantee a sufficient storage capacity to cover the information of the existing plants before the expansion project - old ones.
- Allow fast, massive and automatic capture - using metadata - of various types of documents, among others: PDF, various CAD formats and Office files.
- Capture data of drawings of different formats
- Allow the creation of a WBS to organize the information
- Allow the search for information based on the TAG (TAG-Centred)

Additionally, the Cartagena Refinery planned to view and modify 3D models and P&IDs, for the revision of the designs made by the Engineering Contractor.

Fortunately for the Digital Transformation in Ecopetrol, the Cartagena Refinery, take into account the existing difficulties, at that time with the IT platform that supported MOC -see section 1.2-, also decided to include within the requirements, the possibility of managing MOC; The above, from the technical point of view, implies the possibility of carrying out 'workflows', which meant, as will be explained later, opening the possibility of implementing other corporate processes of PS and GA.

Stage 2. MOC and PSI

With the installed infrastructure to guarantee the technical information of the expansion project, the bases were laid to ensure the rest of the technical information of the refinery, that is, the one corresponding to the plants already installed before the expansion project. With the insured technical information, the structuring of another of the key elements in Process Safety starts: PSI. To implement this element, it was enough to define and implement the appropriate metadata. In this way, another important component of PS was operative, which is also required in several of the subprocesses of AM.

Stage 3. MOC, Engineering, and Projects

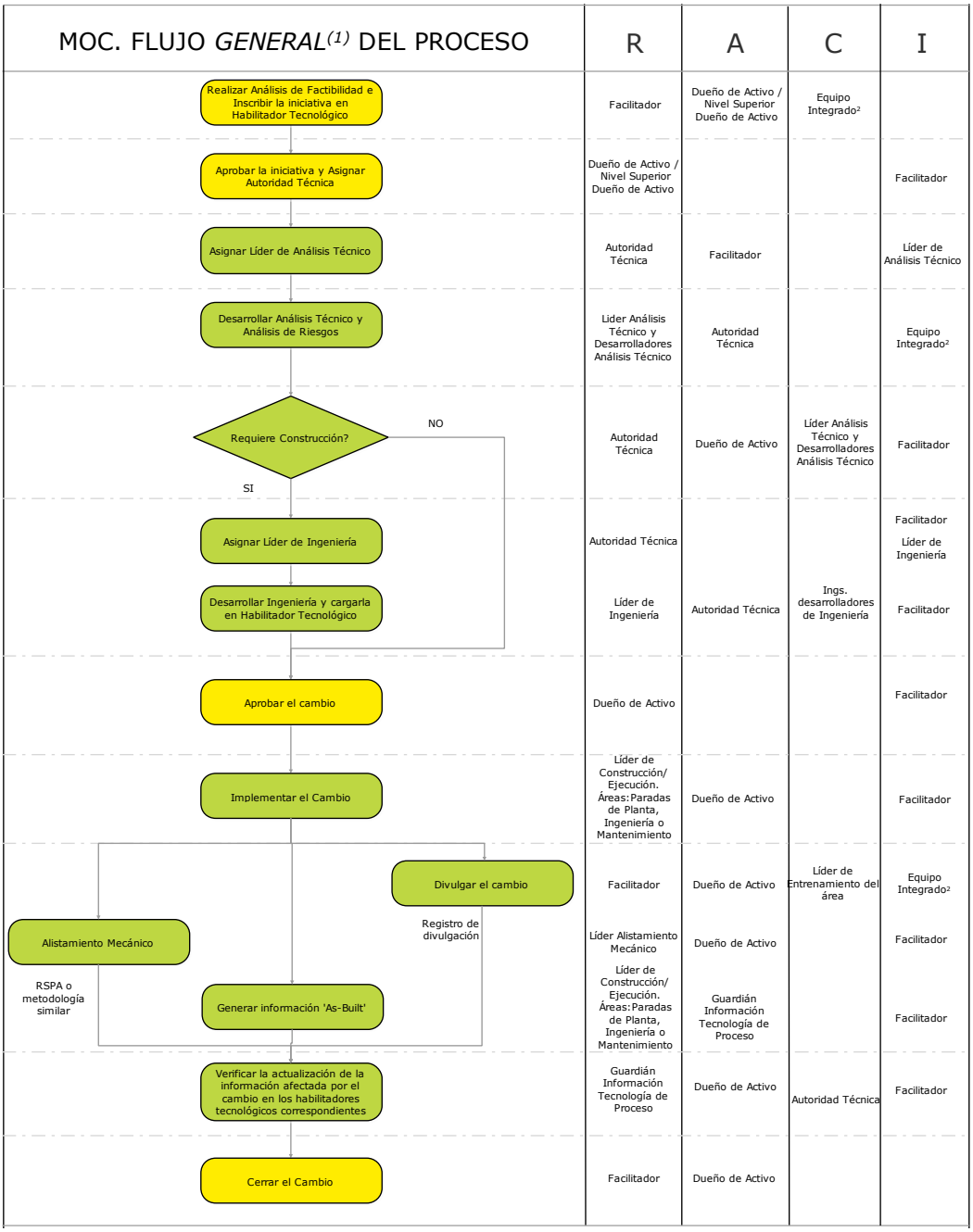
Simultaneously to the start-up of the management of technical information and PSI, the Cartagena Refinery initiated the operation of MOC, a process that demands close interaction between several areas and actors: Engineering, Maintenance, TA,

Operations, Risks and Document Management. It begins, in this way then, to potentiate the need for the integration of the information, evidenced by the information demands of MOC and the need that it is updated and available after the changes are made. Figure 3 shows the general flow of the MOC process in Ecopetrol

In addition to integrating with the PSI, MOC demands a close relationship with Engineering, which is a subprocess of Asset Management (Incorporation), because generally any modification implies a new design or the revision of an existing design. This establishes the need to exchange information between these two subprocesses, MOC requires Engineering for the analysis and design of modifications, Engineering requires -as input- all the information that has been updated as a result of previous change processes.

On the other hand, the existence of the 3D models, provided for the new plants by the engineering contractor and a great effort was made to rebuild the 'piping' database, allows the Refinery to enter a new stage, to carry out its studies and designs directly in SmartPlant. Additionally, the need to integrate the existing and new crude plants motivates the beginning of a project that demands complex engineering. Furthermore, the old plant, with more than 40 years of service, does not have completely updated information, consequently the need to carry out Reverse Engineering was planned as a mitigation. The conjunction of these aspects plus having a contractor who has the same technological platform for the development of their designs, favours Ecopetrol requesting that the engineering of the project be carried out directly in SmartPlant and also fosters a paradigmatic change when modifying the request for a ' Dossier 'of Engineering, generally constituted of paper, magnetic discs with CAD, Word, Excel files, among others, for a set of completely electronic information constituted by a database of SmartPlant, that can be guarded and available in the IT infrastructure of the Cartagena Refinery .

Fig. 3. MOC general 'Workflow' in Ecopetrol S.A.



Stage 4. MOC, Engineering and TA

TA process is part of Asset Management macro process in its 'Major Maintenance' component, generally it can be classified as a project.

Taking account that the engineering of the projects can and should be supported from SmartPlant and considering the TA process as a project that in most cases make changes, an immediate link is established between MOC, Engineering and TA. Taking

advantage of the ability to implement 'workflows' in SmartPlant and its IT infrastructure, the implementation of a new 'workflow' is undertaken, whose purpose is to guarantee the fulfilment of all phases of planning in the short, medium and long term for TA.

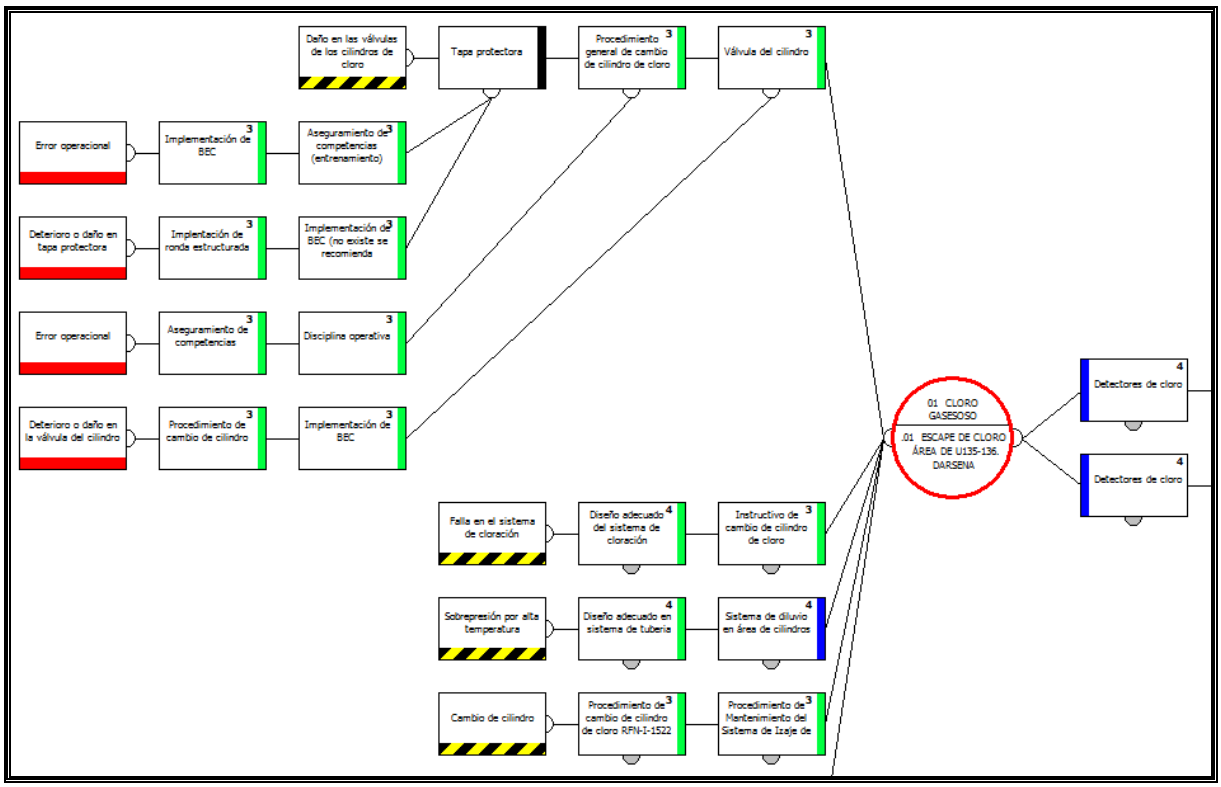
Stage 5. Dynamic Risk Management

Having integrated MOC, PSI, Engineering and TA, knowing that all these processes have the ultimate goal of managing risk in all its perspectives (people, environmental, financial, clients and reputation), the need is clear to handle them in an integrated way, since, for example, the risk analysis of a plant is updated by a MOC process, by a Project, or by a Plant Stop; In any of these cases, the risk analysis must be updated and preferably centralized to ensure proper management. In addition, there are other Asset Management processes, for example: maintenance inspections, operational inspections (rounds), PSSR (Pre-Startup Safety Review) that also identify risks.

Additionally, with respect to the ideas described in the last paragraph, risks are ***dynamic***, and due the risk reduction factors may vary by a variety of causes, for example: unexecuted inspection or an unexecuted test, requerided for a preventive barrier or a mitigation barrier.

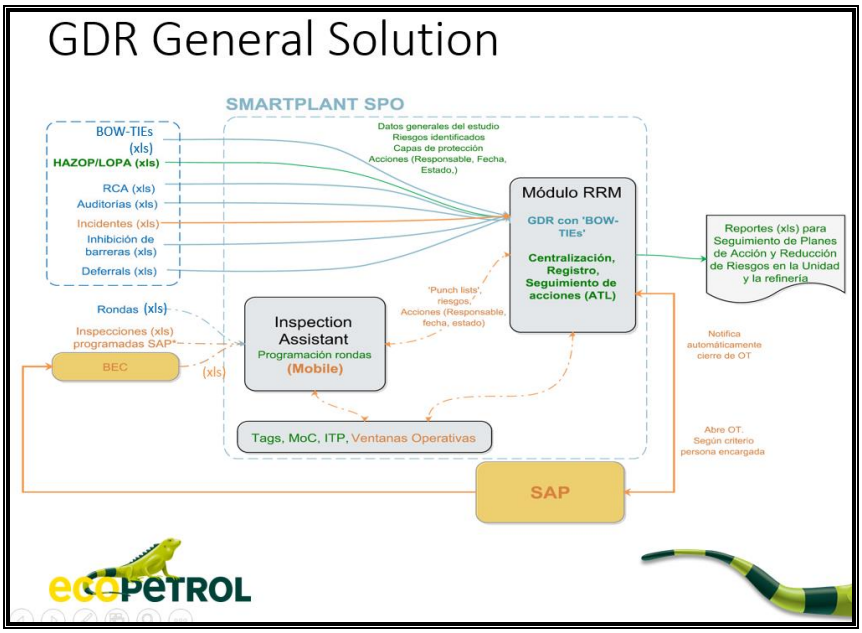
All mentioned risks must be centralized, controlled and continuously monitored to guarantee the adequate performance in the operation and the safety of the facilities.

Fig. 4. Bow-tie showing layers of protection of a Top Event. Source: Ecopetrol



Ecopetrol takes advantage of two existing SmartPlant modules to achieve the implementation of this process. Figure 5 shows the general concept of Dynamic Risk Management and its implementation

Fig. 5. General concept of Dynamic Risk Management



Stage 6. SITREC Expansion and SPiGA´s birth

Once the MOC, PSI and TA processes are in operation and GDR proof is consolidated in the Cartagena Refinery, SITREC is included in a program that seeks to standardize the best practices at the Refining Vice Presidency, thus SITREC is extended to the Barrancabermeja Refinery to meet the needs described in section (1.1). From the experiences of SITREC in Cartagena, the symbiosis between the AM and PS processes, gives birth to *the concept of the Integrated System for Process Safety and Asset Management SPiGA*, based upon concepts such as: risk management, intrinsically safe design, change management, information, mechanical integrity, structured operation, knowledge, condition monitoring, training, projects, TA, , . SPiGA is based on integrated and comprehensive management of those processes through a centralized database.

Figure 6 shows the constitutive processes of SPiGA today in Ecopetrol S.A. and Figure 7 shows its general architecture.

Fig. 6. Constitutive processes of SPiGA today. Source: Ecopetrol S.A.

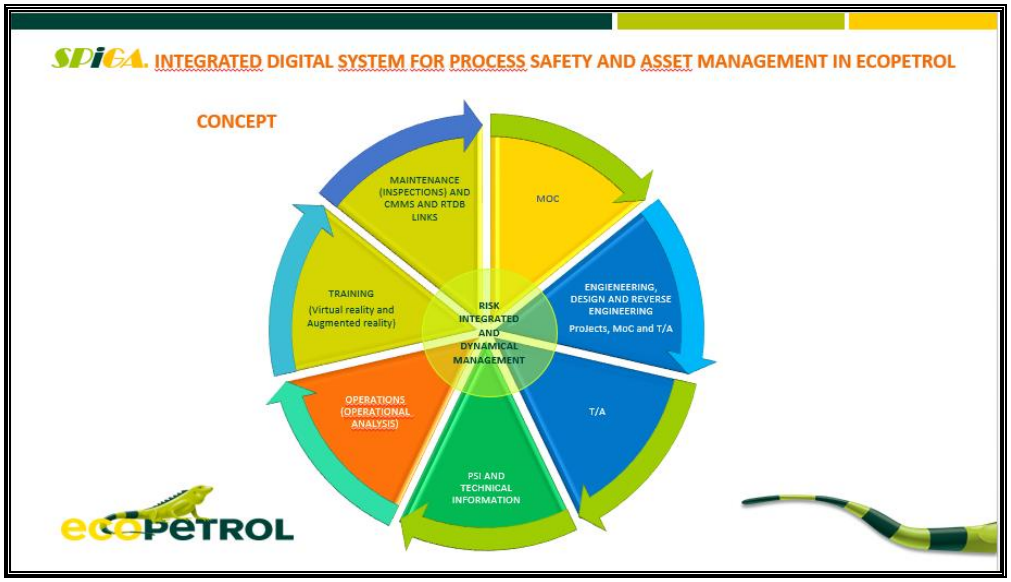
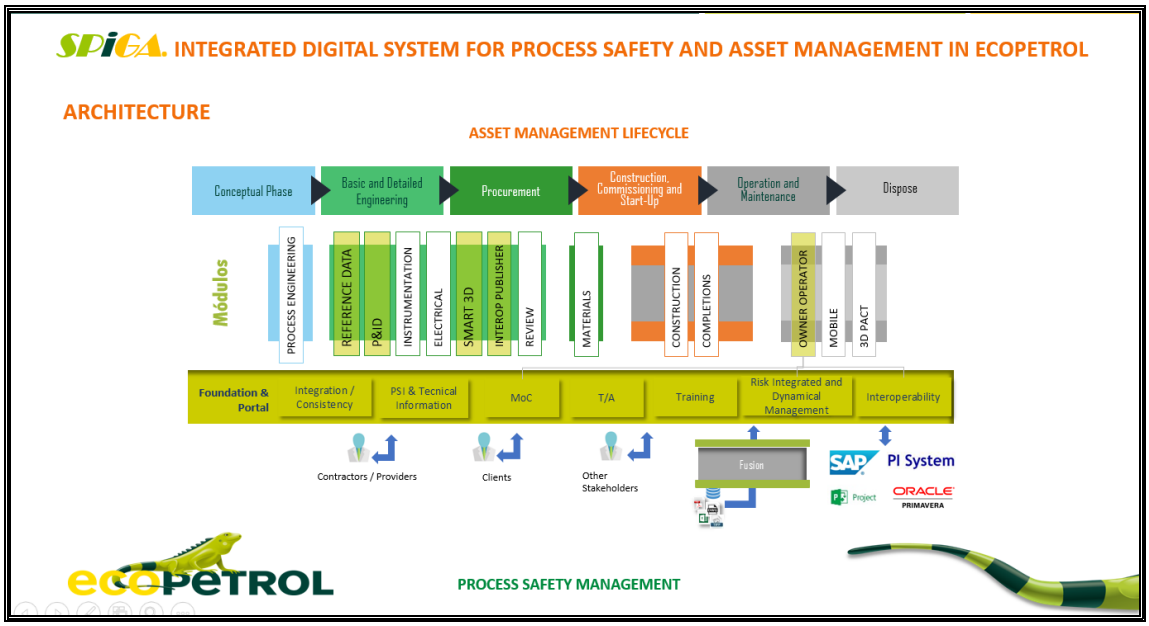


Fig. 7. SPiGA's general architecture. Source: Ecopetrol S.A.



Stage 7. SPiGA's Consolidation

With the expansion of SPiGA to the entire Refining Vice Presidency and considering that, due to its nature, this area has a corporate leadership in risk management and for this reason it is a benchmark, the Vice Presidency for Development and Production –VDS-adopts SPiGA to manage the Security of Processes and Asset Management in their facilities. Initially, his plan included the installation of the MOC, PSI , TA and GDR processes. Today VDS is planning the strategy to develop their first deliverables of PSI directly in SPPID, SPI and SPEL, modules of SmartPlant, which will later facilitate MOC and Project processes.

The future of SPiGA

Short Term

- The total implementation of the current SPiGA processes at the Barrancabermeja Refinery
- The total implementation of current SPiGA processes in the Vice Presidency of Production
- The use of the 3D models integrating the information of the Process Technology will facilitate, in conjunction with simulators, the training of Engineers, Technicians and Operators; making use of the Virtual Reality and the Augmented Reality.,.
- The assurance of the entire chain for Reverse Engineering, from laser scanning to the "intelligent" 3D model, that is, containing all the information of the PSI and, in general, the technical information of the plants

Medium and Long Term

- The quantum leapECOPETROL S.A. will have, to get a new level of management, will be based on diagnosis, analysis, prediction, optimization and risk-based decision making, using Digital Twins, augmented reality, virtual reality and 'machine learning'; supported by: a) Continuous improvement of the processes and subprocesses of AM and SP, b) The integration of SmartPlant with 'Data historians' to verify the performance of the assets in real time and historical, c) The PSI and other technical information, d) The progress of Digital Technology (see figure 8)

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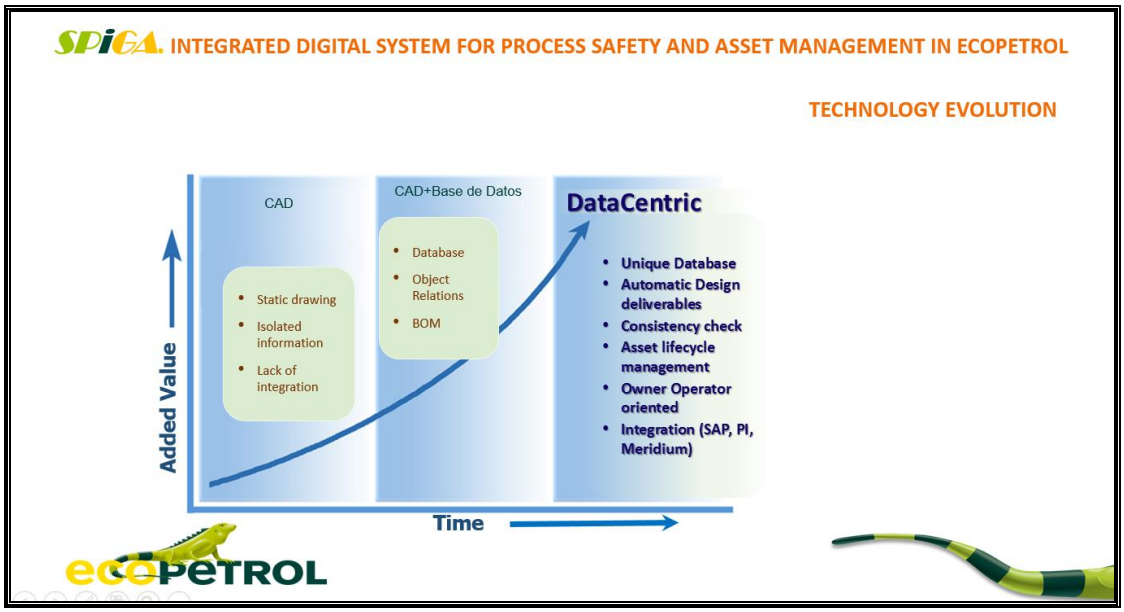
Fig. 8. Digital Technology Evolution. Source: HEXAGON



Conclusions

- Any organization committed to its shareholders needs to adequately manage its PS and its assets, which entails establishing processes that demand sharing information and keeping it updated. The most expeditious way to achieve this is to share a single database.
- Sharing the information between AM and SP, likewise among its different subprocesses, generates its continuous improvement, favoring the integral management of a corporation.
- The implementation of an integrated process for PS and AM is a process that takes time. It requires persistence and a clear vision that can be modified but its essence must remain invariant. It is a cultural theme, which breaks silos, avoids re-works and leads to collaborative work.
- Avant-garde concepts such as Digital Twins, Virtual Reality, Augmented Reality, Machine Learning, Artificial Intelligence are concepts of today, 'maybe from yesterday', which should be used by the industry to optimally manage risk and to maximize value.

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