# PHOTON BEAMLINE CONTROL SYSTEM AS A PRODUCT

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*Abstract*

Every beamline is different, which makes it impossible to buy a control system off the shelf. Nevertheless well tested and customizable building blocks can be prepared, which are then put together according to customer requirements. Delivering a fully operational control system is not just software development, but also gathering specifications, writing documentation, testing the hardware and trimming the software on site. Based on the delivery of a number of working beamline control systems, this paper will prove that we have optimized all stages and can guarantee that the purchased control system will be delivered on time, will work according to specifications and will be properly documented. The customers can also count on support.

## INTRODUCTION

Cosylab has been producing control systems for beamlines since 2003. In this period, we have delivered control systems (CS) for 8 beamlines and are considered the leading company in the field [1].

As with all things there can be a big difference between different control system solutions. It is one thing to implement the controls directly from the manual, while it is another when users are involved to tailor functionality which will make their work easier. To make the control system robust, significant amount of time must be spent on testing with hardware and modifying the CS to accommodate any hardware misbehaviour. A good CS must have machine protection capabilities and all subsystems must fit together. The code must be readable and configurable and documentation and support must be provided for the user to be able to modify or extend the system.

After gaining technical experience with the first four beamlines, special emphasis was put on optimizing procedures for delivering CS service. We call it a service, since it is not just about software code, but also consultations, training, support and upgrades. The idea was to make all parts of the CS configurable and thus recyclable. By recycling components, we have reduced the effort for the last two CS by a factor of 3 compared to the first ones. This shows that Cosylab is now able to deliver state of the art CS with minimal effort.

## HISTORY

We have analysed already finished projects, to find where time can be saved and to learn how to predict effort and cost for future projects. We were not only interested in the total effort, but in the effort of individual tasks, which can differ significantly among projects (Figure **1**).

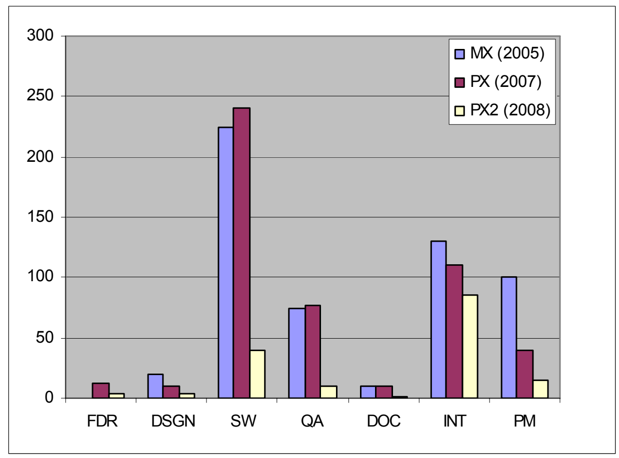


Figure 1: Effort in man days for different stages of 3 CS projects. FDR: final design review meetings. DSGN: design preparation. SW: software development. QA: quality assurance. DOC: documentation. INT: software integration with hardware. PM: project management.

The first CS was developed for U55 beamline at University of Dortmund. It was a fairly simple CS with only individual motor motion control and was excluded from the analysis.

Other CS included all the major beamline components and complex specifications. In all projects we have worked with hardware manufacturer Oxford-Danfysik (OD) [2] who was the main contractor. The scope of the first project (MX) was to deliver CS for 3 identical beamlines to DLS [3]. In the next two projects CS for PX and PD beamlines (PX) and for PX2 and SAXS/WAXS beamlines (PX2) at the ASP [4] were delivered.

In case of MX specifications were prepared by OD and included practically all the functionality possible with existing hardware. Compromises were made with the customer in the design phase, which resulted in non optimal solutions and work a rounds were required at later stages. Due to hardware delays, software was integrated together with hardware fixing, which resulted in longer integration times. Since it was not obvious how much of additional effort was influenced by hardware delays, management effort is also higher compared to the other two projects. It should be noted that the estimated time for the project was 3 times underestimated mostly due to significantly longer integration.

In the course of MX, we have learned several lessons:

- Management procedures and interactions need to be explicitly defined.
- Specifications need to be communicated directly with the final customer.
- Scope needs to be well defined and all changes need to be tracked.
- Hardware needs to be available during software development.
- The effort was significantly larger that previously envisaged.

Applying lessons learned to PX, resulted in reducing management effort from 100 man days (md) in case of MX to 40 md in case of PX. Better procedures for tracking progress and changes resulted in less friction between the companies.

By using the actual MX effort for PX effort predictions, PX went only 30% over budget with most of the budget over runs attributed to making CS building blocks recyclable and thus paving the way for future projects.

Since different hardware was used for PX as for MX, most of the design and software code needed rewriting. Therefore similar amount of effort was required for stages before integration.

In contrast to MX where CS for 3 identical beamlines was delivered, the 2 beamlines of the PX project were significantly different. This resulted in 30 % to 40 % integration effort increase, compared to MX where no significant effort increase was observed. If we take this into account, the integration time in case of PX was reduced from 130 md at MX to 80 md. Two additional integration visits were required at PX due to hardware delays.

For PX2 the similar hardware as for PX was used. Specifications and design work was striped down to revising the PX documents. Since we had future projects in mind when developing PX software modules, all PX modules could be reused with different configuration parameters. The time spent for software was mostly adding modules for hardware not already supported. As for the other two projects, quality assurance for new building blocks was around 25% of software development effort. Since the hardware was well prepared for software integration, the integration time was reduced by 25%.

After the last project it is safe to say that Cosylab has well defined procedures, which allow reduction of effort for CS development to a minimum.

## CONTROL SYSTEM PRODUCTION CYCLE AT COSYLAB

Control system production cycle at Cosylab comprises the following phases:

1. Specifications
2. Design and Prototyping
3. Implementation/Test procedures/Documentation
4. Integration/Testing/Debugging
5. Customer acceptance

First specifications need to be defined. It is very important to include the final user in the process of making specifications. In this way developers get to understand user needs, while users get a glimpse of what the CS will look like. Without detailed specifications, design changes might be required at a later stage, which can significantly increase effort and consequently friction between the developers and users. It is easy to spend a couple of weeks for specifications or even more in case of first time users.

After specifications are confirmed by users, the Design and Prototyping phase can start. CS for a beamline is complex enough that a bad design can lead to significant problems at implementation stage or when additional features are required at the end. It is essential that design is confirmed with hardware in the prototyping phase. Since Cosylab has experience in a number of solutions currently used in accelerators worldwide, the Design/Prototype phase can be reduced to below a week, although it can take several weeks otherwise.

The CS design is usually modular. Some modules need to be developed, while others can be found in accelerator community. Unless you are really familiar with the existing module or no modifications are required, not much time is saved by using existing modules. Producing all the modules for a beamline with testing and accompanying documentation takes around 200 md, where around 40 % are spent for motor controls. At Cosylab we have developed a number of modules that can cover most of the beamline components. In addition to the software code, test procedures, user manual and technical manual are also part of the module. By deciding to use Cosylab standard modules, this phase can be avoided entirely.

After all modules are developed, they must be put together and configured for particular hardware. The integration of modules into CS software is done automatically from an Excel spreadsheet [5]. User documentation and technical documentation are also automatically generated from templates pertaining to different modules. It takes a couple of days to build the CS software and check module configuration.

Although individual modules have already been tested on test systems, tests with the actual hardware need to be made. The modifications in this stage are usually not made in the module code, but in the configuration parameters, which need to fit the actual hardware. Apart from insuring that the software is properly configured, also problems with the hardware can be detected.

Before handing over the beamline to the final customer, it is ensured that the CS passes all the test procedures. Although the test procedures are updated to detect all known bugs, a 1 year warranty is given to the customer to report bugs. Current experience shows that after the commissioning phase when some configuration parameters need tuning, no problems are reported.

## CONTROL SYSTEM PRODUCTS

All control systems delivered by Cosylab are of the highest standards. They range from CS build from standard modules to fully customizable solutions.

Our standard CS solution is based on EPICS and is optimized for FMB-Oxford hardware. If the standard solution is selected, the only effort required is to configure the CS and integrate it with hardware. In this case around 50 man days are estimated and would be mostly spent on integration (PROD 1 in Figure 2). The customer does not need to be involved in any stage of the project.

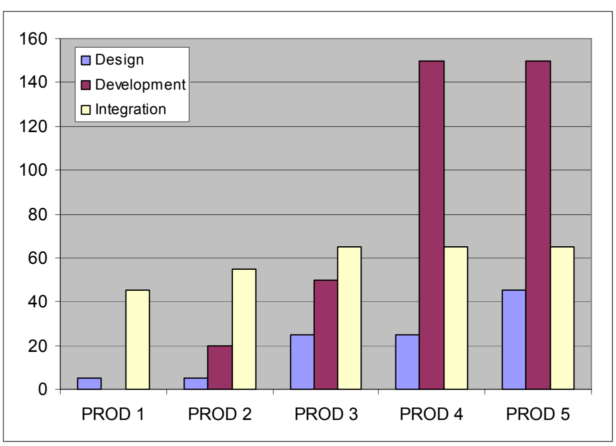


Figure 2: Estimated effort in man days for different CS products depending on the required customization.

In most cases some development work is required even if FMB-Oxford hardware is selected. Let us assume a couple of serial devices need to be supported and some additional features are required for the DCM. The development work would take around 20 man days and there would be also additional effort of around 10 man days at integration. Customer involvement is still not required and the total estimated time in around 80 md (PROD 2 in Figure 2).

Since Cosylab has extensive knowledge in hardware used in various accelerator facilities, even if selecting hardware not included in the standard solution, no learning effort is required. Still significant software development and additional integration time is required to bring the CS to desired standards. A rough estimate to provide CS with hardware outside the standard solution is 140 md (PROD 3 in Figure 2) and 230 md if also motor controls need to be developed (PROD 4 in Figure 2). If the customer wants to be highly involved in specifications and design phase, an extra 20 md are easily spent (PROD 5 in Figure 2).

## CONCLUSIONS

Cosylab has the experience to produce state of the art control systems for photon delivery beamlines. Since emphasis was taken to make control system building blocks recyclable, a state of the art control system can be produced with minimal effort.

Software development work accounts for around 50 % when producing the first control system. Effort required for consecutive control systems can be significantly reduced, if modules are properly designed. By using standard well tested modules, Cosylab has reduced total effort by a factor of 5 compared to the first delivered photon delivery beamline control system.

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Apart from providing control systems with standard modules, Cosylab can deliver also fully customizable control systems. Due to experiences with control system solutions used in accelerator facilities world wide, the customer is ensured that the control system is developed in a most effective way.

From our experience, it is very difficult to properly estimate control system production effort before actually delivering a fully functioning control system. This has mostly to do with time spent to achieve optimal compatibility with hardware. Cosylab has now enough experience to estimate production effort within a 10% margin.

## REFERENCES

[1] http://www.cosylab.com/info/references/.

[2] FMB-Oxford, http://www.fmb-oxford.com.

[3] Diamond Light Source, http://www.diamond.ac.uk.

[4] Australian Synchrotron Project, http://www.synchro tron.vic.gov.au.

[5] G. Pajor et. al., “Systematic production of beamline and other turnkey control systems”, ICALEPCS07.