

Effectiveness of the Lessons Learned Process in the European Space Agency (ESA) Directorate of Operations (OPS)

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Abstract: The European Space Agency (ESA) Directorate of Operations (D/OPS) has the need to continuously challenge for improvement the working practices, the deployed resources, the delivered products and services. Since 2007 D/OPS has put in place the process of Lessons Learned to address proposed changes coming from the performed experience. The positive outcome of this process over the years is visible in the implemented organisational improvements and in the general learning-based culture accumulated. As part of EN9100-based QMS, it is essential to have evidence that the process is effective, i.e. whether it is carried out according to expectations of the process owner. The paper will present the introduction of Key Effectiveness Indicators (KEI) on the Lessons Learned process, their measurement and the analysis of the collected data for identification of possible improvement actions. Some pre-conditions for definition and implementation of KEIs (for any process) need to be satisfied. Then it is possible to identify few strategic points in the process where expectation on the discipline of the organisation can be translated in a quantitative target. A typical measurement of effectiveness is the duration in performing a specific step of the Lessons Learned process (i.e. in terms of timeliness). The paper will present: The identified KEIs for the Lessons Learned process The identified homogeneous environments where the instances of the process are running The (current) targets set by the process owner The time scope of effectiveness measurement. The analysis of collected data has demonstrated weaknesses in the process to be corrected but also highlighted the current strengths. This initiative confirmed that the continual improvement of the organisation relies also on the effectiveness of the Lessons Learned process itself, and not only on the contents to be learned (i.e. the performance indicators on the organisation itself).

Keywords: Lessons learned, Improvement, Process, Effectiveness, Indicators

1. Background

In the European Space Agency (ESA) the Directorate of Operations (OPS) has the need to continuously challenge the working practices for their possible improvement, the deployed resources for their efficient use, the delivered products and services for their performance and delivery. Since 2007 the OPS Directorate has put in place the process of lessons learned to address proposed changes coming from the performed experience. The positive outcome of this process over the years is visible in the implemented organisational improvements and in the general learning-based culture accumulated in the entire OPS workforce.

For sake of clarity the meaning of a lesson learned in OPS is a recommendation for a change, justified by an unexpected experience, either negative or positive.

2. Current Need

The OPS Directorate has realised that it is not sufficient to have a formal process to identify and manage improvement, as described in the OPS Quality Management System. For the OPS managers it is also necessary to have clear evidence that the process itself is under control.

This need is in parallel solicited by a specific ISO9001 / EN9100 requirement (committed by OPS), specifically point c) in the clause 4.4.1.

4.4.1: Quality management system and its processes

The organization shall establish, implement, maintain, and continually improve a quality management system, including the processes needed and their interactions, in accordance with the requirements of this International Standard.

The organization shall determine the processes needed for the quality management system and their application throughout the organization, and shall:

c) determine and apply the criteria and methods (including monitoring, measurements and related performance indicators) needed to ensure the effective operation and control of these processes.

For OPS the lessons learned process, as any other process in the OPS QMS, needs to be associated with indicators measuring its effectiveness. Investing in a proper process management will contribute to cope with the continuous struggling between limited resources available to improve the organisation and the increasing number of activities to manage and perform.

3. Process

For OPS a process is a documented description of a series of actions jointly taken by various players to achieve a predefined result. The process moves from a clear starting point to reach a defined ending condition, with all necessary intermediate steps and milestones.

The process owner of the lessons learned in OPS is the Product Assurance and Safety Office. The responsibility of the process owner is to maintain and adapt the process description and resources according to any needed evolution. Changes to the process may come from recommendations from the internal players, from requests from interacting entities (e.g. other ESA directorates) or from new requirements in the applicable international standards.

The context of the OPS process of lessons learned is represented by a turtle chart, reporting:

- need of the organisation,
- input to the process,
- resources used by the process,
- players of the process,
- rules followed by the process,
- process indicators,
- the expected output.

The structure of the lesson learned activities in OPS is organised in 3 levels, each one representing a dedicated sub-process:

- Improvement at organisational level
- Improvement at team level
- Individual lesson learned life-cycle.

Each sub-process is described with a flow-chart involving the necessary players. Each sub-process adapts the basic concept of Plan-Do-Check-Act.

4. Key Effectiveness Indicators

The process owner wants to determine the quality of the implemented lesson learned process via specific process indicators. The adopted definition of Key Effectiveness Indicators (KEI) is: *a quantifiable measurement of the actual progressing execution of a process with respect to the expectations of the organisation (i.e. the process owner).*

The owner of the lessons learned process has then to identify strategic points in the steps of the process where a quantitative parameter provides evidence of the ongoing correct execution. As an example, the target time to execute a specific step of the process may significantly drive the overall effectiveness of the process.

The necessary condition to allow for the identification of KEI of the lessons learned process is the presence of accessible data. When the process is supported with records documenting its progress, then the KEI can automatically exploit them with suitable queries and formulas.

On the other hand the lack of recorded data on the execution of the lessons learned process prevents the identification of KEI to be immediately calculated. Hence it is not recommended to invest in manual collection of process data, as the organisation needs immediate visibility of the execution of the process and the possibility to quickly react to unfavourable trends. When convenient, it is recommended instead to invest in a careful expansion of the process data to enable the collection of strategic KEI (e.g. adding new fields in a database of lessons learned).

The main category of KEY is about completion of intermediate individual steps of the process. The sub-process "Individual lessons learned life-cycle" has 3 KEI identified for this first category. The peculiarity of these 3 KEI is that each one is referring to a separate instance of process implementation:

- “Time to assess”, it is relevant to any new lesson;
- “Time to evaluate”, it is relevant to validated lessons escalated at higher level;
- “Time to implement”, it is relevant to lessons enforced by the OPS Review Board.

A second category of KEI is about open-end indicators: these indicators are measuring a step of the process which is not yet completed (e.g. current delay for records left not yet assessed). They are meant for real time monitoring purpose, specifically to identify forgotten records.

A third category of KEI is about embedded/overlapping indicators: these indicators are covering tasks embedded in each other (e.g. the overall completion of the record life-cycle is aggregating the measurements of the intermediate steps). Here the measurements of these indicators imply dependency between each other: bad performance in one point of the process can be easily propagated in other affected indicators. Such dependency will add complexity in the subsequent analysis of the collected measures. It is also evident that KEI measuring the end of the process (e.g. overall life-time of a single lesson learned) do not allow for possible immediate reaction, as the relevant activities are over.

The following table lists all KEI relevant to the sub-process of “Individual lesson learned life-cycle”. The KEI category is specified in the associated index. KEI with thresholds are highlighted in bold.

KEI\Instances	Lessons for Team	Lessons for OPS			Lessons for ESA
		Proposed LL	Validated LL	Enforced LL	
Delay to assign ⁽²⁾		x			x
Time to assign ⁽¹⁾		x			x
Delay to assess ⁽²⁾	x	x			x
Time to assess ⁽¹⁾	x	x			x
Delay to evaluate ⁽²⁾			x		
Time to evaluate ⁽¹⁾			x		
Delay to implement ⁽²⁾				x	
Time to implement ⁽¹⁾				x	
Time to close/reject ⁽³⁾	x	x	x	x	x

Another category of KEI is the frequency of a repeated step in a re-iterated process: these indicators are responding the need of the organisation to have tasks performed with a regular pace. For the OPS lessons learned process at organisation level these are:

- Frequency of meetings with Domain Responsibles,
- Frequency of Review meetings with LL Review Board.

Here the measurements of these indicators can be of three types: historical accumulation of measures, or interval with respect to the last step performed, or delay for new upcoming step. The first measure does not highlight the recent behaviour of the team: it considers only completed steps. The second measure does not address the behaviour of the team in the previous years. The third measure is an open-end indicator (i.e. delay in having the next meeting).

The following table lists all KEI relevant to the sub-process of “Improvement at organisational level”. The KEI category is specified in the associated index. KEI with thresholds are highlighted in bold.

KEI\Instances	LL Review Board	Domain Responsibles
Cumulated frequency ^(1/3)	x	x
Last meeting interval ⁽¹⁾	x	x
Delay to next meeting ⁽²⁾	x	x

Note that the OPS QMS procedure for lesson learned does not prescribe how to process internal lessons within each team: no KEI for their processing steps. However, it is expected that generated lessons are not forgotten and that they always complete their (autonomous) life-cycle.

Similarly, no KEI can be defined for process activities performed outside OPS, such as the processing of lessons escalated at ESA level. The received feedback however allows to measure how long ESA takes to assess the escalated lessons from OPS.

It is highlighted also that in OPS the escalation mechanism, when positively assessing a proposed lesson, is splitting the logical life-cycle of the lesson learned in two separate records: the original record that will be closed/rejected at the completion of the assessment step, and a new cloned escalated record. This is why the overall KEI "Time to close/reject" has two different data sets for the lessons to be learned by OPS (i.e. the original and the escalated ones) and as well for the lessons to be learned by ESA (i.e. the original and the escalated ones).

Now, once the KEI are identified, the next step is to associate acceptability thresholds to the collected values for the indicators important to analyse and report. The thresholds reflect the expectation by the process owner in the proper execution of the process. In OPS the classical traffic light approach is adopted:

- GREEN, acceptable KEI measures within a specific threshold;
- RED, unacceptable KEI measures beyond a different specific threshold;
- YELLOW, intermediate KEI measures between the GREEN and the RED ranges.

The setting of these thresholds usually is based on the experience on how the process has been executed in the past. It may also be tailored or re-visited according to the applicable organisation strategic objectives. In OPS for example the implementation on an enforced lesson is expected to be completed within 3 months (GREEN range), and not beyond 6 months (RED range).

5. Other Indicators

Beside the quality of the process it is always possible to measure the quality of the product as result of the process execution. In the specific case of the lessons learned process the "product" is the improvement. In OPS two Key Performance Indicators (KPI) are currently identified:

- Improvement identification rate, i.e. the capability to identify improvement by a specific team. The target is 1 lesson generated per year per 10 team members. The objectives is also to visualise which teams in OPS are not willing to identify possible improvements.
- Process improvement rate, i.e. the implemented changes in the way of working in specific OPS domains. The target is to have 1 improvement implemented per year per OPS core process. The objective is also to visualise which OPS core process is not impacted by the improvements from the lessons learned process.

Finally, also indicators on the quality of the process data can be identified: Key Records Indicators (KRI). They are meant to measure aspects such as the completeness of recorded information and the quality of the contents of the records.

6. Measurement and Reporting

The needed presence of process data implies the deployment of a tool able to store records. The records are to be organised per separate instances of the process implementation. For example, every team in OPS shall have available a dedicated repository for lessons learned. In parallel also at organisation level a central repository allows the OPS management to process the escalated lessons and assign the appropriate actions. A separate repository is needed for the escalated lessons to the outside world. The tool supporting the lessons learned process shall be able to interact with the outside world:

- importing capabilities shall allow to manage lessons received from outside (in a preferable format) meant for OPS to learn
- exporting capabilities shall allow OPS to submit proposed lessons (in a selected format) to collaborating entities.

Beside the repository for lessons learned supporting all needed instances of the organisation, suitable technology shall be developed/procured to perform the KEI/KPI/KRI measurement from the process data. In OPS three levels of data processing have been implemented:

- KEI measured at organisation level (queries on all lessons from the various repositories of each active team)
- KEI measured within the records belonging to a team (queries on lessons generated by a team)
- Select KEI measured within the individual record itself (direct calculation within the single record of lesson learned).

The measurement of process indicators implies a minimum of statistical processing, with sophistication adequate to the available data. Note that the data population is limited for the lesson learned process in OPS: all records within any selected scope shall be addressed, not just a random sample of them. In OPS it is selected to calculate:

- the average derived from individual values in the queried records
- the associated standard deviation.

The average represents the KEI indicator with respect to the selected scope of instances of the process. The resulting average is to be compared with the given acceptability thresholds.

The standard deviation indicates the distribution of the individual values of the record population, with the possibility to identify significant deviations in the execution of the process.

The scope of the measurement can be a fixed calendar period (e.g. from Jan. 1st to Dec. 31st) or a relative calendar period (e.g. last 12 months from today). The reporting can be regular (e.g. once per year at the Management Review Meeting) or/and an on-line dashboard providing real-time measures.

It is essential that the measurement of process indicators is properly validated: queries shall be able to handle any status of the records, in particular in case of empty fields. Independent data collection can be used as well to validate the results of the automatic calculation: e.g. using direct queries on the process data or a separate tool.

In OPS the results of KEI measures are displayed with a gauge to be configured with the following settings:

- KEI Identifier
- Instance identifier
- Relevant units
- Time scope of the measurement
- Min. and max. values of the scale in the gauge
- Clockwise or counterclockwise direction of the values from good to bad
- Boundary value from GREEN range to YELLOW range
- Boundary value from YELLOW range to RED range
- Average calculated indicator of the sample, with value classified in the available ranges
- Symmetric standard deviation range at each side of the average value, to indicate the statistical distribution of the record population.

As an example, the three KEI of the “Individual lesson learned life-cycle” have the following recorded measurement.

KEY EFFECTIVENESS INDICATORS - LESSON PROCESSING

Area- KEI	0610-R-1 Time to assess a proposed lesson	0610-R-2 Time to evaluate a validated lesson	0610-R-3 Time to implement an enforced lesson
OPS central			
OPS proposed lessons			

Example of dashboard of measured KEI for lessons learned in OPS.

Example of measurement at individual lesson learned record. In this case the assignment to an expert was done in 2 weeks (no threshold applied for this indicator), the assessment by the expert took more than 1 month (i.e. beyond the expected good practice), and the overall processing of the record was about 2 months (again no threshold applied for this indicator).

Effectiveness Indicators	
Time to assign	15.2 days
Delay to assign	Undefined
Time to assess	48.0 days
Delay to assess	Undefined
Time to evaluate	Undefined
Delay to evaluate	Undefined
Time to implement	Undefined
Delay to implement	Undefined
Time to complete/reject	63.2 days

Example of measurement at individual lesson learned record, escalated in the central OPS repository. In this case the Review Board took more than 2 months to evaluate the escalated lesson (still within the expected good practice), however the assigned implementation action took several months to complete (i.e. beyond the acceptable threshold), leading to an overall life-cycle of more than 1 year (no threshold applied for this indicator).

Effectiveness Indicators	
Time to assign	Undefined
Delay to assign	Undefined
Time to assess	Undefined
Delay to assess	Undefined
Time to evaluate	71.1 days
Delay to evaluate	Undefined
Time to implement	306.9 days
Delay to implement	Undefined
Time to complete/reject	378.1 days

7. Analysis of Data

The OPS process of lessons learned is always evolving. The analysis of the collected measures shall consider various evolving aspects: players may change (e.g. replacement of domain expert), new teams can appear (e.g. new mission/project) and disappear (e.g. end of mission/project), etc. So the meaning of the data can change according to the selected scope of the measurement. Each measurement will reflect a specific historical baseline in time of the process. Fluctuations in measured data are normally expected over the different years for the specific process of lessons learned.

The analysis of data focuses on the main indicators of the process and the collected average values.

If the resulting averaged measures of process indicators are GREEN, this means that in this moment all the expectations by the process owner are met and the process is well under control. In particular,

- for KEI the lessons learned process is correctly and timely executed by all involved players.
- for KPI the teams demonstrate willingness to improve and the various practices are becoming more efficient.
- for KRI the process data are containing all the necessary valuable information.

At this point the process owner, together with the OPS management, may assess whether the assigned thresholds should become more stringent. This positive conclusion confirms the expectation by the process owner.

Instead, when the resulting average measure of a main process indicator is RED, there is a non-conformance to the OPS lesson learned process. An analysis of the RED measurement shall be done to understand what the problem is and where it is located. Each gauge chart will be associated with the chart of the values selected for the sample: the graphical distribution of individual values will help in identifying those mostly contributing to the unwanted deviation from the acceptable threshold. This supporting chart will also indicate the contributions to the calculated standard deviation (e.g. presence of spikes). For the considered main KEIs some individual values are linked to individual responsibilities of staff (e.g. lesson assessment, action implementation), whereas others are due to the organisation of the process (e.g. meeting frequency).

As a RED result represents a deviation from the expectation, the identification of the causing individual values will determine if immediate corrections are needed and by whom.

In a second step the analysis will then attempt to identify the root cause(s) of such deviation:

- the direct root cause, i.e. who introduced this deviation in the process (and when);
- the indirect root cause, i.e. who did not notice the presence of this deviation in the process (and starting from when).

Complex situations may lead to the identification of several independent root causes and relevant contributing factors.

An example of analysis is the result of the minor KEI "Time to assign". During the year 2022 the staff generated 32 lessons to be learned by OPS and by external parties. The resulting KEI measurement (to complete the lesson assignment task) is an average of 86 day, with standard deviation of 64 days. Although acceptability thresholds are not formally defined for this indicator, the measured averaged value is not appreciated by the process owner. Moreover, the value of the standard deviation indicates that there were some individual cases of lessons not assigned for assessment within 3 months. The root cause is a lack of frequent regular monitoring during the year by the Lessons Learned Officer: lessons were not assigned for assessment because the Lessons Learned Officer was not aware of their generation.

8. Improvement of the Process

The next step after the analysis of collected data is to define corrective actions to remove the identified root causes. Most of the actions could be within the frame of re-training people (e.g. domain experts) and teams on specific steps of the lessons learned process. Other actions may require escalation to higher authorities (i.e. line management) to remind assigned duties and responsibilities of the involved staff. An evident example was the request to a head of division to push a domain expert to assess the assigned lessons (due to unacceptable time to assess). New technological solutions may help in preventing other issues.

The effect of the implemented corrective actions may only be seen at next collection of process indicators. The availability of historical trends of measured KEI will help in assessing the effectiveness of the process improvement, assuming most of the context conditions are stable.

Please note that some time iterations and discussions on possible corrective actions may generate opportunities for improvement on the process itself. An example has been the introduction of a variant in the process to deal with minor validated lessons learned, as triggered by the struggling of the domain experts in specific assessment conditions.

Continuing the example above, a corrective action to ensure the immediate detection of new generated lessons learned is to systematically implement a mechanism for automatic notification to the Lessons Learned Officer from every team repository. This mechanism makes the Lessons Learned Officer immediately aware of any new lesson generated by the staff.

9. Conclusion

The OPS directorate of the European Space Agency has implemented a programme of Key Effectiveness Indicators (KEI) in the lessons learned process. The identified indicators are measured at three levels: within a single record of lesson learned, at level of single team, at organisational level. In parallel the corresponding QMS procedure has been updated to reflect the adoption of these process indicators. Data are collected both in real time and at specific points in time (e.g. at the end of each year). A formal reporting is issued at the annual Management Review, with associated analysis of the possible weaknesses of the process. The access to the collected data of OPS KEI for the lessons learned process is public within ESA.

With this implemented KEI programme the OPS Directorate can measure the effectiveness of the lessons learned process implementation and identify possible weaknesses. The objective of an effective lesson learned process is to make the organisation more efficient, thanks to the improvements directly derived from the experience.

In summary:

- The adoption of strategic KEI is focused on the quality of the OPS lesson learned process.
- The compliance to the expectation of the process owner is based on the correct behaviour of all involved players and on the joint willingness to improve the organisation and its interfaces.
- Technological solutions are needed to implement the KEI programme, also ensuring transparency on the collected results.

References

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