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THE HYBRID IDENTITY OF A CONTROL SYSTEM ORGANIZATION: BALANCING SUPPORT, PRODUCT, AND R&D EXPECTATIONS

S. Baymani†, Paul Scherrer Institute, Villigen, Switzerland

Abstract

Controls organizations are often expected to fulfil a dual role as both a support organization and an R&D organization, providing advanced and innovative services. This creates a tension between the need to provide services and the desire and necessity to develop cutting-edge technology.

In addition, Controls organizations must balance the competing demands of product development, maintenance and operations, and innovation and R&D. These conflicting expectations can lead to neglect of long-term strategic issues and create imbalances within the organization, such as technical debt and lack of innovation.

This paper will explore the challenges of navigating these conflicting expectations and the common traps, risks, and consequences of imbalances. Drawing on our experience at PSI, we will discuss specific examples of conflicts and their consequences.

We will also propose solutions to overcome or improve these conflicts and identify a long-term, sustainable approach for a hybrid organization such as Controls. Our proposals will cover strategies for balancing support and product development, improving communication, and enabling a culture of innovation.

Our goal is to spark a broader discussion around the identity and role of control system organizations within large laboratory organizations, and to provide concrete proposals for organizations looking to balance competing demands and build a sustainable approach to control systems and services.

INTRODUCTION

Accelerator facilities are complex in the sense that they are at the same time cutting edge technology (or were at the time of conception), while being production grade services, with the operational expectations that come from that. In many ways, particle accelerators at research labs are the ultimate "prototype gone production" system.

In such settings, any middleware becomes key: it makes the glue that keeps the parts together, and therefore directly affects the operation, fine-tuning, and usage of the system as well as the output of its users.

Controls organizations of labs and institutions across the world have somewhat different constitutions: some include PLCs and safety groups and some not. Some include central IT responsibilities and some not. Some include beamline support and some not. Some include data analysis and scientific software, and some not. And so on.

Furthermore, the emphasis and focus on work changes over time: in the youth of each facility, the weight is put on development and slowly shifts towards maintenance. Likewise, at the conception of a facility, the team is small but slowly grows over time, making room for more experiments, again changing the composure and dynamics of the organization.

Regardless of constitution and age, a common pattern exists: Controls organizations have a very wide range of responsibilities and expectations - both explicit and implicit.

It is relevant to approach this observation with an analysis: Which are the expectations? Which ones are explicit, and which are implicit? What actual roles are they connected to?

Using the Paul Scherrer Institute as a case study, this paper presents a novel analytical framework that frames some key roles and tensions experienced by controls organizations. From our observations, this analysis contributes to similar debates in other organizations.

ABOUT PSI

The Paul Scherrer Institute [1], as it looks today, is the result of many changes over many years.

The institute, named after the Swiss physicist Paul Scherrer, was first created in 1988 when EIR (Swiss Federal Institute for Reactor Research, founded in 1960, "East side") was merged with SIN (Swiss Institute for Nuclear Research, founded in 1968, "West side").

The PSI accelerator complex comprises four facilities, HIPA, SLS, PROscan and SwissFEL. The oldest part of what is now High Intensity Proton Accelerator, HIPA - a cyclotron machine, was commissioned in 1974 with subsequent parts added later, building the chain that makes up the HIPA of today. Still in operation almost 40 years later, HIPA still delivers protons, muons and neutrons with more or less the same setup as from the start. The Swiss Light Source, SLS - a synchrotron, was commissioned in 2001, achieving a, for its time, ultra-thin beam. In 2007, a compact cyclotron, COMET, was built specifically for the proton therapy patients, who since 1984 had been served with a split off part of the beam from HIPA. The newest addition to the family is the SwissFEL, a free electron laser, commissioned in 2018. The next big projects on the accelerator side are the ongoing SLS upgrade project, SLS 2, and later on IMPACT, adding two targets in the HIPA accelerator. At SwissFEL, new end stations as well as a fourth transfer line, Porthos, are planned in the coming years. The accelerator complex at PSI is indeed complex, and under the responsibility of the division of Large Research Facilities, GFA.

CONTROLS AT PSI

The PSI Controls section is part of the GFA division, with its stakeholders mainly split between the GFA machine side expert groups and the research groups of the

† simaolhoda.baymani@psi.ch

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photon research division PSD. Originally, the Controls organization at PSI was separated into the HIPA Controls and SLS Controls organizations but was merged together in order to unify the control system across facilities. With only two facilities, this scaled down scenario worked using informal work organization, and alignment and prioritization on an individual level between all parties.

The Controls section today consists of nominally 34 employees and currently 3 temporary personnel. The section manages all four accelerator facilities and uses EPICS as the main control system across all accelerators. At PSI there is always at least one facility in operation, except for the twice-yearly full weekend shutdowns for electrical and IT infrastructure maintenance.

For scale, the total number of IOCs running in our facilities is 1994, including 587 at SLS, 118 at HIPA, 53 at PROscan, and 1236 at SwissFEL.

The section has more than 60 stakeholders, comprising the expert groups on the machine side for 4 machines, the Center for Proton Therapy, as well as the research and support groups on the photonics side. In addition, there are also the PSI wide projects running in parallel. On the core systems side, we have more than 16 areas where we offer fundamental infrastructure and software with which end user needs are met.

Putting these rough numbers together, on the integration side, each section member covers at least 3 stakeholders each and on the core services side, each section member covers at least one service each, which they operate, maintain, support, upgrade and develop, see Fig. 1.

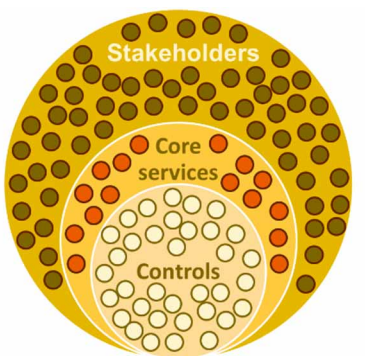

Figure 1: PSI Controls, core services and stakeholders.

For each stakeholder, and also core service, the requirements and needs are often expressed as local optima and a global scope is not always taken into consideration by the stakeholder. At this scale of operation, individual alignment becomes more difficult: an overview is hard to gain and requires effort on the person. Decisions made as local optima could influence the global scope, where the decision might have been different.

The result is that a lot of decisions land with the individual Controls engineer who has to make a best effort decision based on information currently at hand, within their and their team's and line manager's knowledge. These local optima all converge within the Controls section, which often has to detangle, structure and communicate conflicting needs, priorities and requests at a global scope, i.e., in relation to (all) other local optima.

EXPLICIT AND IMPLICIT EXPECTATIONS AND ROLES

At PSI, Controls has a designated role as a service provider, which is not unusual across labs. This is the most visible role we have and with the most explicit expectations. However, there are clearly also other expectations, and their corresponding roles, that are less explicit, and more assumed.

For other software and systems to work, and for the service provider role to be able to deliver, there needs to be several other things in place:

- There needs to be a core Controls infrastructure in terms of hosts, clusters, file systems, networks, user management, OS provisioning, boot infrastructure etc.
- There needs to be a core Control System software, with the necessary hardware abstraction (drivers) and file system structure to organize the files for controlling devices.
- There are core products that are needed, in order to enable other software, such as archiving, image and data buffering, motion control, UI frameworks, libraries, tooling etc.

And of course, the general maintenance and upkeep of the facilities, planned and unplanned upgrades and so on.

Below, definitions and explanations based on commonly used terms, general industry knowledge and concepts related to software development.

Service Provider

Service providers are often engaged for project-based work and deliver a wide range of services, customized to a stakeholder. Service providers may offer consulting and advisory services to help stakeholders define their software development strategy, choose the right technologies, and make informed decisions throughout the development process. Stakeholders engage service providers to leverage their expertise, reduce development costs, and focus on their core business activities while outsourcing specific aspects of software development.

Support Organization

A support organization is focused on responding to user-reported issues, inquiries, and problems related to software while maintaining a continuous relationship with stakeholders or end-users. They provide reactive assistance for operational availability and immediate troubleshooting for end users, ensuring ongoing support and issue resolution for end-users.

Maintenance Organization

A maintenance organization is responsible for the ongoing care, management, and improvement of software applications or systems that are in production. Their role is ensuring that software remains functional, secure, and up-to-

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date, even after the initial development and deployment phases. They take a proactive approach to improve and extend the lifespan of software systems.

Product Organization

A product organization is dedicated to creating, developing, and managing core software products with a long-term focus. Unlike project-based teams, which complete specific tasks and disband, a product organization has a long-term perspective. It aims to continuously enhance and evolve the software product throughout its lifecycle. A product organization in software development is structured to create and nurture software products as ongoing ventures and adapting to its environment over time. These products are usually standalone and complete solutions.

Platform Organization

A platform organization is responsible for providing a foundational software platform and infrastructure, ensuring consistency, efficiency, and scalability across the larger organization's software ecosystem, emphasizing developer enablement and integration. This platform serves as a foundation on which other software applications or services can be developed, integrated, or hosted. Their main audience is developers, both within the organization and potentially external developers. The goal is to provide tools, services, and APIs that enable others to build on top of the platform.

R&D Organization

An R&D (Research and Development) organization is dedicated to exploring, innovating, and experimenting with new technologies, ideas, and solutions. It focuses on research, experimentation, and innovation to drive technological advancements and enhance the larger organization's competitive position in its domain. It plays a critical role in shaping the future of the company's software products and services in a longer-term perspective.

What to Do With This Knowledge

By knowing and naming the roles put on the organization, an open and transparent discussion is easier to have - expectations are easier to put on the table. What are the main mandates for our organization? Which role has more importance? When there is a conflict, which role has precedence? How much time should each role get?

CONSEQUENCES OF MULTIPLE ROLES

Having this multitude of roles and expectations naturally leads to implications. Naturally, operating under the expectations of multiple roles, be it explicit or implicit, brings consequences to the way work is done, to the quality of solutions and to the health of the organization and its individuals. Some examples:

- *Stakeholder driven work:* decisions are local instead of global, catering to the interests of single entities and not taking into consideration an overall view.
- *Technical debt:* in a situation with many expectations, there tends to be a preference for quick solutions and fast deployment with little time to think about a technically sound solution for the long term. There is no time left for cleanup, refactoring or streamlining.
- *Neglect of long-term strategic issues:* by focusing on the immediate needs, we do only what is needed now and lose track of what lies further ahead and miss out on preventative solutions and innovation in general.
- *Lack of innovation:* innovation needs breathing space to be able to experiment, think and discuss. Creative work cannot be pushed forth and is what keeps us and our labs relevant in the end. By being constantly busy with no slack, we cut the needed room for innovation to grow and instead become obsolete.
- *Lack of direction:* when constantly driven by singular needs with a local optimum, we lose track of the general direction and the feeling of convergence that helps focus our work to something cohesive.
- *Becoming a feature factory:* when giving everyone what they want (being stakeholder driven), it is easy to end up in the trap of becoming a feature factory, feeling as if our purpose is fulfilled by keeping busy and producing output - regardless. However, output is never more important than its outcome: i.e., the feature has an intrinsic value which decides whether it is worth putting an effort into, which should always be considered.
- *Spreading too thin:* by doing a little bit of everything for everyone, it seems like we gain something in the short term which feel good. However, by doing so we spread ourselves too thin, and will in the long term neither be satisfied ourselves nor will our stakeholders.
- *Maintenance overhead:* by agreeing to custom solutions, producing a lot of output instead of taking a step back and considering the whole picture, we end up having to spend more time on maintenance and upkeep.
- *Lack of challenging tasks:* this overall situation generates tasks that are superficial in their nature and geared towards continuous workarounds instead of holistic, properly designed solutions. For our engineers, this doesn't bring enough technical challenge and professional development, instead stagnating them.
- *Demotivation:* with too many expectations, few possibilities of fulfilling them and feeling satisfied about their work as well as not enough technical challenges and professional development, our engineers will slowly become demotivated and seek opportunities elsewhere.

A FRAMEWORK FOR ANALYSIS

In order to do a meta-analysis of the roles of Controls and their expectations from various actors, we identify two dimensions for classification:

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- *Internal or external driving force:* is the role foremost driven from within the Controls organization or is it driven from outside the Controls organization by its stakeholders
- *R&D oriented work or core function-oriented work:* R&D oriented work examples are new developments and innovation of different kind and core function-oriented work is for example platform, maintenance and support activities

Using these dimensions, we can classify each role and therefore propose a novel conceptual framework, centered around the orientation of work, which organizes the roles of Controls in a quadrant system, see Table 1.

Table 1: Role Framework

Internally driven	**R&D, Product organization**	**Maintenance, Platform organization**
	Controls as creators of new SW and novel ideas **Key actors and example activities:** Controls, (research groups, expert groups); archiving, timing, cameras, motion	**Controls as maintainers of systems, providers of SW platform and infrastructure** **Key actors and example activities:** Controls, (research groups, expert groups); EPICS, OS provisioning, infrastructure
Externally driven	**Service organization**	**Support organization**
	Controls as resource in custom projects **Key actors and example activities:** Research groups, expert groups; custom integration, new HW support	**Controls as end-user contact, trouble shooter** **Key actors and example activities:** Research groups, expert groups; resolve operational issues, training
	R&D work	*Core function work*

With such a framework we can analyze further aspects of each role and introduce overlaying dimensions that help understand the overall situation of a Controls organization.

Visible vs Invisible

Drawing from experience, we quickly note that there is a clear aspect of visibility: oftentimes the roles that are externally driven are the ones that are more visible and for which resources and priority is often given, and the internally driven roles are implicit and invisible, being less prioritized, see Fig. 2.

Urgent and Short-Term vs Non-Urgent and Long-Term

Similarly, the internally driven work operates on a long-term horizon and is less urgent, even if important, whereas externally driven work has a short time span and is perceived as more urgent by stakeholders, each operating on quadrant 2 and 1 respectively in the Eisenhower Matrix [2]. The division line for this overlay goes in the same direction as for the visibility overlay.

Local vs Global Perspectives

We also know that externally driven work often has a local perspective, operating with local optima while the Controls internally driven work aims to have a global perspective, balancing many needs for overall benefit and optimization.

Again, the division line for this overlay goes in the same direction as for the previous two, see Fig. 2.

Figure 2: Role framework visibility, urgency, locality.

We conclude that with the same division line in all three overlay dimensions, there is something specific happening at the intersection of internally and externally driven work.

TENSIONS AT THE ROOT

Considering our defined framework and observing that it is oftentimes the case that internally driven work must stand back for externally driven work, i.e., invisible work stands back for visible work, long term work stands back for short term work, and globally important work stands back for locally important work, it is clear that there is a pull in different directions – a potential conflict of interests. We have also previously observed that the division line is the same for all three overlay dimensions: along the line of internally vs externally driven work – the work for Controls itself vs the work for the stakeholders of Controls.

We conclude that that there is evidently a fundamental tension between our core missions and the core missions of our stakeholders, a difference in organizational incentive: custom service and support vs long term product and platform, see Fig. 3. Other aspects of the same difference are:

- Product development vs professional services
- Enabling trending research vs operating professional, scaled-up accelerator facilities.
- Customized, unique solutions vs unified, standardized solutions
- Fast paced, intervention-based work vs long term development
- Quick responses, high availability of support vs subject matter expertise

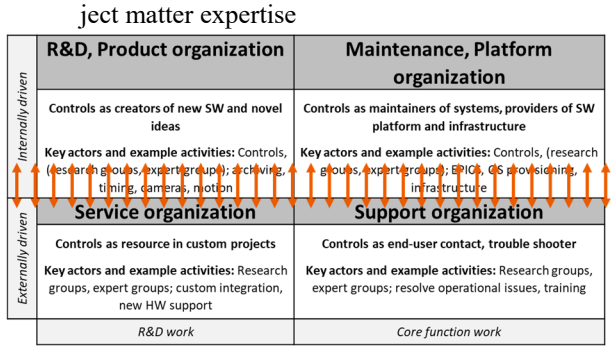

Figure 3: Tension lines of organizational incentives.

These tensions and differences are intrinsic to the organization: regardless of structure, process, coordination and prioritization, these tensions remain at the base, driving the

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interest of different parties in separate directions. To whom do we owe our effort: to the specific experiment or subsystem, needing a customized solution, or to the general operation and stability of the facilities?

This is a recurring position, resurfacing with any major overlap in resources or priority conflict. This is not "just" a problem of too much to do, too few resources and unclear priorities - even though the tensions can be mitigated by structuring the workflow, better prioritization and additional resources, the tensions must be specifically addressed and managed. They can be exacerbated by lack of resources, unclear or conflicting priorities, or lack of a structured workflow.

MANAGING THE TENSIONS

It is in our interest, and arguably also in our responsibility, to keep these tensions in check and not lose track of our core mission(s), while understanding the incentives of our stakeholders.

The differing incentives all coincide within our organization, and whether we want it or not, we are forced to deal with it and reconcile all differing interests. We can structure our work, we can prioritize and ask for more resources, but the tensions will resurface at different points and circumstances. We need to proactively meld these incentives into a coherent plan, looking for patterns that converge similar needs and reduce the outliers. This would lead to a better overall alignment and reduced tension, as everyone knows what to expect.

Therefore, we pose that our most important tool is setting our own agenda to the benefit of all:

- Outline our roadmap, commit to it and follow it ourselves
- Communicate the roadmap to our stakeholders and within our larger organization
- Allow for stakeholder needs to merge into, but not diverge too far from, the path

By doing this, we are giving the general direction - a reference point to start discussions at - while inviting for collaboration and a diversity of opinions. By setting the path, it's clear that the end goal for all involved parties is to accept the existence of other specific interests (awareness of other stakeholders, with equal rights as oneself) as well as the general interest of the overall organization (operation, stability, long term improvements, innovation).

By transparently sharing our path forward, we also make the invisible roles and responsibilities more visible, bringing them to the front. This is also in our interest, as we bring our internally driven work to the stage and on par with the externally driven work. This has to be done repeatedly, and as an accepted part of a communication strategy: building the foundation on which research is made, will always be shadowed by the research it enables.

Realistically, a research organization as diverse as an accelerator lab, will seldom be able to state that one research project is more important than another. It may do so for very large and resource consuming projects, but the ever-ongoing, basic and applied research that happens each day will always be a discussion. These discussions and tensions will continue to converge in whatever organization that has to merge and glue the needs together into a whole. Often, this will be the Controls organization.

Therefore, managing this discussion by setting the stage with a realistic plan for the underlying platform and product portfolio, while taking into consideration the needs for each stakeholder, ensures that the foundation on which innovation and new discoveries are built, will always be taken into consideration and technology will be up to date enough for new research to be conducted.

SAMPLE MITIGATION STRATEGIES FOR MANAGING MULTIPLE ROLES FROM OTHER ORGANIZATIONS

Whether by design or out of necessity, many Controls organizations must relate to the multiple roles put on them, to manage resources, priority conflicts and the incoming requests. Our reality is that we often don't have any choice - we must relate to all of the roles.

During the research for this paper, we observed some organizational mitigation strategies for multiple roles that are used to address the roles and their expectations.

Dividing the Organization

One way is to divide the organization into focus areas, e.g., R&D, maintenance, customizations, and platform. This brings us closer to "pick one role and stick to it" philosophy. However, separating roles requires team members that accept the scope of their role and do not find it too confining. Furthermore, the risk still exists that customer driven requests create a chain reaction that ends up taking a large chunk of the long-term development work, which must be managed [3].

Decision Boards

Some labs have control boards or advisory boards that decide on the priority, importance, and order of projects on a larger scope [4, 5]. A well-functioning board will streamline the work and align the organization, but a board in which the parties are unequal will exacerbate conflicts of interest. A challenge for multi-facility labs will be whether to have a board for each facility, and in that case, how to align cross-facility interests.

Stakeholders "Paying" For What They Want

A strategy related to having a decision board, is to regulate what stakeholders get by requiring them to contribute to the resources pool, either with funding or with personnel, and accepting loss of support and development in some areas in favor of a specifically desired feature. There is an incentive to find agreements with other stakeholders around the same interests, naturally converging their needs.

A risk with this approach is of course that focus lies strongly on stakeholder needs and there is no room left for the internal needs of Controls.

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Tracking and Visualization to Balance Needs

By defining components, or simply using the role definitions, one could track each type of effort and strive for a balance: a certain percentage of time or resources to be spent on each type of activity or role [3, 5, 6]. By tracking the efforts, one can generate statistics and visualize how much was spent where and start prioritizing based on the desired weighing scheme. This strategy requires an acceptance for tracking work and continuous follow up as part of the normal workflow. For a highly autonomous and individual work culture, this might be perceived as controlling. Conversely, this strategy might help bring focus and deliberation to the work environment.

How Well Do Mitigation Strategies Address the Intrinsic Tensions?

The listed mitigation strategies are interesting in terms of managing the multiple roles and responsibilities, and creating work structure and organization: some are more focused on giving each role a slice (dividing the organization, tracking and visualizing work) whereas others are focused on resolving conflicts in priority and assignment of resources (decision boards, "pay" for what you want).

However, the mitigation strategies only indirectly deal with the tensions in organizational incentive: they do improve on the situation by bringing more structure and alignment, but the tensions are still there. There needs only to be slight changes in circumstances for tensions to resurface. The overall cohesion and reconciliation of interests is mainly spot wise and addressed only partially.

SUMMARY AND OUTLOOK

Controls as an organization is expected to fulfil many roles. These roles pull in different directions, based on a difference of interest and organizational incentive between the Controls organization itself and its stakeholders. This pull creates a tension that converges within Controls, which must reconcile and manage these tensions.

We define a novel framework for analysing the roles of Controls and to identify the division line of the tensions, based on the dimensions of work driving forces (internal, external) and work orientation (R&D, core function).

By adding overlay dimensions for visibility of work and needs, the time horizon for them and the perspective in which they have effect, we show that the tension line can be drawn between internally and externally driven work.

By naming the roles, understanding the incentives of our stakeholders, and accepting the existence of tensions, we can better devise a strategy to manage the situation. The framework in turn can help us understand the sources of many of our challenges and identify why we are sometimes pulled in different directions.

Knowledge about the tensions can help us prioritize in times of high pressure. Tensions can also be a catalyst for creativity and new solutions. Controls as an organization has an opportunity to lead while addressing these tensions. The most important tool to manage the tensions with is communication and roadmap. By transparently sharing our roadmap, we show how all interests are reconciled and how each party will get their needs met, directing the path for a viable future that allows for both urgent needs to catch on with trending research, while building up the technological foundation on which such research can be conducted.

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