THE PRIZE FOR….THE SUCCESSFUL CONSTRUCTION AND COMMISSIONING OF THE SPALLATION NEUTRON SOURCE

N. Holtkamp

ITER*, Cadarache, 13108 Saint-Paul-lez-Durance (France)

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Abstract

The Spallation Neutron Source collaboration between six Department of Energy laboratories was a unique arrangement in its mission to build a large science facility, with equally distributed responsibility for design, construction, project management and budget. The Oak Ridge National Laboratory, with no previous experience in large accelerator construction, was selected as the project site, the team was recruited worldwide and the management team was exchanged several times during the construction period. The constraints of such a collaboration, a new team having to work together on a complex project, facing demanding scientific and technical challenges, is a cocktail that can easily lead to failure, but also to success, as proven. Was it luck or good management that decided the fate of the project? Can the weakness of such a situation simultaneously become its strength? In hindsight, it is interesting to reflect on how it was done and what became of some of the key players. Certainly in many ways this experience provided the author with a key to face a much larger challenge, namely the management of an international science project shared between seven Countries, called ITER. A project that takes the concepts tried at SNS to another extreme. Comparisons will be provided and some of the unique features will be discussed.

Figure 1: Overview of the construction site with accelerator systems, target buildings, the central laboratory office, JINS, CNMS and several support buildings overlaid on a early site photo on top of Chestnut Ridge at Oak Ridge National Laboratory.

INTRODUCTION

“The achievement prize for a recent, significant contribution to the accelerator field with no age limit, is awarded to Norbert Holtkamp, ITER (formerly ORNL/SNS)”. When I received the notification for the prize, I was very proud for SNS and for myself. The endless hours of work and all the enthusiasm and engagement had paid off, and were crowned by an international award for the achievements of the project. It was always my intention to write up how the challenge was finally mastered. Especially when things were extraordinarily difficult and when almost no solution seemed available. I promised myself many times to do so, but then other issues took priority, new professional challenges arose and the time never came. The presentation of this prize and the associated paper in these proceedings provide an opportunity to write up something that was long overdue - namely a small part of the story of how I came to SNS and SNS to me.

The citation reads "for the construction and successful commissioning of the linac-driven Spallation Neutron Source (SNS) on time and to budget, within the constraints of a multi-laboratory collaboration. His inspirational leadership and outstanding management skills, combined with a thorough understanding of the technical and scientific challenges, were the essential components in successfully bringing together the highly effective SNS team."

* ITER is a joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power. The partners in the project - the ITER Parties - are the European Union (represented by EURATOM), Japan, the People’s Republic of China, India, the Republic of Korea, the Russian Federation and the USA

These are strong words, if a single person has to measure up to them. Luckily SNS, and almost all major projects, was not the achievement of an individual. While some individuals undoubtedly played key roles in the success, so many others played their part too. And they must be recognized for it, if not mentioned by name. So here are a few elements of the story.

WHAT IS SNS?

The SNS [1] project was officially authorized for construction in FY1999 and finished at the end of May 2006 with a total project cost of M$1,405 (versus the planned cost of M$1,412) one month ahead of the scheduled finish date of June 2006. This is a success story for the Department of Energy, for Oak Ridge National Laboratory (ORNL), as well as the other partner labs involved and the people that were there to build and operate it.

The Spallation Neutron Source delivers a proton beam of up to 1.4 MW beam power to a mercury target for neutron spallation. The accelerator systems, the part of the project I was responsible for, consist of a full energy injector linac and an accumulator ring, operated at a repetition rate of up to 60 Hz and an average current of 1.6 mA. The basic parameters of the facility are summarized in Table 1.

Table 1: Baseline Parameters for the SNS

Beam energy on target	MeV	1000
Beam current on target	mA	1.4
Power on target	MW	1.4
Pulse repetition rate	Hz	60
Macro pulse duty cycle	%	6
Average current per pulse	mA	26
H- peak current from Front End	mA	38
RFQ output energy	MeV	2.5
DTL output energy	MeV	87
CCL output energy	MeV	186
Med β sc linac output energy	MeV	397
High β sc linac output energy	MeV	1000
Accumulator ring circumference	m	248
Ring fill time	msec	1
Ring beam extraction gap	nsec	250
Protons per pulse on target		1.5×10^{14}
Proton pulse width	nsec	695
Target material		Liq Hg

The linac produces a 1 msec long, 38 mA peak, chopped beam pulse at 60 Hz for accumulation in the ring. A high-energy beam transport line (HEBT) for diagnostics and collimation after the linac injects into an accumulator ring for compressing the 1-ms pulse to ~700 ns for delivery onto the target through a ring-totarget beam transport beam line. Neutrons are produced by spallation in the mercury target, and their energy is moderated to useable levels by supercritical hydrogen and water moderators.

SNS was constructed within a collaboration composed of six national laboratories (ANL, BNL, TJNAF, LANL, LBNL, ORNL) in which the partner labs were largely responsible for design, construction, assembly and delivery and ORNL carried out the integration, assembly, installation, testing and commissioning with the support of the labs.

Following the initial commissioning of the SNS excellent progress has been made. The availability as well as the beam performance has steadily increased resulting in it being the highest power facility today. Actually today, “The Department of Energy's Spallation Neutron Source at Oak Ridge National Laboratory has been confirmed by the Guinness Book of World Records as the world's most powerful pulsed neutron spallation source: March 4th, 2008”. In June 2008 SNS reached another key milestone by providing almost one half megawatt of beam power to the target station and with that is well on its way to achieving the >1 MW target as predicted within the first four years of operation.

THE FORMULA FOR SUCCESS

The successful construction on time and within budget is a miraculous formula that every project leader will want to achieve. It is therefore useful to discuss how the SNS team could achieve this. First of all, it is important to establish the criteria for success early on in the project. For SNS this was done by defining exactly the deliverables that were supposed to be achieved at the end, which was the number of protons to be accelerated in a single pulse, the number of neutrons produced in the target, and a basic number of neutron scattering instruments installed. Such deliverables should be agreed upon by the construction management team and the owner in order to have a defined set of measurements that will undoubtedly establish “success”. These basic criteria for the SNS were far away (typically a factor of 10-100) from the actual maximum performance criteria of SNS. At the same time SNS would achieve in its final performance factors of 10 in performance higher than any other facility, so how could anybody promise to deliver that at the end of construction without any experience of operation of the facility.

In order to be “successful” a similar approach is necessary for the schedule and the cost. In both cases SNS had a schedule established in 2001, with an end date that the team never had to change afterwards. As part of this schedule we also had about 460 days of explicit float. Effectively then SNS was finished using up about 400 of these days, and therefore finished 60 days ahead of the promised date. This schedule float was managed by the central team at the top management level, which was important to balance the different players.

For the cost a contingency of approximately 25% was established at the beginning. This amounts to approximately 300M$. SNS was finished to budget, using up almost all of it. Nevertheless, it is true also that much of it was also used for increasing the scope of the project. The final answer on what is the right amount of contingency is therefore difficult to give and depends certainly on the complexity of the project. If a project is to be finished to budget, meaning within a cost threshold established at the beginning, zero contingency is definitely a recipe for not being successful.

ITER

After successfully finishing a project, apart from the fatigue that is overwhelming from time to time, new opportunities appear. Just following some of my colleagues' career steps shows a startling list of promotions. People who grew out of the SNS project are divisional directors, associate lab directors or even lab directors who manage 0.01-1.0 billion dollar annual budgets.

When I was approached to join ITER [2] as the technical director and project integrator, I realized that a striking sum of more than 5 billion Euros had to be spent in order to build the project within the 10 year time frame. Moreover, ninety percent of the project was to be in "in-kind" contributions, in which the seven partners, namely the European Union (represented by EURATOM), Japan, the People´s Republic of China, India, the Republic of Korea, the Russian Federation and the USA, would deliver components of ITER which they would have built to finally assemble the Tokamak in Cadarache, the South of France.

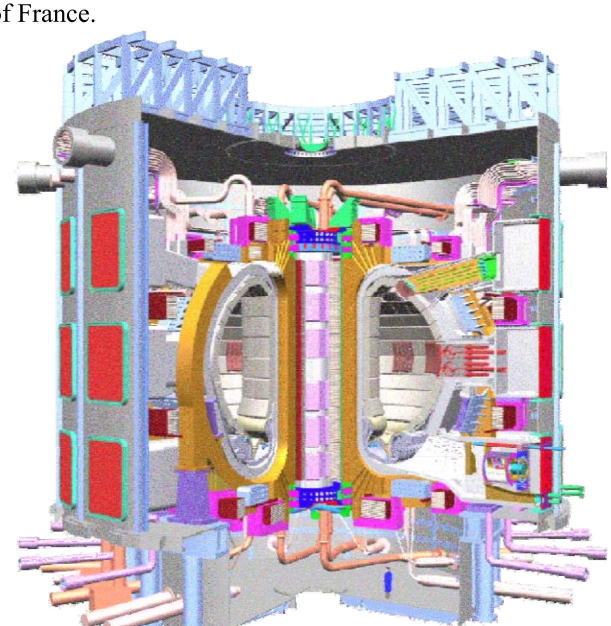

Figure 2: The ITER tokamak. On the right lower side a person can be seen for size comparison. ITER will be the world's largest tokamak producing more than 500 MW of fusion power.

The technical complexity of ITER is enormous on any scale measurable today, if compared to other large scale science projects. Only very few come to mind, the international space station, parts of LHC, ALMA and so on. In addition, a tokomak is a highly integrated device, as one can see from figure 2. Managing all the interfaces with the additional requirement to build these components in-kind is probably an unprecedented challenge. This can be seen even better in figure 3, which shows the procurement responsibility of the different partners. Every partner wants to be able to master every technology at the end of the ITER construction. An obvious goal, that ITER, if successful, could open up an infinite source of clean energy.

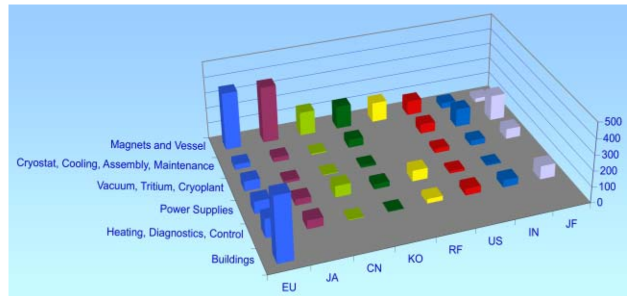

Figure 3: Procurement sharing between the different ITER partners.

In addition people from different cultures are governing the construction project. All of the parties have successfully executed construction projects. Nevertheless, the concept of schedule and cost contingency, definition of project deliverables and the way to track and report performance is very different from country to another. It is therefore very important to establish a common understanding of how this project should be managed. An exercise that is still ongoing within ITER, while the construction of the components and the preparation of the site have already started. -- Another interesting challenge to come.

SUMMARY

I am indebted to the prize committee for recognizing the SNS and my contribution to it with the prize that I am receiving today. I am even more grateful to the people that gave me the opportunity to be deeply involved in the construction project and who supported my work during this time. Most of this gratitude I want to express to those who have helped me with construction in day to day life. They are the owners of this success as much as I am.

I also want to thank my teachers and there are many of them. Foremost is Professor G.A. Voss, former technical director of DESY as well as Dr. T. Weiland, presently professor at the University of Darmstadt and my PhD advisor. They among others have taught me many of the things that I needed.

REFERENCES

[1] http://www.sns.gov/
[2] http://www.iter.org