MANAGING THE DEVELOPMENT OF PLANT SUBSYSTEMS FOR A LARGE INTERNATIONAL PROJECT

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Abstract

ITER is an international collaborative project under development by nations representing over one half of the world's population. Major components will be supplied by "Domestic Agencies" representing the various participating countries. While the supervisory control system, known as "CODAC", will be developed "in fund" by the International Organization at the project site in the south of France, the EPICS and PLC-based plant control subsystems are to be developed and tested locally, where the subsystems themselves are being built. This is similar to the model used for the development of the Spallation Neutron Source, which was a US national collaboration. However the much more complex constraints of an international collaboration preclude the use of many specifics of the SNS collaboration approach. Moreover, procedures for final system integration and commissioning at ITER are not yet well defined. This paper will outline the particular issues either inherent in an international collaboration or specific to ITER, and will suggest approaches to mitigate those problems with the goal of assuring a successful and timely integration and commissioning phase.

CONSTRAINTS AND CONSEQUENCES

ITER is too big and expensive an undertaking not to be done as an international collaboration. Without such a collaboration, bringing together the technical and financial resources of most of the developed world, ITER would simply not happen. Members of the partnership have different cultures, different scientific governance, different funding mechanisms, and possibly even different reasons for participating, with the result that political imperatives must inevitably result in some compromises and extra overhead. In addition to addressing very difficult technical challenges, ITER must learn, perhaps often only by trial and error, how best to minimize those inefficiencies and live with certain constraints. With success, ITER should become a model for future large international collaborations, such as the ILC.

As much as possible of the work of building ITER must be shared among the participating countries through their Domestic Agencies (DAs). This was the *sine qua non* of international participation, and it constrains the amount and type of work that is done by the ITER Organization (IO) at Cadarache. The work of IO is primarily to prepare contracts with the DAs, the specifications for these contracts sometimes being "build to print" but more commonly functional specifications. Very little "hands-on" work is done at IO, and much of the design work is accomplished by external contractors.

CODAC, the central common high-level supervisory control system for ITER, is developed "in fund" by IO as opposed to "in kind" by the DAs. The same approach is used for CODAC development as for other IO work, and many of the same constraints apply. Some of the constraints that affect the work and management of the CODAC group are discussed in the paragraphs below.

Staff Size Limitation

In part for reasons of cost containment and in part because of the ITER emphasis on outsourcing, the size of the permanent CODAC staff is severely constrained. The total manpower effort for CODAC design and development at Cadarache is currently set at a level comparable to that used for SNS – a project of about one third the scope. As a consequence, CODAC is required to outsource most of its development work.

Outsourcing

The R&D program has been carried out largely by external contracts, as is (and will be) much of the development of ITER-specific hardware and software. The technical staff is therefore required to spend much of its time writing technical specifications and managing contractors – a task that does not make optimal use of their training and skills. Contractors are located in partner countries all over the world and supervision is impaired by the resulting lack of face-to-face meetings. Although the practice is discouraged by senior management (contracts with well-defined deliverables are preferred), there has been some success with "insourcing," defined here as supplementing staff with external contractors working on site on relatively loose "framework" contracts. More recently, limits have been set on external contractor remuneration that are in some cases below market rates. As a result, some contracts have been suspended, and others cannot be awarded.

Laboratories

For reasons having to do partly with (possibly temporary) space limitations, partly with safety considerations, and partly deriving from the general approach of limited "hands-on" work by IO, the CODAC team currently has only a small "technical area" for prototype testing and development – too small even for a technician's bench. Software developers seldom have the opportunity to turn on a light they can see. As a consequence, they are somewhat disconnected from the concept that what they are doing must eventually relate to real equipment.

Plant System Integration

The most important constraint on the work of the CODAC Group deriving from the ITER agreement is the nature of the interface with the various plant systems – the major components of ITER. It is the role of the ITER Controls Group and CODAC to effect an integration of these components in such a way as to provide to operations a uniform view of an extremely complex system. It is this integration that presents the major challenge for the CODAC Team.

THE INTEGRATION CHALLENGE

The ITER project is broken down into 33 "plant systems." (Magnets, Cryogenics, Cooling Water, Buildings, etc.) These "plants" are to be delivered to the ITER site at Cadarache "in kind" by the participating Domestic Agencies. In many cases, however, the plants are made up of a number of subsystems each with its own specific functional requirements and each to be delivered separately *with its own Instrumentation and Control (I&C) system* by the responsible Domestic Agency. These "stand-alone" I&C systems are referred to as "Plant System I&Cs." There are approximately 220 such Plant I&Cs. (The exact number is a function of design and is subject to change.) All of these plants, plant subsystems and plant system I&Cs are the subjects of contractual arrangements between ITER and the responsible DAs. In some cases more than one DA is responsible for the delivery of a single plant subsystem. In those cases, responsibility for testing and integration remains to be clarified. In any case, it is the responsibility of the CODAC group to do the final integration of these 220 plant system I&Cs with the CODAC infrastructure at Cadarache.

Three important strategies have been adopted to mitigate this difficult integration challenge. Firstly and most obviously, the CODAC group has developed an extensive set of standards that are to be used by plant system developers. They include specific hardware, software, naming convention, development tools, acceptance tests, documentation and procedures. These standards are bound together in the "Plant Control Design Handbook" (PCDH) which is made available to all plant system developers and potential vendors. It is an ITER mandate that they be followed, with enforcement occurring at design reviews.

Secondly, and notwithstanding that it represented an activity clearly not defined within its scope, the CODAC team created an I&C Support activity and dedicated considerable resources to it. They assigned liaisons and created a mechanism to work with the plant teams in the definition of interfaces and functional requirements. They have solicited and collected rack requirements for plant I&Cs. Recently this activity has been recognized in the baseline for the CODAC scope of work.

Thirdly, and from the outset, the proposed architecture envisaged a common interface between plant system I&Cs and CODAC [1]. This was to be effected by the use of a CODAC-supplied "Plant System Host" (PSH) which would front-end each plant system I&C using a mandated common protocol and software interface. The PSH is still a keystone element of the CODAC design, and EPICS channel access is the mandated common protocol [2]. CODAC will also provide developers with a "mini" version of CODAC for testing and development. The adoption of EPICS and Channel Access as the standard supervisory control infrastructure effectively assures a standard interface. The pieces appear to be in place for a seamless integration and commissioning phase.

WHAT COULD GO WRONG?

But here's the thing. There is very little incentive for Domestic Agencies and plant system developers to follow the standards. Rather, because systems are delivered "in kind," there is strong motivation for suppliers to do things as economically as possible; and it is almost always possible to build a specific system more economically – even better – using an optimized selection of hardware and software. Already there have been examples of DAs questioning the standards, or even stating that they do not intend to, or cannot, follow them. "Why do we have to use this over-specified PLC?" "…but we can use an existing design from our last project and save the design costs." "… but we need to spend our money domestically; your standard is only available overseas." "This plant system comes with its own control system – it can't be changed." Hard to argue with any of that.

Even if all the standards were to be followed, it is clear that there would be integration issues. Plant system acceptance tests will not have been done in the same environment as the final configuration. Network issues and conflicts can be anticipated. Use of rack space, already insufficient, can only be optimized centrally. Cable runs and grounding implementations will have to be adapted to the physical situation at Cadarache.

Because of the way procurements have been distributed, some systems have many more distinct I&C systems than is necessary or desirable. It is not clear who will integrate these systems, or where. This is a result of architectural design by "procurement arrangement" rather than by technical considerations. Optimization requires a centralized view.

The current implementation model is referred to as the "black box" model (you have no idea what's inside what you get) or sometimes the "thrown over the wall" model (you might catch it but you're not sure what to do with it.) There will be no trained on-site expertise to commission and maintain these systems. It seems that seamless integration is a pipe dream. Something similar, however, has been managed before.

THE SNS EXPERIENCE

The SNS construction project was a national collaboration of US Department of Energy Laboratories. Each delivered one or more major subsystems (Front End, Linac, Superconducting cavities, Storage Ring, Neutron Target) of the accelerator facility "in kind," and each of these subsystems was delivered with a control system that plugged into the common or "global" services. Like ITER, the Controls Group anticipated integration issues and responded with standardization and the selection of EPICS to be used throughout. But also like ITER, the project Work Breakdown Structure (WBS) placed control of the "plant system I&Cs" (to use ITER language) into the hands of the different partner laboratories, who had many good reasons for going their own way. There was no effective mechanism for enforcing standards, and no effective mechanism for optimizing on-site integration. This was the scenario presented to the SNS Conceptual Design Review (CDR) committee in 1997.

The Committee: "This isn't going to work."
SNS: "But we have standards and we have EPICS."
The Committee: "Good luck with that. Change it."

The SNS WBS was subsequently changed to place the control system at the top level and move both technical and financial responsibility for plant system I&Cs to the central group at Oak Ridge. In practice very little changed – the work was still distributed. Partner lab I&C teams remained at home and worked with local subsystem developers. Only now the funding passed through the central controls office in Oak Ridge, giving it the "clout" to enforce standards. Software was deposited weekly in a central repository at Oak Ridge, and built in that environment. Team leaders at the partner laboratories met frequently in the early days, and reported regularly later. Partner lab teams participated in the integration and commissioning in Oak Ridge, and some funds were set aside for their later intervention if required. Final integration went reasonably well.

APPLYING THE SNS MODEL TO ITER

In the fall of 2010, a proposal was made to ITER management to adopt an approach similar to that which had been successful at SNS. The interface to CODAC would move from a simple Ethernet connection to the PSH to the front panel of the I/O modules that are connected directly to the actuators and sensors of the plant systems. (These would remain the responsibility of the Domestic Agency and their plant system designers.) I&C teams would be formed at each of the Domestic Agencies to oversee and/or implement the plant system I&Cs. These teams would be funded as part of the centralized CODAC activities, and the team leaders would report to the CODAC Division leader at Cadarache. Equipment purchases for plant system I&Cs would be approved and funded centrally. Members of the DA I&C teams would participate in the installation, testing and eventual commissioning of their systems at Cadarache. The CODAC I&C Support team at Cadarache would consider issues related to optimization and integration of subsystems coming from more than one source and facilitate that task.

The cost of the plant system I&Cs (equipment, software and manpower) might be expected to be 50% - 70% of the total cost of the ITER control systems. (It was 60% for SNS.) As that work is not in the current budget for CODAC, a transfer of funds would be needed to finance this increase in scope. The mechanism proposed was a "tax" on each DA requiring I&C, calculated on the basis of anticipated costs of their plant I&Cs according to various "rules-of-thumb."

Although this proposal was put forward primarily as a risk mitigation, citing the risk of both cost and schedule overruns at integration time, it did suggest a potential cost saving to the DAs because of efficiencies that might accrue through bulk purchases and reduced hardware and space requirements. It was unfortunately this rather speculative cost saving, which would not in any case benefit the ITER Organization at Cadarache, that attracted the most attention, particularly as the proposal arrived just as a frenzy of cost containment was initiated at ITER.

The proposal generated considerable interest and discussion both at ITER IO and among the Domestic Agencies. Modified versions were advanced in which more hardware and software would be provided to plant I&C developers, but with no transfer of responsibility or funds. In the end the proposal was rejected for a number of reasons, perhaps most significantly because the "tax" was unacceptable. Worse, some stakeholders seemed to be of the opinion that plant I&Cs were already within the scope of CODAC in any case. That misinformed opinion forebodes an even greater train wreck.

THE PROPOSAL EVOLVES

As noted above, each DA is itself responsible for the design, construction, testing and delivery to Cadarache of a significant number of plant I&C systems. Europe, for example, will deliver the following systems, many extremely complex in themselves, most made up of multiple plant systems and including many plant I&C systems:

Two Cryogenic Plants (LN2 and 80K)
4 Remote Handling Systems
Tritium Plant Systems
Building Management Systems
Electrical Distribution Systems
Waste processing System
Test Blanket
14 Plasma Diagnostic Systems
3 Additional Heating Systems
Standalone Instrumentation
More…

This collection alone is probably comparable in range, cost and complexity to the complete SNS control system. One "additional heating system," for example, is a complete accelerator in itself, with ion source, RF systems, vacuum and cooling systems, beam line components, etc. It becomes immediately apparent that the integration issue presents to the DAs an (only slightly) smaller version of the same concerns that are perceived by CODAC.

For that reason, the controls team at the European DA last spring made a proposal similar to CODAC's for oversight, management and in some cases design and development of the plant I&C systems for which they are responsible. (Figure 1.) Like the CODAC proposal, they have proposed a small team of control system and project management experts to be located at the European DA offices in Barcelona. This team would take responsibility for oversight of all the plant system I&Cs that fall under the European purview. No black boxes. No walls. Like the CODAC proposal, they have appealed to the responsible DA ("Fusion for Energy," or "F4E") for funding to support this activity.

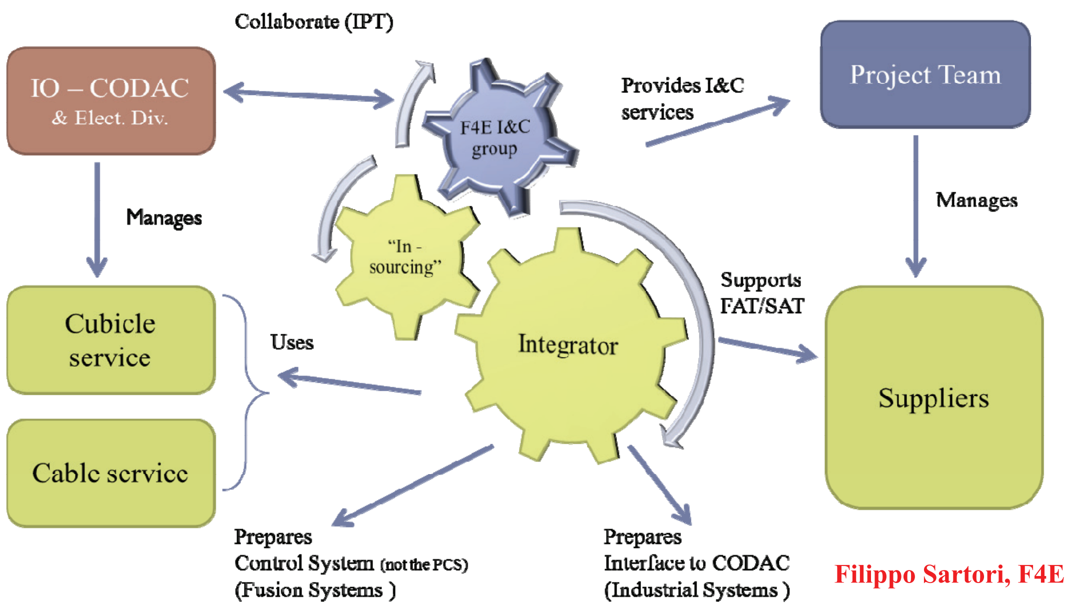

Figure 1. The European Proposal for plant I&C system development.

There are however important differences between the European proposal and the CODAC proposal. In this scenario, the DA controls team would be managed and funded from within the Agency and not through CODAC. Moreover, rather than using a significant number of F4E staff members, the European proposal suggests using a very small staff team and contracting most of the work to two external contractors: one "insourced" to supplement the staff in Barcelona and a second "outsourced" to an integrator that would perform much of its work wherever the subsystems are being built. (The CODAC proposal suggested using ITER staff members.) Formal approval is still required before this proposal becomes the official European approach to delivering plant system controls, but the idea of assigning most work to external contractors is consistent with the general ITER approach, and the proposal seems likelier to receive support for that reason. A meeting of potential integrators has already been held. Because this proposal advocates adherence to CODAC standards and recognizes the importance of a close collaboration with IO, the CODAC team is strong in its support.

CONCLUSIONS

Development of the ITER Control System is taking place in the presence of numerous constraints imposed by the imperatives of an international collaboration. Integration of plant control systems from many different suppliers distributed over the world presents a particularly difficult challenge. Centralizing the development of plant I&C systems was not accepted, however a compromise of centralizing development at the responsible DAs has been proposed by Europe. Learning to work effectively in this environment will be invaluable for future large international collaborations in science and other domains.

REFERENCES

[1] ITER CODAC Conceptual Design Report, ITER internal report

[2] Wallander et al, "News from ITER Controls – a Status Report", this conference

The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.