A PUBLICATION OF THE INTERNATIONAL COUNCIL ON SYSTEMS ENGINEERING

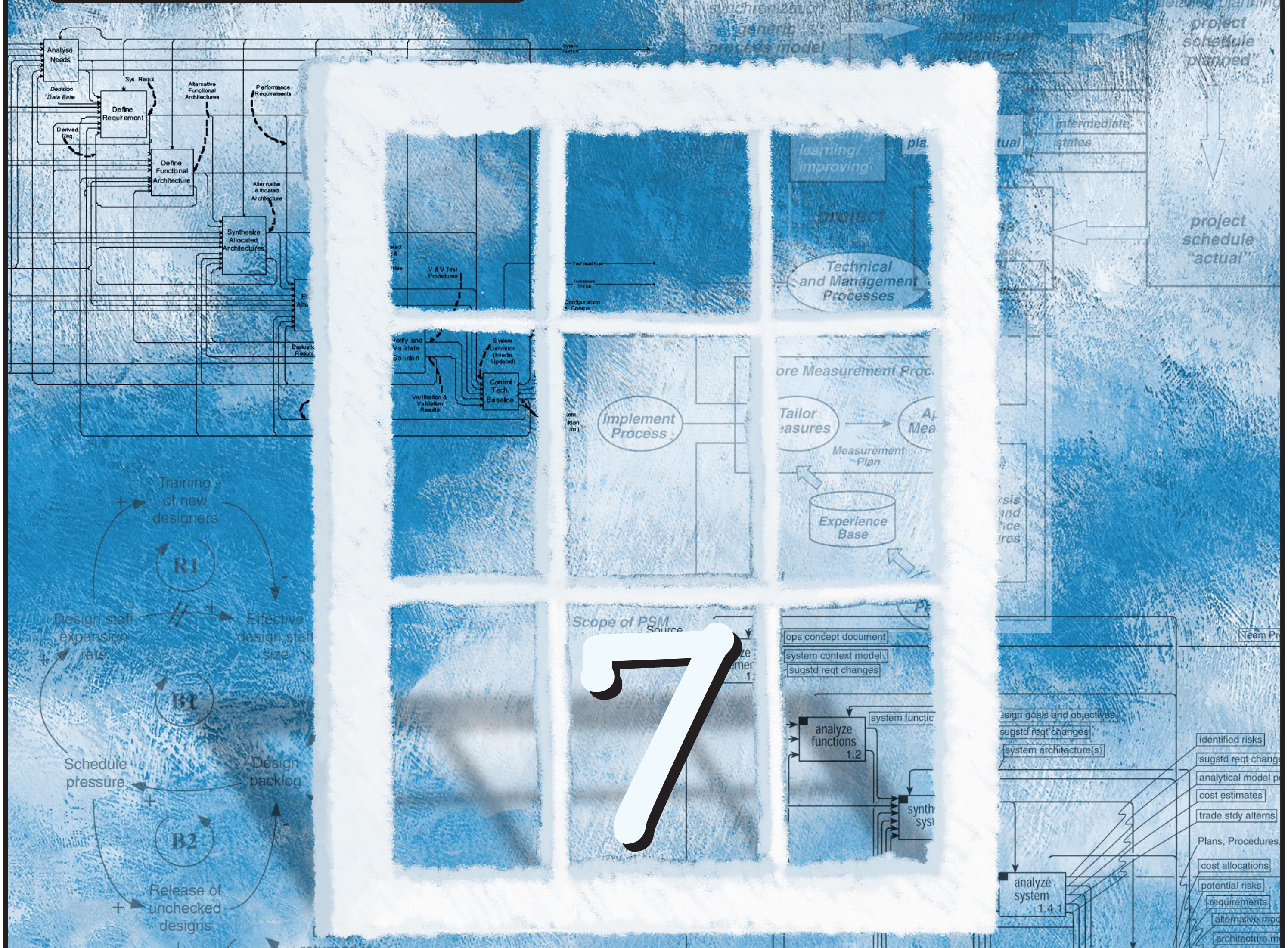
Fall 1999

INCOSE

Vol 2 Issue 3

INSIGHT

INSIGHT SPECIAL FEATURE



Insights into Process Modeling and Management for IPPD

Development Integration and Implementation of Engineering Processes at Oerlikon Aerospace

Claude Y. Laporte, claporte@yortar.com, Sylvie Trudel, strudel@oerlikon.ca

Abstract: In order to reduce cycle time, increase customer satisfaction and lower costs, Oerlikon Aerospace initiated a series of projects to define and implement engineering and management processes. The first initiative, in 1992, defined a software engineering process. A second initiative was started in 1995 with the objective of defining and implementing a systems engineering process, and integrating this process to the software engineering process already in use. We present a brief description of the context, then describe the systems engineering process. Organizational mechanisms to better manage changes are also described. Finally, lessons learned are presented.

Process Development Background

Oerlikon Aerospace (OA) is the systems integrator of an air defense missile system. More than 100 systems and software engineers were involved in the development and maintenance of the system. In fall 1992, recognizing that engineering was a core competency, the OA president approved the budget for a software capability assessment, as well as for the preparation of a Process Improvement Plan (PIP). In spring of 1993, assessors certified by the Software Engineering Institute (SEI) performed a formal software assessment. During a second formal assessment conducted in February 1997, OA achieved a strong SEI level 2 certification, and even satisfied eight of seventeen goals for SEI level 3 certification.

Although the organization had been ISO 9001 certified since 1993, it was decided that a systems engineering process also had to be developed in order to seamlessly integrate disciplines associated with systems engineering. In 1995, a mini assessment of systems engineering practices was performed. After the assessment, it was decided to use, as frameworks, the Systems Engineering Capability Maturity Model (SE-CMM)©[1] and the Generic Systems Engineering Process (GSEP)©[2] developed by the Software Productivity Consortium (SPC 1995). An in-depth description of the systems engineering process has been presented at a symposium of INCOSE (Laporte 1997).

Development of a Systems Engineering Process

The GSEP document describes, using the IDEF notation (USAF 1981), management and technical activities, and the artifacts produced by each activity. The major management activities are: Understand context, analyze risk, plan increment development, track increment development and develop system. The major technical activities, as illustrated in Figure 1, are: Analyze needs, define requirements, define functional architecture, synthesize allocated architecture, evaluate alternatives, validate and verify solution, and control technical baseline. Each

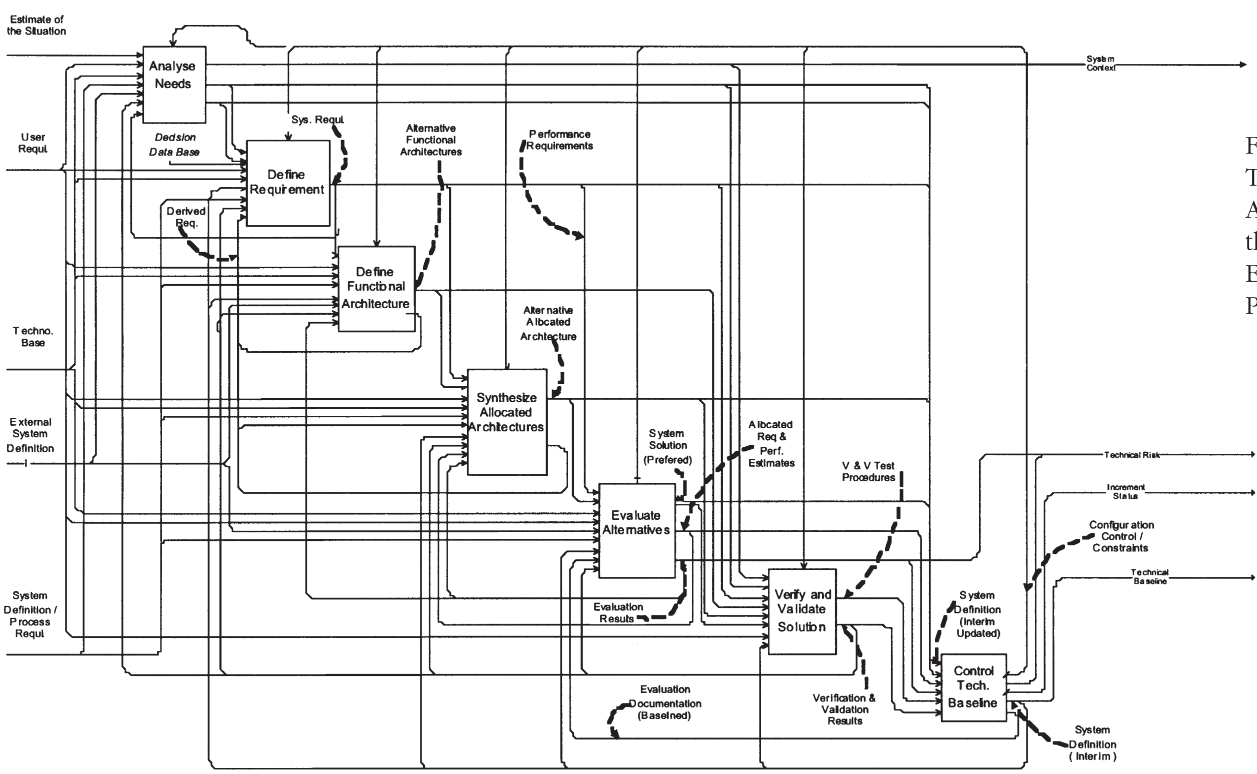
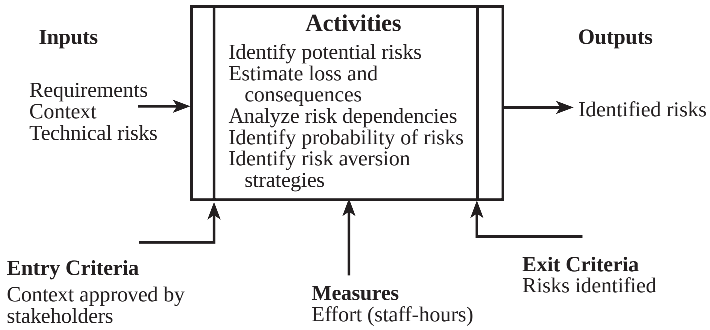


Figure 1: Technical Activities of the Systems Engineering Process

Figure 2. Example of a modified ETVX Notation – Perform Risk Analysis



major activity is broken down in a certain number of smaller activities that are described, individually using a modified Entry criteria-Task-Validation-eXit criteria (ETVX) notation (Radice 85). This notation was also used to document software process and management processes such as the project management process. As an example, the "Analyze Risk" top-level activity is composed of four lower level steps: Perform Risk Analysis, Review Risk Analysis, Plan Risk Aversion, and Commit to Strategies. One step titled Perform Risk Analysis is illustrated, using the modified ETVX notation, in Figure 2.

Integration of the Software Engineering Process to the Systems Engineering Process.

We have used, as a framework to integrate the software engineering process to the systems engineering process, a document produced by the SPC entitled: Integrated Systems and Software Engineering Process (ISSEP)©[3] (SPC 1996). ISSEP defines a set of management and technical activities and the following interfaces: (1) interfaces between the management and technical activities, (2) interfaces among management activities, (3) interfaces among technical activities, and (4) interfaces between the systems and software or hardware development processes. Similarly to the GSEP, ISSEP is adaptable and tailorable to a range of applications and project environments.

Deployment of the Systems Engineering Process

The systems engineering process was deployed for the first time for the re-engineering of two subsystems of the air defense system, namely the launcher control electronics and the operator consoles. The launcher control subsystem is composed of a main data processor which coordinates the operation of the sensors, the launch and guidance of the missiles; a missile tracker processor; a target tracker processor; and a servo control processor. The operator consoles consist in a radar console, which allows controlling the radar and communication subsystems, and an electro-optical console, which allows controlling optical sensors and missile launcher.

Both re-engineering projects were divided into increments: a definition phase and a detailed hardware/software development phase. The identification of each increment was based on the nature of the deliverable product at the end of the increment. In both cases, the first increment deliverable was a system requirement specification, and the second increment deliverable was a set of design and equipment specifications, plus a qualified working pre-production prototype. An in-depth description of the re-engineering project can be found in paper presented at the 1998 INCOSE Symposium (Laporte 1998).

The Management of Change

Since the management of change is a key element of a successful process improvement program, a series of actions were planned in order to facilitate the development, the implementation and the adoption of the processes, methods and tools. As an example, to build the sponsorship level, the president attended a one-day executive seminar on process improvement and two directors attended a three-day seminar discussing the CMM, process, process assessment and improvement. Briefing sessions were held and articles were written in each company's newsletter to explain the why, what and how of process assessment and improvement activities and describing the progress made. Finally, surveys were conducted to assess the organization's readiness to such a change in practices. The surveys identified strengths of the organization and potential barriers to the planned improvement program.

Also, in order to get support and commitment for the future implementation of processes, working groups were staffed with representatives from many departments, including software engineering, systems engineering, sub-systems engineering, quality assurance, contract management, and configuration management. Each working group was managed like a project. It had a charter, a budget and a schedule. A process owner, (i.e. a manager responsible for the definition, implementation and improvement of each process) was part of the working group. A member of the working group acted as a facilitator in each group. Therefore, the process owner would focus on the content of a specific engineering process while the facilitator would focus on the process of developing a process.

Lessons Learned

Certain lessons that could benefit other organisations in the future are discussed below.

Lesson 1: Tie Process Improvement Activities to Business Objectives. It was observed that software and systems engineering process improvement really picked up momentum when a common focal point was created between management, engineers and customers. They understood that the real benefit of process improvement is that it has the potential to improve product quality, reduce time to market, and reduce cost. Consequently, it improves the ability of an organization compete. Additionally, a multi-year Process Improvement Plan (PIP) was a very important tool to illustrate the links between business objectives, project requirements and process development or improvement. Essentially the PIP illustrated that the engineering of processes was not a paper exercise but an important infrastructure for the successful accomplishment of projects. Being a multi-year plan, the PIP also showed practitioners the long-term commitment of management to business and process improvement activities.

Lesson 2: Train all Users of the Processes, Methods and Tools. Once processes are defined, it is essential to train all users. Otherwise, process documents will end up getting dusty on shelves. It is illusory to think that developers will study, on their own initiative, new processes in addition to their workload. Training sessions also serve as a message that the organisation is moving ahead and will require that its developers use these practices. During the training sessions, it is necessary to indicate that, even with everybody's good will, errors are bound to happen while using new practices. This message may help reducing developers' level of stress when using these new practices. It would be a good thing to have a resource person available to help developers (e.g. on a hot line) when they face obstacles while implementing new practices.

Lesson 3: Manage the Human Dimension of the Process Improvement Effort. We wish to make you aware of the importance of the human dimension in a process improvement program. The people responsible for these changes are often extremely talented engineering practitioners, who may not be trained in change management skills. The reason for this is simple: their academic training focused on the technical dimension and not on the human aspect. However, the major difficulty of an improvement program is precisely the human dimension.

While preparing the technical part of the improvement action plan, the change management elements have to be planned. This implies, among other things, a knowledge of (1) the organisation's history with regard to any similar earlier efforts, successful or not; (2) the company's culture; (3) the motivation factors; and (4) the degree of urgency perceived and communicated by management, the organization's vision, and genuine support. We are convinced that the success or the failure of an improvement program has more to do with managing the human aspect than managing the technical aspect.

Lesson 4: Process Improvement Requires Additional "People Skills." In an organisation that truly wants to make substantial gain in productivity and quality, a cultural shift will have to be managed. Such a cultural shift requires a special set of "people" skills. The profile of the ideal process facilitator is someone with a major in social work and a minor in engineering. The implementation of processes implies that both management and employees will have to change their behaviour. With the implementation of processes, management will need to change from a "command and control" mode to a more "hands-off" or participative mode. As an example, if the organisation truly wants to improve its processes, ideas should come from those who are working, on a daily basis, with the processes. This implies that management will need to encourage and listen to new ideas. This also implies that the decision making process may have to change from the autocratic style, e.g. "do what you are told," to a participative style, e.g. "let us talk about this idea." Such a change requires support and coaching from someone outside the functional authority of the managers who have to change behavior. Similarly, employees' behavior should change from being the technical "heroes" that can solve any problem, to team members that can generate and listen to others' ideas.

Facilitating behaviour changes requires skills that are not taught in technical courses. It is highly recommended that the people responsible for facilitating change be given appropriate training. The authors recommend two books that may facilitate the management of change: the first one (Block 1981) gives advice to anybody acting as internal consultant; the second one (Bridges 1991) provides the steps to be followed for writing and implementing a change management plan.

Lesson 5: Select Pilot Projects Carefully. It is also very important to select carefully pilot projects and participants to the pilots since these projects will foster adoption of new practices throughout the organization. Also, first time users of a new process will make mistakes. It is therefore mandatory to coach properly the participants and provide them with a "safety net." If participants sense that mistakes will be used to learn and make improvements to the process instead of to "point fingers," the level of anxiety will be reduced and they will bring forward suggestions instead of "hiding" mistakes. As an example, the main objective of a formal inspection process is to detect and correct errors as soon as possible in the project lifecycle. Management has to accept that in order to increase the errors detection rate, they should not make public the results of individual inspection, but only the composite results of many inspections. When management accepts this rule, employees may feel safe to identify mistakes in front of their peers instead of hiding them. The added benefit to correcting errors is that those who participate in an inspection may learn how to avoid these errors in their own work.

Lesson 6: Conduct Process Audits. Process audits should be conducted on a regular basis for two main reasons: First, to verify that practitioners are using the process, and second, to discover errors, omissions, or misunderstandings in the application of the process. Process audits help to assess the degree of utilization and understanding by the

Activity	Results from First Audit	Results from Second Audit
Comments made by reviewers	38 %	78%
Approval matrix completed	24%	67%
Effort log completed	18%	33%
Review checklist completed	5%	44%
Configuration management checklist completed	5%	27%
Distribution list completed	38%	39%
Document formally approved	100%	100%

Table 1. Results of audits performed on the Documentation Management Process

practitioners. As an example, a documentation management process was released and practitioners were asked to produce and update documents using this new process. It is widely known that engineers are not prone to documenting their work. An audit was launched to measure process compliance. As expected (see Table 1), results of the first audit were not exhilarating. The engineering manager kindly reminded engineers, in writing, to use the process. He also informed them that a second audit would be performed. As shown in the table, the results of the second audit are substantially better than the first audit. Also, the auditor gathered feedback from engineers; this information is used by the process owner to improve the process.

Lesson 7: Conduct Team Effectiveness Surveys. Surveys (Alexander 1991) may promote open discussion with members of a group since most people are not inclined to raise “soft” issues. Also, such tools provide the facilitators with information that help them probe delicate issues. As an example, if the majority of a working group reports that interpersonal communications are weak, the facilitator can probe the members and invite them to propose solutions. After a few meetings, the results of a new survey will show if the proposed solutions really helped the team improve performance and communication.

Lesson 8: Get Support from Organizational Change Experts. As mentioned above, surveys were conducted in order to “measure” issues such as culture, implementation history, and team effectiveness. Once the surveys were compiled, we had some indications of organizational strengths and weaknesses. The difficult part was to decide what to do next. As an example, one issue from the survey is taking risks, and that people are not willing to take risks. One possible reason for such behavior was that people did not want to be blamed for an error. Having found this cause was not too helpful, since we would have no influence over the cause for this behavior. It would have been very helpful to have access to someone with expertise in organizational change. This would have saved a lot of long discussions and many wrong answers.

Lesson 9: Start a Process Initiative from the Top Level Process. The process improvement initiative was a bottom-up exercise, i.e. first software process was developed, then systems engineering process, then project management process where. Each additional process “sits” on top of the other. Historically, this was the selected strategy because, in 1992, only the software CMM was available; then, came the systems engineering CMM and after, the Body of Knowledge in project management (PMI 1996). If an organization had to start a process initiative today, it would be easier and more efficient to start from the top by developing the project management process, then the systems engineering process and finally the software process. It would also be possible to develop these processes in parallel once the requirements for the top-level process are stabilized.

Lesson 10: Adopt a Common Vocabulary. To succeed in any project endeavor, a common vocabulary is a basic requirement. As we developed these processes, we realized that different players had different meaning for the same word, or the same word had different meanings, and some words were not well known to some individuals. We therefore mandated one team member as the “glossary keeper.” His role was to collect a vocabulary, propose some “clean-up” in the terminology, and to build gradually a common glossary for all processes.

Conclusion

We have shown that the development and deployment of engineering and management processes entail technical and management competencies. Five elements are necessary for successful implementation of organizational changes. First, management sets a direction, and process objectives are linked to business objectives. Second, people are trained to perform new tasks. Third, incentives are provided to facilitate the adoption of changes. Fourth, resources are estimated and provided. Fifth, an action plan is developed and implemented. We also learned that the constant attention to the “people issues” is critical to the success of a change project.

Improvements required significant investments, but both the technical and management processes will allow complex projects to be developed in a disciplined environment.

As a final word, a quotation from Pfeffer: “It is almost impossible to earn above-normal, exceptional economic returns by doing what everyone else is doing. It is also impossible to achieve some lasting competitive advantage simply by making purchases in the open market – something that anyone can do." (Pfeffer 98).

Footnotes:

1 SE-CMM is a service mark of Carnegie Mellon University

2 Copyright by the Software Productivity Consortium

3 Copyright by the Software Productivity Consortium

References

Alexander, M., The Encyclopedia of Team-Development Activities, edited by J. William Pfeiffer, University Associates, San Diego, California., 1991

Bate, R., "A Systems Engineering Capability Maturity Model," version 1.1, Software Engineering Institute, CMU/SEI-95-01, November 1995.

Block, P., Flawless Consulting, Pfeiffer & Company, 1981.

Bridges, W., Managing Transitions, Addison Wesley, 1991.

EIA, "Systems Engineering Capability," EIA/IS 731.1 Part 1: Model, Electronic Industries Alliance, 1999.

Laporte, C., Papiccio, N., Development and Integration of Engineering Processes at Oerlikon Aerospace, Proceedings of the Seventh International Symposium of the International Council on Systems Engineering, August 3-7, Los Angeles, California, 1997.

Laporte, C., Guay, A., Tousignant, J., The Application of a Systems Engineering Process to the Re-Engineering of an Air Defense System, Proceedings of the 8th International Symposium of the International Council on Systems Engineering, July 26-30, Vancouver, Canada, 1998.

Pfeffer, J., "The Human Equation Building Profits by Putting People First," Harvard Business School Press, 1998.

Paulk, M. et al, "Capability Maturity Model for Software," Software Engineering Institute, SEI/CMU-93-TR-24, 1993.

PMI, "A Guide to the Project Management Body of Knowledge," Project Management Institute, 1996.

Radice, R., "A Programming Process Architecture," IBM Systems Journal, vol. 24, no. 2, 1985.

SPC, "A Tailorable Process for Systems Engineering," Software Productivity Consortium, SPC-94095-CMC, January 1995.

SPC, "Integrated Systems and Software Engineering Process," Software Productivity Consortium, SPC-96001-CMC, May 1996.

USAF, "Integrated Computer-Aided Manufacturing Architecture," Function Modeling Manual (IDEF0), United States Air Force, AFWAL-TR-81-4023, 1981.

Biographies

Claude Y. Laporte *has a Bachelor in Science, a MS in physics, a MS in Applied Sciences. He was an officer in the Canadian Armed Forces for 25 years. At Oerlikon Aerospace he coordinated the development and implementation of engineering and management processes. In 1999 he started to offer consultating services in process engineering and change management.*

Sylvie Trudel *obtained in 1986 a Bachelor degree in Computer Science. She worked 10 years in development and implementation of management information systems. She joined Oerlikon Aerospace in 1996 as the process control analyst.*