FEEDBACK CONTROL IN PROJECT-BASED MANAGEMENT

L. Scibile
ST Division – Monitoring and Communication Group (ST/MC)
CERN, Geneva, Switzerland

Abstract
Project management is a well-known management technique that has gained success because it encourages better organization and good engineering practice. This technique is also being used at CERN where projects are managed by engineers. They usually find themselves not at ease with a methodology and a jargon that are typical of an economical context. This paper presents a different approach to the project-based management. The notion of feedback control theory is introduced to help engineers in the organization and the supervision of the project, as well as to provide a context that is more familiar to them. This new approach is illustrated for the Antiproton Deceleration Access Control project.

1. INTRODUCTION

Project-based management is being used at CERN and its results in terms of management, organization and personnel satisfaction have shown a distinct success [1-5]. Other presentations in this Workshop talk about management; however, in this paper, the interest is focused on the interaction between the engineers and the context of project management. Indeed, it is not unusual that projects are managed by engineers and they find themselves not at ease with a methodology and a jargon that are typical of an economical context.

A project can be divided in various phases depending on the application, and each phase can be organized in inter-linked processes [6-7]. Simple projects can have just one phase. The main processes can be organized in five main groups: Initiating, Planning, Executing, Controlling and Concluding. For example, a schematic diagram of a two phase project is shown in Figure 1.

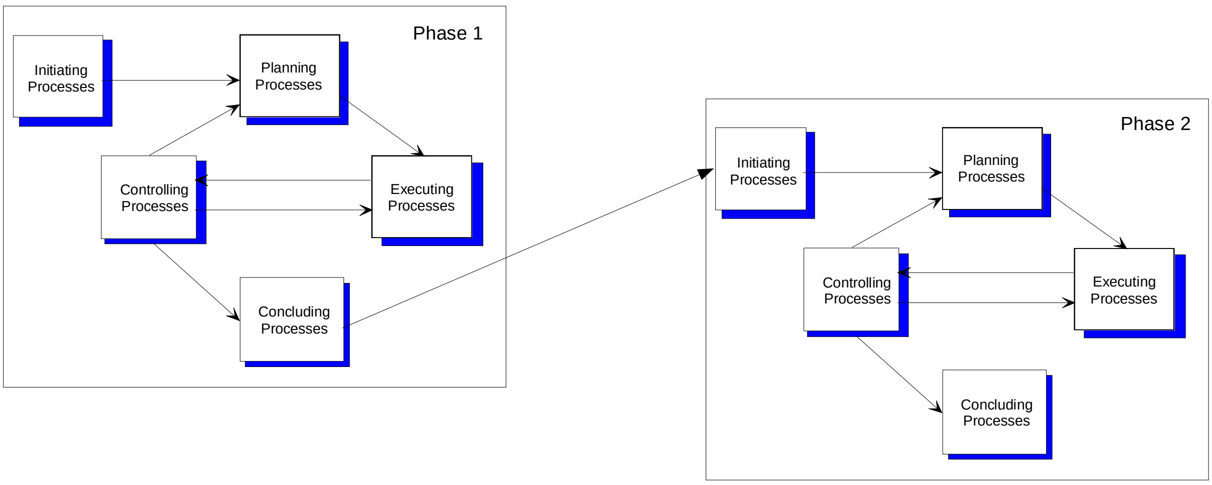

Fig. 1 Two phases project.

The aim of this paper is to focus on the controlling processes.

In Section 2, areas of project management are illustrated and a new approach is presented based on the notion of feedback control theory. In Section 3, the Antiproton Deceleration (AD) Access Control project management organization is illustrated with reference to this new approach.

2. FEEDBACK CONTROL IN PROJECT-BASED MANAGEMENT

To introduce the problem of feedback control in the project-based management, it is useful to rearrange the group processes as shown in Figure 2.

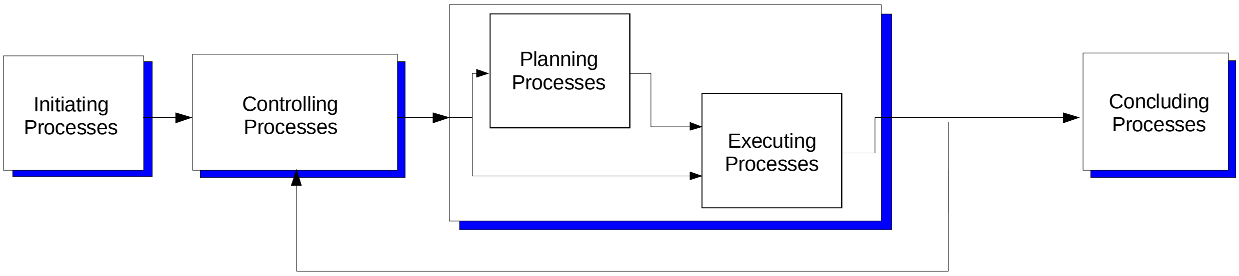

Fig. 2 Block diagram of group processes.

From this schematic diagram, the analogy with a feedback control system is evident. The initiating processes give a set point; the controlling processes monitor the results of the executing processes, assign appropriate resources, and define strategies which are then used by the planning and executing processes. The results of the executing processes are feedback to the controlling processes that adjust the resources and the strategies to optimize some assigned criteria like optimal resource allocation, minimum time delivery, "Just in time" delivery, and minimum cost. Once the outputs reach a level of defined satisfaction, the project phase is concluded.

Having shown that the control process of a project can be supported by elements of feedback control theory, these elements can be used by engineers in a management context. This is described in the following paragraphs.

2.1 Problem Definition

How can this approach be used for project management?

Let us define some variables associated to the processes:

T_{proj} is the duration of the project

C_{proj} is the cost of the project

R_{proj} are the resources of the project

H_{proj} are the constraints imposed on the project

P_{ref} is the set point given by the initiating processes:
- Definition of objectives
- Definition of scope

P_{in} are the actions taken by the controlling processes:
- Change of scope
- Change of control strategy
- Change of resource allocation

P_{out} are the tangible results of the executing processes (output/performance):
- Milestones
- Percentage of execution
- Cost
- Quality

P_{end} is the status of the completion:

- Not completed
- Partially completed
- Completed

In a perfect world, the tangible results of the executing processes, P_{out}, can be estimated quite accurately (see also the presentation of B. Jenssen in this Workshop). Once the resources and the control strategy are fixed, the planning processes will give the exact time of project completion. A typical behaviour of P_{out} as a function of time is shown in Figure 3. However, in a project, there may be unpredictable events that act on the processes as a disturbance: it is in these cases where a control system is required.

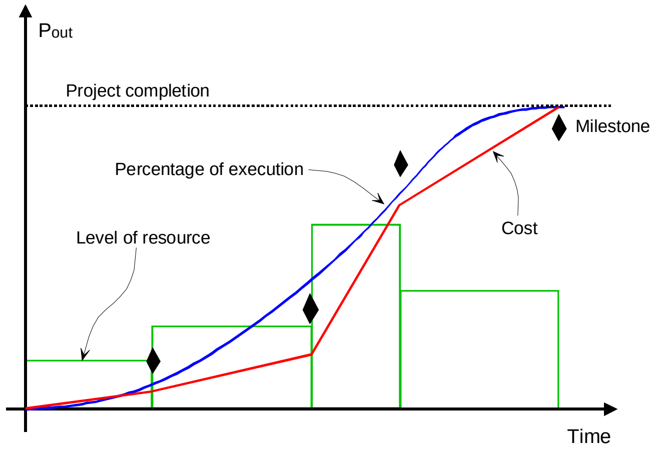

Fig. 3 Typical time behavior of the tangible results of the executing processes (output/performance).

The project leader acts as a process observer and he should estimate the main characteristics of the processes such as dynamic of the process variables, couplings between variables, and control constraints. It is not uncommon that there might be some unknown factors in the processes (like exact delivery day of materials) and these should be treated as random variables. Unforeseeable events, such as accidents, should be treated as disturbances on the processes they interfere.

2.2 Define control strategy

Once the processes variables are defined, the tasks of the project leader is to monitor them and implement the defined control strategy. Here follows a list of possible control strategies with a brief description of the control objectives.

- **Optimal Resource Allocation (ORA)**
  The control objective of the ORA is to assign the minimum amount of resources to achieve the maximum level of process execution (performance). In other terms, the objective is to optimize the efficiency of the resource allocation.
- **Minimum Time Delivery (MTD)**
  The control objective of the MTD is to minimize the amount of time taken to complete a project. The control strategy should take into account the constraints posed by the limited resources and the noise/disturbances.
- **"Just In Time" Delivery (JITD)**
  The control objective of the JITD is to achieve the end of the project in the given time, making use of the minimum amount of resources or maximizing the quality.
- **Minimum Cost (MC)**
  The control objective MC is to minimize the cost of the project. Typically, the cost can be controlled by reducing the quality of the product or by extending the project duration.

2.3 Discrete time control analogy

A project leader should fix times for performance revisions. At each revision a control action is taken. In analogy with the discrete time control systems, each revision time represents a sampling time and therefore it can be fixed according to the processes dynamic and some appropriate deviation bounds. For example, a weekly revision is sufficient if goods delivery is once a week. In fact, a prompt control action would have no immediate effect in the case of delayed delivery.

3. AN EXAMPLE: AD ACCESS CONTROL PROJECT MANAGEMENT

In the following example, the application of the feedback control is illustrated in the AD Access Control project management. Since the project has just completed the feasibility phase, it will be shown how the control problem has been set up.

The first step is the definition of the control variables as described in Section 2.1. For this, particular project, the *User Satisfaction*, has been added to the tangible results of the executing processes *Pout*. The control strategy is based on a combination of Optimal Resource Allocation and Minimum Cost. A formal representation of the optimization criteria is

$$\min_{\substack{Resources\\Cost}} \left(J_{ORA+MC}\right).$$

The objective function $\boldsymbol{J_{ORA+MC}}$ is given by

$$J_{ORA+MC} = \int_{0}^{T_{proj}} \left[\hat{P}_{out}(\tau) + \hat{C}_{proj}(\tau)\right] d\tau$$

where:

- $\hat{P}_{out}$ is a function of the project resources R_{proj} and represents the deviation of the actual performances from the planned ones.
- $\hat{C}_{proj}$. is the deviation from the planned project cost.

Project constraints H_{proj} have been fixed, like the use of industrial equipment.

An example using the $\boldsymbol{J_{ORA+MC}}$ objective function is shown in Figure 3.

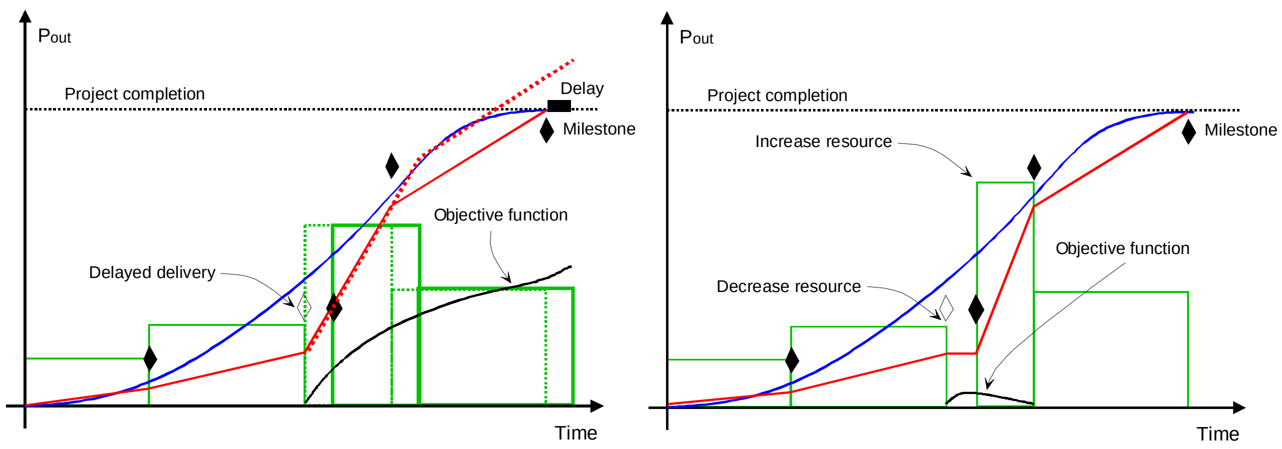

Fig. 3 Example using the $\boldsymbol{J_{ORA+MC}}$ objective function.

The initiating process has produced a list of *Project objectives* and the *Project scope*. The project life cycle has been divided in phases characterized by the completion of the following deliverables:

Project phases	Deliverable/Milestone
Feasibility	Feasibility study
Planning and Design	Detailed design/Design review meeting Approval of the design
Procurement for prototype	Delivery
Construction prototype	Working prototype
Off-line testing	Successful testing Approval of commissioning procedure execution
Procurement for full production	Delivery
Construction final system	System ready for final testing
On-line testing	Successful testing
Training operators	Full operations

The first phase, Feasibility, has been particularly successful thanks to the high degree of user satisfaction.

4. CONCLUSION

In this paper, a new approach to the project-based management is presented. It is shown that the control process of a project can be supported by elements of feedback control theory. This is in line with the typical experience of an engineer and, therefore, it stimulates the natural attitude towards technical problem solving in a management context. This results in better control of the project and less overhead for the managing engineers.

ACKNOWLEDGEMENTS

I wish to thank P. Ciriani for his encouragement and for giving me the opportunity to work on this project.

REFERENCES

[1] A.Bland, P.Charrue, P.Ribeiro, R.Rausch, M.Vanden Eynden, *CERN SL Powe PC Project History Document - Turning Hardware and Software Project Management into a CERN Reality* - CERN SL Note 97/03 (CO) (1997).

[2] P.Ninin et al., *Technical Data Server - Another Vision of Large Scale Supervision,* Proceedings of ICALEPCS'97 , Beijing, China (1997).

[3] M.Vanden, P.Ninin, *Project Management as a Breakthrough at CERN,* Proceedings of ICALEPCS'97 , Beijing, China (1997).

[4] B.Denis - CERN SL Controls Group, *Outsourcing the Development of Specific Application Software Using the ESA Software Engineering Standards - The SPS Software Interlock System,* Proceedings of ICALEPCS'95 , Chicago, USA (1995).

[5] R.Billen, P.Charrue, C.Frisk, V.Paris, G.Robin, M.Vanden Eynden, J.Wenninger, *CERN SL Apollo97 Project Management Plan,* CERN Controls Group Internal Note - 12 Feb. 1997.

[6] W.R.Duncan, *A Guide to the Project Management Body of Knowledge*, Project Management Institute (1996).

[7] J. Rodney Turner, *The Handbook of Project-based Management*, McGraw Hill, ISBN 0-07-707656-7 (1992).